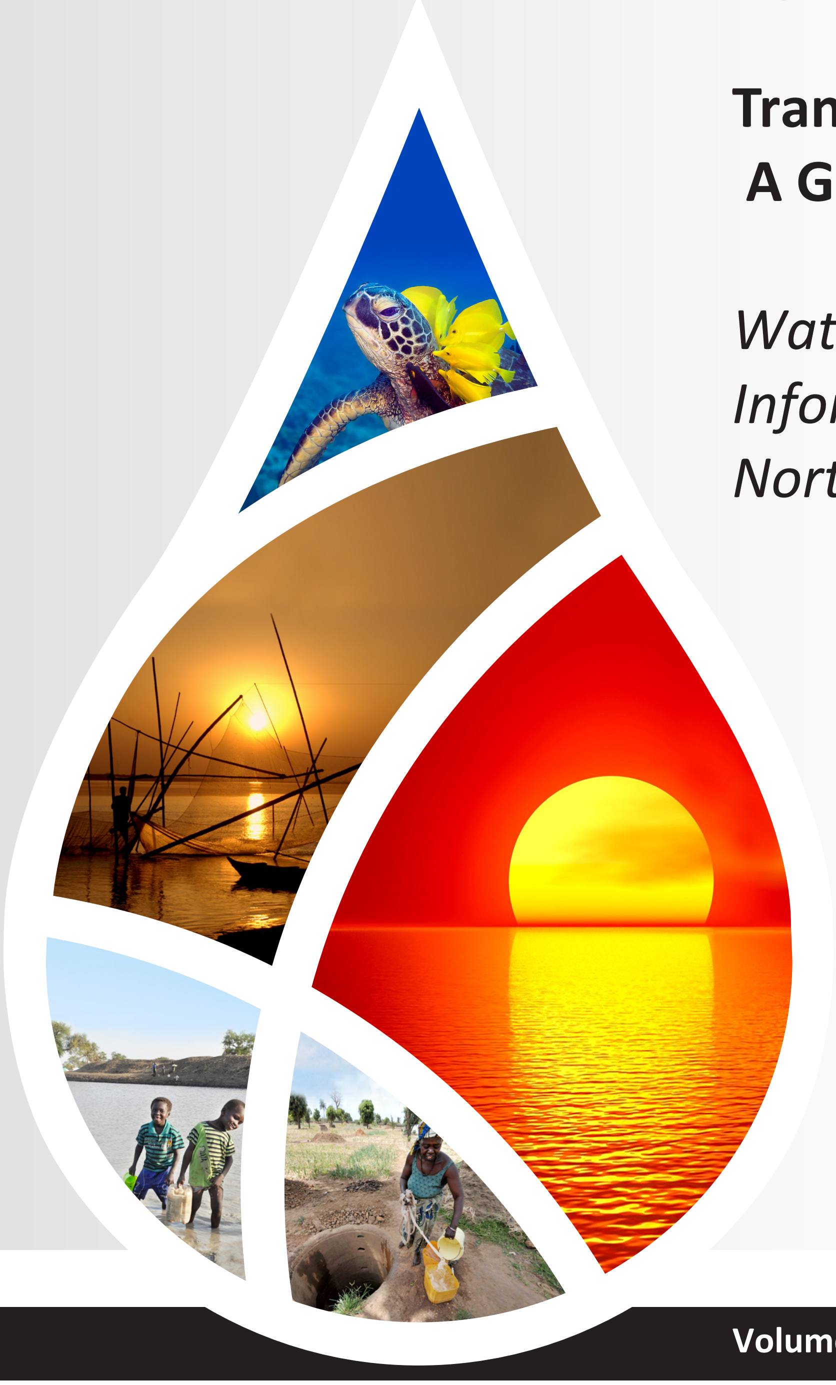
TWAP
TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

Transboundary Waters: A Global Compendium

Water System Information Sheets: Northern America



Volume 6 - Annex A: Northern America

UNEP

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Volume 6-Annex A

Transboundary Waters: A Global Compendium

Water System Information Sheets: Northern America

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GLOBAL IGBP CHANGE
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Geosphere-Biosphere
Programme

IUCN

SIWI

CUNY The City University of New York

OSU
Oregon State
UNIVERSITY

Center for International Earth
Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY

CESR Center for Environmental Systems Research

Delta Alliance

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GLOBAL IGBP CHANGE
International
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Programme

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Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

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UNESCO
United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental
Oceanographic
Commission

GOOS
Global Ocean
Observing System

WCRP
World Climate
Research Programme

GACS
Global Alliance of
CPR Surveys

PML Plymouth
Marine Laboratory

CERMES

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Administrative Boundaries: Source of administrative boundaries used throughout the assessment: The Global Administrative Unit Layers (GAUL) dataset, implemented by FAO within the CountrySTAT and Agricultural Market Information System (AMIS) projects.

Contents (Volume 6, Annex A)

Preface

The Global Environment Facility (GEF) approved a Full Size Project (FSP), "A Transboundary Waters Assessment Programme: Aquifers, Lake/Reservoir Basins, River Basins, Large Marine Ecosystems, and Open Ocean to catalyze sound environmental management", in December 2012, following the completion of the Medium Size Project (MSP) "Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme" in 2011. The TWAP FSP started in 2013, focusing on two major objectives: (1) to carry out the first global-scale assessment of transboundary water systems that will assist the GEF and other international organizations to improve the setting of priorities for funding; and (2) to formalise the partnership with key institutions to ensure that transboundary considerations are incorporated in regular assessment programmes to provide continuing insights on the status and trends of transboundary water systems.

The TWAP FSP was implemented by UNEP as Implementing Agency, UNEP's Division of Early Warning and Assessment (DEWA) as Executing Agency, and the following lead agencies for each of the water system categories: the International Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) for transboundary aquifers including groundwater systems in small island developing states (SIDS); the International Lake Environment Committee Foundation (ILEC) for lake and reservoir basins; the UNEP-DHI Partnership – Centre on Water and Environment (UNEP-DHI) for river basins; and the Intergovernmental Oceanographic Commission (IOC) of UNESCO for large marine ecosystems (LMEs) and the open ocean.

The five water-category specific assessments cover 199 transboundary aquifers and groundwater systems in 43 small island developing states, 204 transboundary lakes and reservoirs, 286 transboundary river basins; 66 large marine ecosystems; and the open ocean, a total of 756 international water systems. The assessment results are organized into five technical reports and a sixth volume that provides a cross-category analysis of status and trends:

Volume 1 – ***Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends***
Volume 2 – ***Transboundary Lakes and Reservoirs: Status and Trends***
Volume 3 – ***Transboundary River Basins: Status and Trends***
Volume 4 – ***Large Marine Ecosystems: Status and Trends***
Volume 5 – ***The Open Ocean: Status and Trends***
Volume 6 – ***Transboundary Water Systems: Crosscutting Status and Trends***

A ***Summary for Policy Makers*** accompanies each volume.

Volume 6 presents a unique and first global overview of the contemporary risks that threaten international water systems in five transboundary water system categories, building on the detailed quantitative indicator-based assessment conducted for each water category. As a supplement to Volume 6, this global compendium of water system information sheets provides baseline relative risks at regional and system scales. The fact sheets are organized into 14 TWAP regions and presented as 12 annexes. Volume 6 and the compendium are published in collaboration among the five independent water-category based TWAP Assessment Teams under the leadership of the Cross-cutting Analysis Working Group, with support from the TWAP Project Coordinating Unit.

Transboundary Waters: A Global Compendium

The technical teams of the Transboundary Waters Assessment Programme(TWAP) assessed transboundary aquifers, lakes & reservoirs, river basins, and large marine ecosystems and prepared information (fact) sheets for water systems that were evaluated. Each fact sheet provides basic geomorphological information and presents baseline values of quantitative indicators that were used to establish relative risk levels. The water system fact sheets are organized into 14 TWAP regions that were used in the Crosscutting Analysis described in Volume 6. The regional compilations are presented as 11 annexes (A-K) of a global compendium, combining Southern & Southeastern Asia into one annex (I), and the Pacific Island Countries, Australia & Antarctica into another (Annex K). Each annex highlights contemporary regional risks as well as water system-specific risks. The annexes are:

Annex A.	**Transboundary waters of Northern America**
Annex B.	Transboundary waters of Central America & the Caribbean
Annex C.	Transboundary waters of Southern America
Annex D.	Transboundary waters of Eastern, Northern & Western Europe
Annex E.	Transboundary waters of Eastern Europe
Annex F.	Transboundary waters of Western & Middle Africa
Annex G.	Transboundary waters of Eastern & Southern Africa
Annex H:	Transboundary waters of Northern Africa & Western Asia
Annex I:	Transboundary waters of Southern & Southeastern Asia
Annex J:	Transboundary waters of Eastern & Central Asia
Annex K:	Transboundary waters of the Pacific Island Countries, Australia & Antarctica

In the case of the open ocean, which is the largest transboundary water system of planet earth, selected quantitative indicator maps prepared by the Open Ocean Assessment Team, are compiled in Annex L to highlight the contemporaneous state of the global ocean.

Annex L:	Selected indicator maps for the open ocean

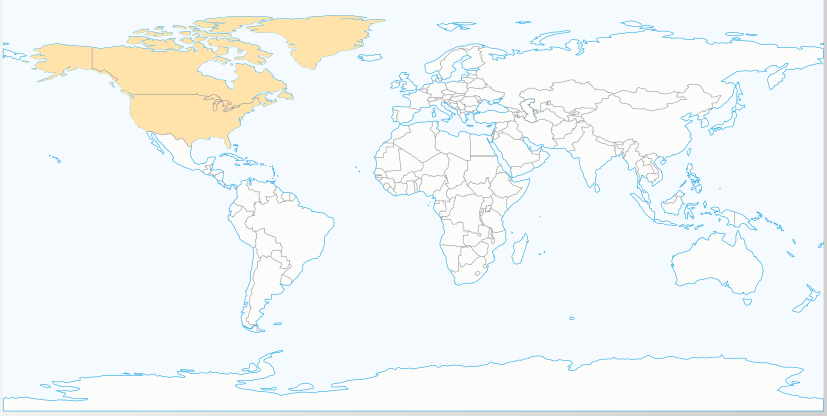
All information sheets and indicator maps for the open ocean may be downloaded individually from the following websites:

Transboundary Aquifers: http://twapviewer.un-igrac.org
Transboundary Lakes/ Reservoirs: http://ilec.lakes-sys.com/
Transboundary River Basins: http://twap-rivers.org
Large Marine Ecosystems: http://onesharedocean.org
Open Ocean: http://onesharedocean.org

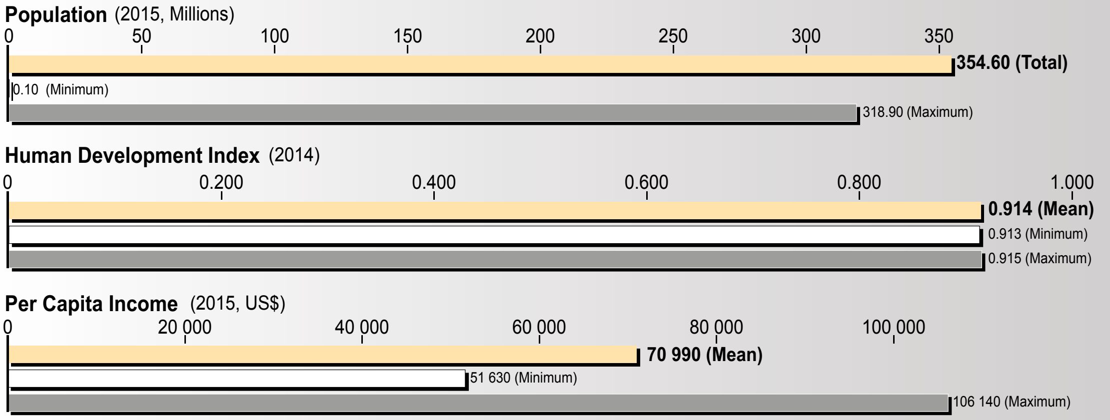
All TWAP publications are available for download at http://www.geftwap.org

Over the long term, it is envisioned that these baseline information sheets will continue to be updated by future assessments at multiple spatial and temporal scales to better track the changing states of transboundary waters that are essential in sustaining human wellbeing and ecosystem health.

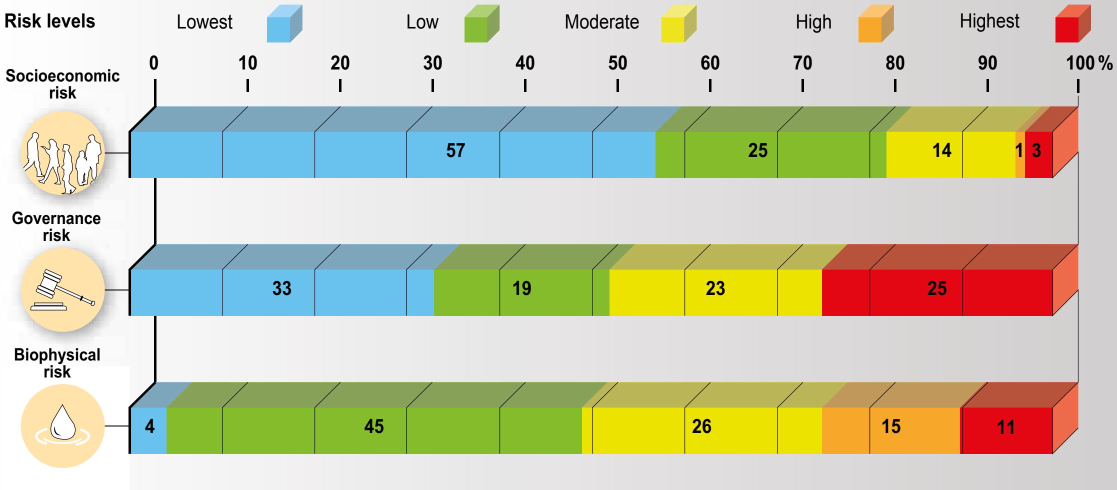
TRANSBOUNDARY WATERS: NORTHERN AMERICA



The region belongs to the very high HDI group with a regional average HDI of 0.914, and a population reaching 355 million in 2015. Contemporary risks of water systems by water category and theme expressed as percentages are shown at top right. Across 50 transboundary waters in the region (bottom left), about 82% experience low to lowest socioeconomic risks; 52% are subject to low to lowest governance although another 25% are at very high governance risk; and 52% are at moderate to highest biophysical risk. On average ((bottom right), the region's transboundary waters are at low socioeconomic risk, and at moderate governance and biophysical risks. Lake and river basins both are at low risks averaging all risk themes, and aquifers and LMEs are at moderate risk.

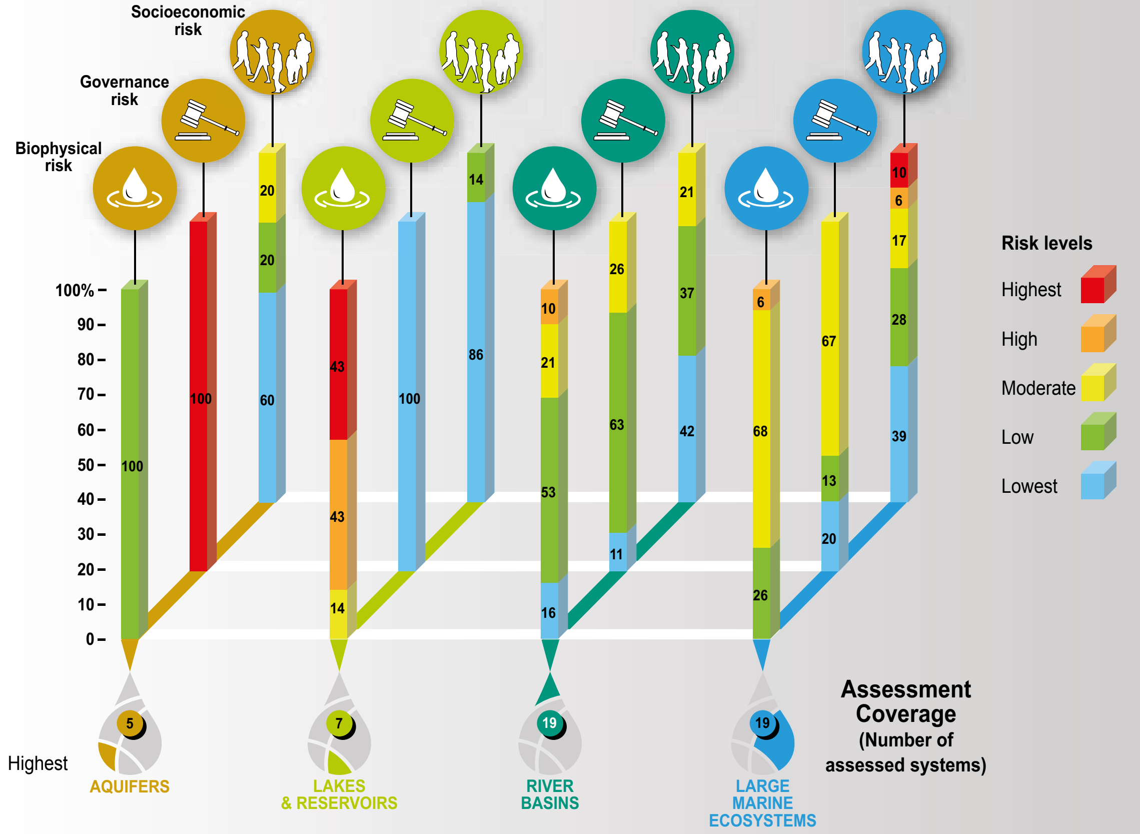


Contemporary Risks by Theme



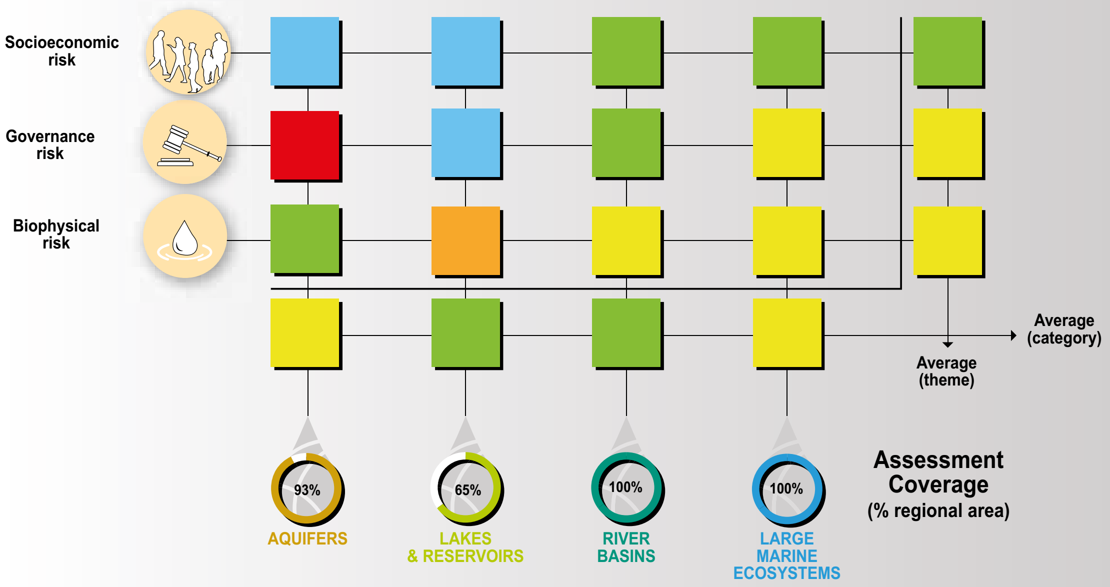
Regional Risks by Water Category

Contemporary Risks by Water Category



Average Risks

Risk levels Lowest 🟦 Low 🟩 Moderate 🟨 High 🟧 Highest 🟥



Socioeconomic risk	🟦	🟦	🟩	🟩	🟩
Governance risk	🟥	🟦	🟩	🟨	🟨
Biophysical risk	🟩	🟧	🟨	🟨	🟨
	🟨	🟩	🟩	🟨	Average (theme)
	93%	65%	100%	100%	
	AQUIFERS	LAKES & RESERVOIRS	RIVER BASINS	LARGE MARINE ECOSYSTEMS	

Transboundary Aquifers of Northern America

1. Cuenca Baja del Rio Bravo-Grande
2. Cuenca Baja del Rio Colorado
3. Edwards - Trinity - El Burro
4. Poplar
5. Judith River
6. Milk River
7. Northern Great Plains

United Nations Educational, Scientific and Cultural Organization
International Hydrological Programme
International Groundwater Resources Assessment Centre
GOETHE UNIVERSITÄT FRANKFURT AM MAIN
SFU SIMON FRASER UNIVERSITY ENGAGING THE WORLD

17N - Cuenca Baja del Rio Bravo-Grande

Geography

Total area TBA (km^2): 25 000

No. countries sharing: 2

Countries sharing: Mexico, United States of America

Population: 2 600 000

Climate zone: Semi-arid

Rainfall (mm/yr): 600

Hydrogeology

Aquifer type: Multiple layers hydraulically connected

Degree of confinement: Whole aquifer semi-confined

Main Lithology: Sediment - sand

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No cross-section available

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

17N - Cuenca Baja del Rio Bravo-Grande

TWAP Groundwater Indicators from Global Inventory

	Recharge (mm/y) (1)	Renewable groundwater per capita (m^3/y/capita)	Natural background groundwater quality (%) (2)	Human dependency on groundwater (%)	Groundwater depletion (mm/y)	Groundwater pollution (%) (3)	Population density (Persons/km2)	Groundwater development stress (%) (4)	Transboundary legal framework (Scores) (5)	Transboundary institutional framework (Scores) (6)
Mexico	11	120	<5	100	0		95	15	A	C
United States of America							130			
TBA level							**100**			

(1) Recharge: This is the long term average recharge (in m^3/yr) divided by the surface area (m^2) of the complete country segment of the aquifer (i.e. not only the recharge area).

(2) Natural background groundwater quality: Estimate of percentage of surface area of aquifer where the natural groundwater quality satisfies local drinking water standards.

(3) Groundwater pollution: A. No pollution has been identified; B. Some pollution has been identified; Positive number: Significant pollution has been identified (% of surface area of aquifer).

(4) Groundwater development stress: Annual groundwater abstraction divided by recharge.

(5) Legal framework: A. Agreement with full scope for TBA management signed by all parties; B. Agreement with limited scope for TBA management signed by all parties; C. Agreement under preparation or available as an unsigned draft; D. No agreement exists, nor under preparation; E. Legal Framework differs between Aquifer States (see data at National level).

(6) Institutional Framework: A. Dedicated transboundary institution fully operational; B. Dedicated transboundary institution in place, but not fully operational; C. National/Domestic institution fully operational; D. National/Domestic institution in place, but not fully operational; E. No institution exists for TBA management; F. Institutional Framework differs between Aquifer States (see data at National level).

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

TWAP Groundwater Indicators from WaterGAP model

	Recharge, incl. recharge from irrigation (mm/yr)	Renewable groundwater per capita			Human dependency on groundwater (%)	Human dependency on groundwater for domestic water supply (%)	Human dependency on groundwater for irrigation (%)	Human dependency on groundwater for industrial water use(%)
		Current state (m^3/y/capita)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)				
Mexico	92	1100	-14	-13	10	35	3	28
United States of America	160	1400	-19	-13	10	12	12	6
TBA level	**110**	**1200**	**-16**	**-13**	**10**	**26**	**6**	**14**

17N - Cuenca Baja del Rio Bravo-Grande

	Groundwater depletion (mm/y)	Population density			Groundwater development stress		
		Current state (Persons/km2)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)	Current state (%)	Projection 2030 (% point change to current state)	Projection 2050 (% point change to current state)
Mexico	-1	83	19	29	8	6	9
United States of America	-1	110	16	26	7	4	3
TBA level	**-1**	**91**	**18**	**28**	**8**	**5**	**7**

Key parameters table from Global Inventory

	Distance from ground surface to groundwater table (m)	Depth to top of aquifer formation (m)	Full vertical thickness of the aquifer (system)* (m)	Degree of confinement	Predominant aquifer lithology	Predominant type of porosity (or voids)	Secondary Porosity	Transmissivity (m^2/d)
Mexico	25	<5	150	Whole aquifer semi-confined	Sediment - Sand	High primary porosity fine/ medium sedimentary deposits	No secondary porosity	540
United States of America								
TBA level								

* Including aquitards/aquicludes

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

Aquifer description

Only Mexico has provided information, so most of the information relates to the part of the aquifer within Mexico.

Aquifer geometry

It is a multiple 7-layered, hydraulically connected, system. The whole aquifer is semi-confined. The average distance of the groundwater level is 25m and average total vertical thickness of the aquifer system is 150m.

Hydrogeological aspects

The main lithology is sediment - sand. The material has high primary porosity fine/medium sedimentary deposits. The average aquifer transmissivity is estimated as 542m²/d. The average annual aquifer recharge is estimated at 200 Mm³/annum, coming from a recharge area of 540 km². The total groundwater volume is 21 km³.

Linkages with other water systems

Recharge into the aquifer system is from precipitation on the aquifer area and discharge from the system is through evapotranspiration.

17N - Cuenca Baja del Rio Bravo-Grande

Environmental aspects

97% of groundwater across the aquifer area is unsuitable for human consumption as a result of elevated levels of natural salinity. Significant pollution has been identified, at this stage only in the surficial layers. The sources are landfills/waste disposal sites, households, agricultural practices and oil/gas production and transport activities. Observed contaminants are salinization, nitrogen species, and pesticides. There is 2% of aquifer area covered with shallow groundwater and with groundwater dependent ecosystems.

Socio-economic aspects

The annual average groundwater abstraction has been estimated as 26 Mm^3/annum, which is also the figure provided for total annual fresh water abstraction. There has been no groundwater depletion.

Legal and Institutional aspects

Mexico makes mention of a Bilateral Agreement with full scope. It also identifies its National Institution that has a full mandate and full capacity. Groundwater management is undertaken according to National law and regulations.

Priority issues

The large extent of unsuitable natural water quality for drinking purposes together with the significant amount of pollution makes this an important aspect on which to focus on and to protect further degradation of the water quality.

Contributors to Global Inventory

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Víctor Manuel Castañón Arcos	Comisión Nacional del Agua	Mexico	victor.castanon@conagua.gob.mx	Contributing national expert
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Considerations and recommendations

Most data in the tables and text above have been provided by national and regional experts (listed above) or have been derived from the global WaterGAP model. See colophon for more information, including references to data from other sources.

The TBA system could not be described fully, because only one of the two TBA countries provided adequate numerical information.

Data gaps and also differences between data from national experts (Global Inventory) and data derived from WaterGAP highlight the need for further research on transboundary aquifers.

17N - Cuenca Baja del Rio Bravo-Grande

Colophon

This Transboundary Aquifers information sheet has been produced as part of the Groundwater Component of the GEF Transboundary Water Assessment Programme (GEF TWAP). **GEF TWAP** is the first truly global comparative assessment of transboundary groundwater, lakes, rivers, large marine ecosystems and the open ocean. More information on TWAP can be found on: www.geftwap.org . **The Groundwater component** of TWAP carried out a global comparison of 199 transboundary aquifers and the groundwater systems of 41 Small Island Developing States. The data used to compile this transboundary aquifer information sheet has been made available by national and regional experts from countries involved in the TWAP Groundwater project. For aquifers larger than 20 000 km2 and which are not overlapping, additional data are available from modelling done by the Goethe University Frankfurt (Germany) as part of TWAP Groundwater. All data were compiled by UNESCO-IHP and the International Groundwater Resources Assessment Centre (IGRAC – UNESCO Category II Institute). Values given in the fact-sheet represent an approximate guide only and should not replace data obtained from recent local assessments. The editors of this information sheet are not responsible for the quality of the data.

For more information on TWAP Groundwater and for more data, please have a look at the TWAP Groundwater Information Management System which is accessible via www.twap.isarm.org or www.un-igrac.org.

Request:
If you have additional data or information about this transboundary aquifer that can improve the quality of this information sheet and the underlying database, please contact us via email at info@un-igrac.org. If appropriate, the information will be uploaded to the database of transboundary aquifers and will also be used in new versions of this information sheet.

References:

- Population: Population has been calculated based on the aquifer map and grid information on population. Source population data: Center for International Earth Science Information Network - CIESIN - Columbia University, United Nations Food and Agriculture Programme - FAO, and Centro Internacional de Agricultura Tropical - CIAT. 2005. Gridded Population of the World, Version 3 (GPWv3): Population Count Grid, Future Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H42B8VZZ. Accessed Jan 2015.
- Rainfall: Average rainfall per TBA has been calculated based on the aquifer map and grid data for precipitation. Source precipitation data: Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978. Grid data download from www.worldclim.org (2015): Data for current conditions (~1950-2000), ESRI grids, 30 arc seconds, Precipitation.
- Climate: Climate indicates the major climate zone which occurs in the aquifer area. If more than 1 climate zone is present the zone with the largest surface area was selected. Source climate data: ArcGIS Online (2015), Simplified World Climate zones. Owner: Mapping Our World GIS Education. Original map: National Geographic World Atlas for Young Explorers (1998).
- All other data: TWAP Groundwater (2015).

Version: October 2015

9N - Cuenca Baja del Rio Colorado

Geography

Total area TBA (km^2): 16 000

No. countries sharing: 2

Countries sharing: Mexico, United States of America

Population: 710 000

Climate zone: Arid

Rainfall (mm/yr): 70

Hydrogeology

Aquifer type: Multiple layers hydraulically connected

Degree of confinement: Whole aquifer unconfined

Main Lithology: Sediment - Sand

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No cross-section available

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9N - Cuenca Baja del Rio Colorado

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	Recharge (mm/y) (1)	Renewable groundwater per capita (m^3/y/capita)	Natural background groundwater quality (%) (2)	Human dependency on groundwater (%)	Groundwater depletion (mm/y)	Groundwater pollution (%) (3)	Population density (Persons/km2)	Groundwater development stress (%) (4)	Transboundary legal framework (Scores) (5)	Transboundary institutional framework (Scores) (6)
Mexico	26	620	35	100	0	B	43	110	A	C
United States of America							44			
TBA level							**43**			

(1) Recharge: This is the long term average recharge (in m^3/yr) divided by the surface area (m^2) of the complete country segment of the aquifer (i.e. not only the recharge area).

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(4) Groundwater development stress: Annual groundwater abstraction divided by recharge.

(5) Legal framework: A. Agreement with full scope for TBA management signed by all parties; B. Agreement with limited scope for TBA management signed by all parties; C. Agreement under preparation or available as an unsigned draft; D. No agreement exists, nor under preparation; E. Legal Framework differs between Aquifer States (see data at National level).

(6) Institutional Framework: A. Dedicated transboundary institution fully operational; B. Dedicated transboundary institution in place, but not fully operational; C. National/Domestic institution fully operational; D. National/Domestic institution in place, but not fully operational; E. No institution exists for TBA management; F. Institutional Framework differs between Aquifer States (see data at National level).

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

Key parameters table from Global Inventory

	Distance from ground surface to groundwater table (m)	Depth to top of aquifer formation (m)	Full vertical thickness of the aquifer (system)* (m)	Degree of confinement	Predominant aquifer lithology	Predominant type of porosity (or voids)	Secondary Porosity	Transmissivity (m^2/d)
Mexico	22	<5	600	Whole aquifer unconfined	Sediment - Sand	High primary porosity fine/ medium sedimentary deposits	No secondary porosity	6400
United States of America								
TBA level								

* Including aquitards/aquicludes

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

9N - Cuenca Baja del Rio Colorado

Aquifer description

Only Mexico has provided information

Aquifer geometry

It is a multiple 2-layered, hydraulically connected, system. The whole aquifer unconfined. The distance to the groundwater level is 22m and the total vertical thickness of the aquifer system is 600m.

Hydrogeological aspects

The main lithology is sediment – sand that have a high primary porosity fine/ medium sedimentary deposits and no secondary porosity. The average aquifer transmissivity is estimated as 6 400 m²/d. The average annual aquifer recharge is estimated at 240 Mm³/annum coming from a recharge area of 860 km². Total groundwater volume is 100 km³.

Linkages with other water systems

Recharge to the aquifer system is from precipitation over the aquifer area and discharge from the system is through submarine outflow.

Environmental aspects

Groundwater quality on 64 % of the aquifer area is unsuitable for human consumption. The problem of elevated salinity occurs only in the superficial layers. Some pollution has been identified, occurring only in superficial layers. The main origin is agricultural practices and the impact has been local salinization. No part of the aquifer contains shallow groundwater or groundwater dependent ecosystems.

Socio-economic aspects

The annual average groundwater abstraction has been estimated as 260Mm³/annum, which is also the figure provided for total annual fresh water abstraction. There has been no groundwater depletion.

Legal and Institutional aspects

Mexico makes mention of a Bilateral Agreement with full scope. It also identifies its National Institution that has a full mandate and full capacity. Groundwater management is undertaken according to National law and regulations.

Emerging issues

Information is only available from one country. Noticeable is that the groundwater abstraction in Mexico is of the same order of magnitude as the average annual recharge to the aquifer in that country.

Contributors to Global Inventory

Name	Organisation	Country	E-mail	Role
Alberto Manganelli		Uruguay	albertomanganelli@yahoo.com	Regional coordinator
Víctor Manuel Castañón Arcos	Comisión Nacional del Agua	Mexico	victor.castanon@conagua.gob.mx	Contributing national expert
Rubén Chávez Guillén	Comisión Nacional del Agua	Mexico	ruben.chavez@conagua.gob.mx	Contributing national expert
Felipe Ignacio Arreguín Cortés	Comisión Nacional del Agua	Mexico	felipe.arreguin@conagua.gob.mx	Lead National Expert
Manuel Martínez Morales	Instituto Mexicano de Tecnología del Agua	Mexico	manuelm@tlaloc.imta.mx	Contributing national expert

9N - Cuenca Baja del Rio Colorado

Name	Organisation	Country	E-mail	Role
Roberto Aurelio Sención Aceves	Comisión Nacional del Agua	Mexico	roberto.sencion@conagua.gob.mx	Contributing national expert
Carlos Gutiérrez Ojeda	Instituto Mexicano de Tecnología del Agua	Mexico	cgutierr@tlaloc.imta.mx	Contributing national expert

Considerations and recommendations

Most data in the tables and text above have been provided by national and regional experts (listed above) or have been derived from the global WaterGAP model. See colophon for more information, including references to data from other sources.

The TBA system could not be described fully, because only one of the TBA countries provided adequate numerical information.

Data gaps and also differences between data from national experts (Global Inventory) and data derived from WaterGAP highlight the need for further research on transboundary aquifers.

Colophon

This Transboundary Aquifers information sheet has been produced as part of the Groundwater Component of the GEF Transboundary Water Assessment Programme (GEF TWAP). **GEF TWAP** is the first truly global comparative assessment of transboundary groundwater, lakes, rivers, large marine ecosystems and the open ocean. More information on TWAP can be found on: www.geftwap.org . **The Groundwater component** of TWAP carried out a global comparison of 199 transboundary aquifers and the groundwater systems of 41 Small Island Developing States. The data used to compile this transboundary aquifer information sheet has been made available by national and regional experts from countries involved in the TWAP Groundwater project. For aquifers larger than 20 000 km2 and which are not overlapping, additional data are available from modelling done by the Goethe University Frankfurt (Germany) as part of TWAP Groundwater. All data were compiled by UNESCO-IHP and the International Groundwater Resources Assessment Centre (IGRAC – UNESCO Category II Institute). Values given in the fact-sheet represent an approximate guide only and should not replace data obtained from recent local assessments. The editors of this information sheet are not responsible for the quality of the data.

For more information on TWAP Groundwater and for more data, please have a look at the TWAP Groundwater Information Management System which is accessible via www.twap.isarm.org or www.un-igrac.org.

Request:
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References:

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- Rainfall: Average rainfall per TBA has been calculated based on the aquifer map and grid data for precipitation. Source precipitation data: Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978. Grid data download from www.worldclim.org (2015): Data for current conditions (~1950-2000), ESRI grids, 30 arc seconds, Precipitation.
- Climate: Climate indicates the major climate zone which occurs in the aquifer area. If more than 1 climate zone is present the zone with the largest surface area was selected. Source climate data: ArcGIS Online (2015), Simplified World Climate zones. Owner: Mapping Our World GIS Education. Original map: National Geographic World Atlas for Young Explorers (1998).
- All other data: TWAP Groundwater (2015).

Version: October 2015

16N - Edwards-Trinity-El Burro

Geography

Total area TBA (km^2): 110 000

No. countries sharing: 2

Countries sharing: Mexico, United States of America

Population: 460 000

Climate zone: Semi-arid

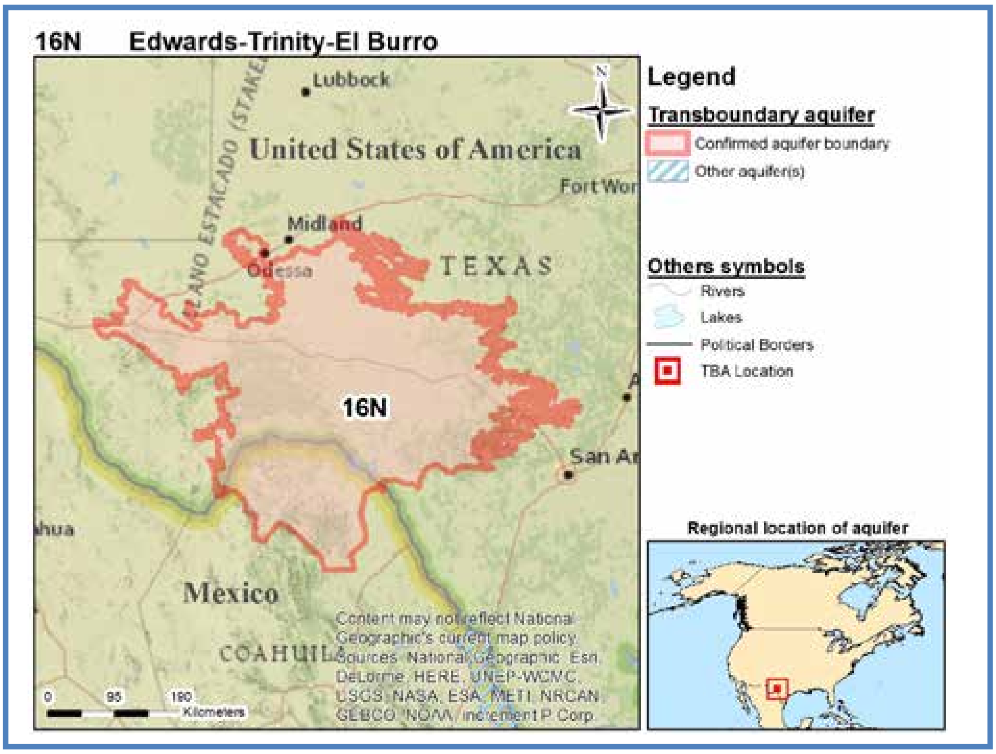
Rainfall (mm/yr): 460

Hydrogeology

Aquifer type: Multiple layers hydraulically connected

Degree of confinement: Whole aquifer unconfined

Main Lithology: Sedimentary rocks - Limestone



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No cross-section available

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

16N - Edwards-Trinity-El Burro

TWAP Groundwater Indicators from Global Inventory

	Recharge (mm/y) (1)	Renewable groundwater per capita (m^3/y/capita)	Natural background groundwater quality (%) (2)	Human dependency on groundwater (%)	Groundwater depletion (mm/y)	Groundwater pollution (%) (3)	Population density (Persons/km2)	Groundwater development stress (%) (4)	Transboundary legal framework (Scores) (5)	Transboundary institutional framework (Scores) (6)
Mexico	1	66	100	100	0	A	9	5	A	C
United States of America							3			
TBA level							**4**			

(1) Recharge: This is the long term average recharge (in m^3/yr) divided by the surface area (m^2) of the complete country segment of the aquifer (i.e. not only the recharge area).

(2) Natural background groundwater quality: Estimate of percentage of surface area of aquifer where the natural groundwater quality satisfies local drinking water standards.

(3) Groundwater pollution: A. No pollution has been identified; B. Some pollution has been identified; Positive number: Significant pollution has been identified (% of surface area of aquifer).

(4) Groundwater development stress: Annual groundwater abstraction divided by recharge.

(5) Legal framework: A. Agreement with full scope for TBA management signed by all parties; B. Agreement with limited scope for TBA management signed by all parties; C. Agreement under preparation or available as an unsigned draft; D. No agreement exists, nor under preparation; E. Legal Framework differs between Aquifer States (see data at National level).

(6) Institutional Framework: A. Dedicated transboundary institution fully operational; B. Dedicated transboundary institution in place, but not fully operational; C. National/Domestic institution fully operational; D. National/Domestic institution in place, but not fully operational; E. No institution exists for TBA management; F. Institutional Framework differs between Aquifer States (see data at National level).

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

TWAP Groundwater Indicators from WaterGAP model

	Recharge, incl. recharge from irrigation (mm/yr)	Renewable groundwater per capita			Human dependency on groundwater (%)	Human dependency on groundwater for domestic water supply (%)	Human dependency on groundwater for irrigation (%)	Human dependency on groundwater for industrial water use(%)
		Current state (m^3/y/capita)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)				
Mexico	6	700	-2	-6	25	39	19	0
United States of America	18	4300	-24	-24	63	70	79	6
TBA level	**16**	**3200**	**-24**	**-23**	**60**	**63**	**74**	**6**

16N - Edwards-Trinity-El Burro

	Groundwater depletion (mm/y)	Population density			Groundwater development stress		
		Current state (Persons/km2)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)	Current state (%)	Projection 2030 (% point change to current state)	Projection 2050 (% point change to current state)
Mexico	0	8	20	30	14	6	14
United States of America	2	4	15	26	27	11	7
TBA level	**2**	**5**	**17**	**27**	**26**	**10**	**7**

Key parameters table from Global Inventory

	Distance from ground surface to groundwater table (m)	Depth to top of aquifer formation (m)	Full vertical thickness of the aquifer (system)* (m)	Degree of confinement	Predominant aquifer lithology	Predominant type of porosity (or voids)	Secondary Porosity	Transmissivity (m^2/d)
Mexico	6	<5	80	Whole aquifer unconfined	Sedimentary rocks - Limestone	High primary porosity fine/ medium sedimentary deposits	Secondary porosity: Fractures	99
United States of America								
TBA level								

* Including aquitards/aquicludes

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

Aquifer description

Only Mexico has provided information

Aquifer geometry

It is a multiple 2-layered, hydraulically connected, system. The whole aquifer is un confined. The average distance to the groundwater level is 6m and the average total vertical thickness of the aquifer system is 80m.

Hydrogeological aspects

The main lithology is sedimentary rocks - limestone that have a high primary porosity as well as secondary porosity: fractures. The average aquifer transmissivity is estimated at 99m²/d. The average annual aquifer recharge is estimated at 12 Mm³/annum, coming from a recharge area of 4 000 km². The total groundwater volume is 9 km³.

Linkages with other water systems

Recharge to the aquifer system is from precipitation on the aquifer area and discharge from the system is through evapotranspiration.

16N - Edwards-Trinity-El Burro

Environmental aspects
Groundwater across the whole aquifer area is suitable for human consumption. No pollution has been identified. No areas with shallow groundwater or groundwater dependent ecosystems have been reported by the countries, although the Edwards Aquifer is notably known for the groundwater dependent ecosystems that are located over its area.

Socio-economic aspects
The annual average groundwater abstraction has been estimated as 0.6 Mm³/annum, which is also the figure provided for total annual fresh water abstraction. There has been no groundwater depletion.

Legal and Institutional aspects
Mexico makes mention of a Bilateral Agreement with full scope. It also identifies its National Institution that has a full mandate and full capacity. Groundwater management is undertaken according to National law and regulations.

Emerging issues
Nothing identified at this stage.

Contributors to Global Inventory

Name	Organisation	Country	E-mail	Role
Alberto Manganelli		Uruguay	albertomanganelli@yahoo.com	Regional coordinator
Víctor Manuel Castañón Arcos	Comisión Nacional del Agua	Mexico	victor.castanon@conagua.gob.mx	Contributing national expert
Rubén Chávez Guillén	Comisión Nacional del Agua	Mexico	ruben.chavez@conagua.gob.mx	Contributing national expert
Felipe Ignacio Arreguín Cortés	Comisión Nacional del Agua	Mexico	felipe.arreguin@conagua.gob.mx	Lead National Expert
Manuel Martínez Morales	Instituto Mexicano de Tecnología del Agua	Mexico	manuelm@tlaloc.imta.mx	Contributing national expert
Roberto Aurelio Sención Aceves	Comisión Nacional del Agua	Mexico	roberto.sencion@conagua.gob.mx	Contributing national expert
Carlos Gutiérrez Ojeda	Instituto Mexicano de Tecnología del Agua	Mexico	cgutierr@tlaloc.imta.mx	Contributing national expert

Considerations and recommendations

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The TBA system could not be described fully, because only one of the TBA countries provided adequate numerical information.

Data gaps and also differences between data from national experts (Global Inventory) and data derived from WaterGAP highlight the need for further research on transboundary aquifers.

16N - Edwards-Trinity-El Burro

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- All other data: TWAP Groundwater (2015).

Version: October 2015

4N - Poplar

Geography

Total area TBA (km^2): 23 000

No. countries sharing: 2

Countries sharing: Canada, United States of America

Population: 16 000

Climate zone: Semi-arid

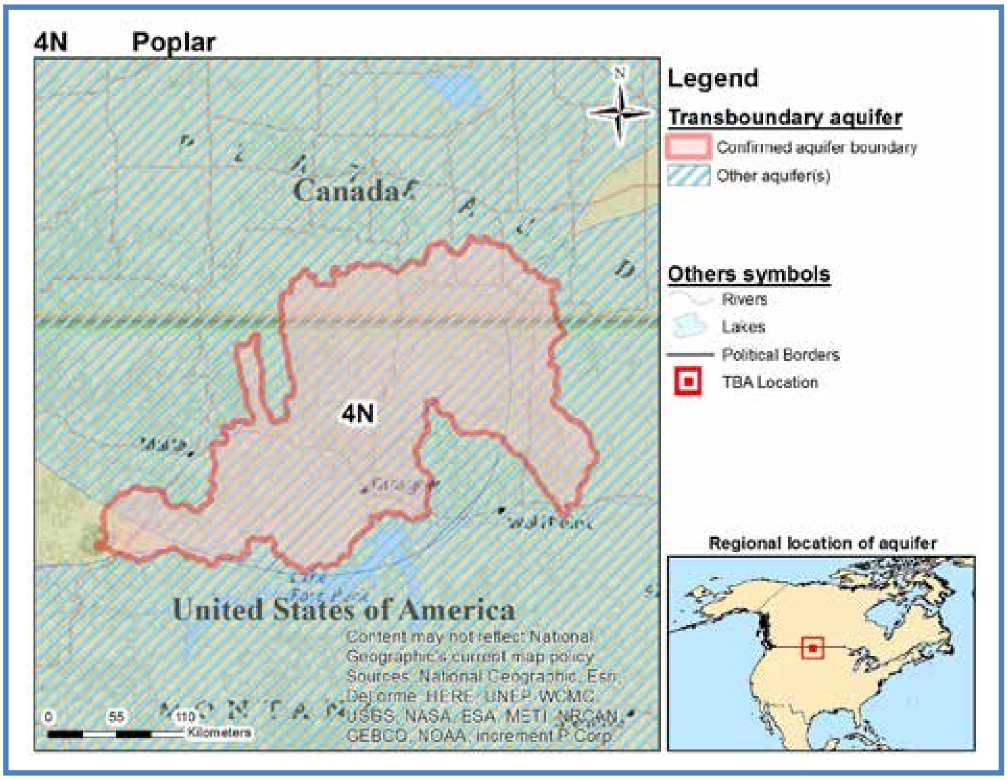
Rainfall (mm/yr): 310

Hydrogeology

Aquifer type: Data not available

Degree of confinement: Data not available

Main Lithology: Data not available



No cross-section available

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

4N - Poplar

TWAP Groundwater Indicators from Global Inventory

No data available.

Key parameters table from Global Inventory

No data available.

Aquifer description

No data available.

Contributors to Global Inventory

No contributions.

Considerations and recommendations

Canada and the United States of America did not provide data to the global inventory. This unfortunately presents a major gap in the first global transboundary groundwater assessment.

Request:
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For more information on TWAP Groundwater and for more data, please have a look at the TWAP Groundwater Information Management System which is accessible via www.twap.isarm.org or www.un-igrac.org.

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- All other data: TWAP Groundwater (2015).

Version: October 2015

19N - Judith River

Geography

Total area TBA (km^2): 170 000

No. countries sharing: 2

Countries sharing: Canada, United States of America

Population: 530 000

Climate zone: Humid Continental

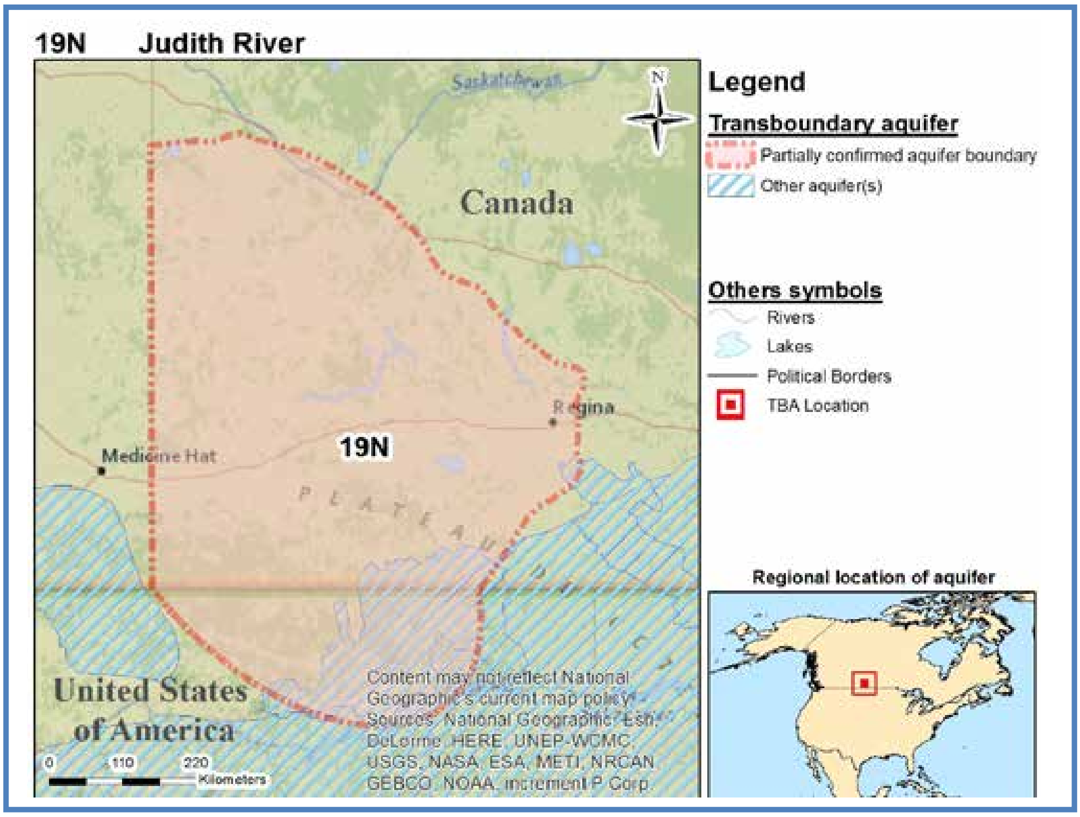
Rainfall (mm/yr): 350

Hydrogeology

Aquifer type: Data not available

Degree of confinement: Data not available

Main Lithology: Data not available



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No cross-section available

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

19N - Judith River

TWAP Groundwater Indicators from Global Inventory

No data available.

Key parameters table from Global Inventory

No data available.

Aquifer description

No data available.

Contributors to Global Inventory

No contributions.

Considerations and recommendations

Canada and the United States of America did not provide data to the global inventory. This unfortunately presents a major gap in the first global transboundary groundwater assessment.

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- All other data: TWAP Groundwater (2015).

Version: October 2015

20N - Milk River

Geography

Total area TBA (km^2): 26 000

No. countries sharing: 2

Countries sharing: Canada, United States of America

Population: 31 000

Climate zone: Semi-arid

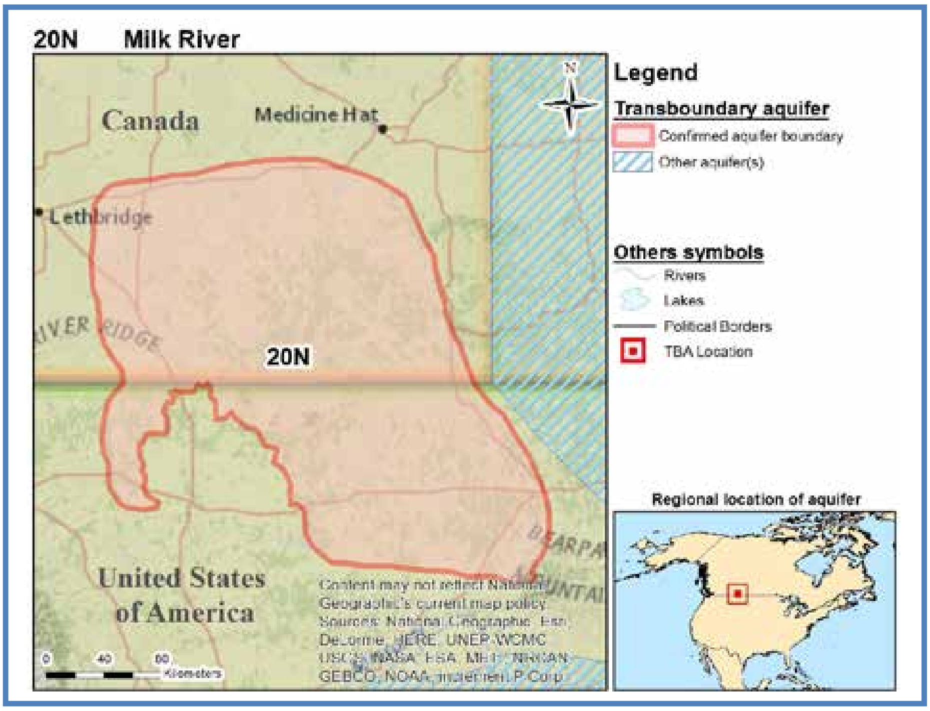
Rainfall (mm/yr): 320

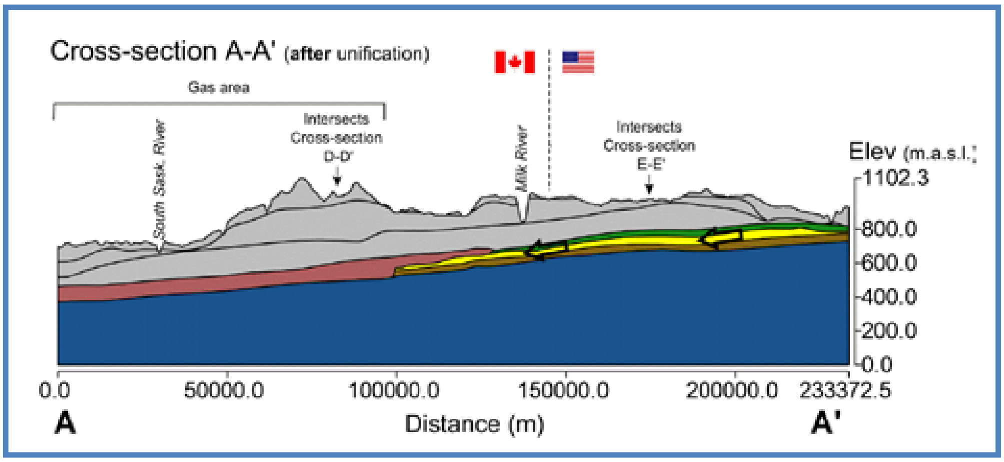
Hydrogeology

Aquifer type: Single layer

Degree of confinement: Confined

Main Lithology: Sedimentary deposits





Simplified Cross-section across part of the aquifer where it crosses the border between the countries

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

20N - Milk River

TWAP Groundwater Indicators from Global Inventory

	Recharge (mm/y) (1)	Renewable groundwater per capita (m^3/y/capita)	Natural background groundwater quality (%) (2)	Human dependency on groundwater (%)	Groundwater depletion (mm/y)	Groundwater pollution (%) (3)	Population density (Persons/km2)	Groundwater development stress (%) (4)	Transboundary legal framework (Scores) (5)	Transboundary institutional framework (Scores) (6)
Canada							1		D	E
United States of America							1			
TBA level							**1**			

(1) Recharge: This is the long term average recharge (in m^3/yr) divided by the surface area (m^2) of the complete country segment of the aquifer (i.e. not only the recharge area).

(2) Natural background groundwater quality: Estimate of percentage of surface area of aquifer where the natural groundwater quality satisfies local drinking water standards.

(3) Groundwater pollution: A. No pollution has been identified; B. Some pollution has been identified; Positive number: Significant pollution has been identified (% of surface area of aquifer).

(4) Groundwater development stress: Annual groundwater abstraction divided by recharge.

(5) Legal framework: A. Agreement with full scope for TBA management signed by all parties; B. Agreement with limited scope for TBA management signed by all parties; C. Agreement under preparation or available as an unsigned draft; D. No agreement exists, nor under preparation; E. Legal Framework differs between Aquifer States (see data at National level).

(6) Institutional Framework: A. Dedicated transboundary institution fully operational; B. Dedicated transboundary institution in place, but not fully operational; C. National/Domestic institution fully operational; D. National/Domestic institution in place, but not fully operational; E. No institution exists for TBA management; F. Institutional Framework differs between Aquifer States (see data at National level).

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

TWAP Groundwater Indicators from WaterGAP model

	Recharge, incl. recharge from irrigation (mm/yr)	Renewable groundwater per capita			Human dependency on groundwater (%)	Human dependency on groundwater for domestic water supply (%)	Human dependency on groundwater for irrigation (%)	Human dependency on groundwater for industrial water use(%)
		Current state (m^3/y/capita)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)				
Canada	73	40 000	-3	-9	0	29	0	0
United States of America	20	15 000	3	-1	4	50	3	0
TBA level	**50**	**31 000**	**-2**	**-8**	**1**	**36**	**0**	**0**

20N - Milk River

	Groundwater depletion (mm/y)	Population density			Groundwater development stress		
		Current state (Persons/km2)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)	Current state (%)	Projection 2030 (% point change to current state)	Projection 2050 (% point change to current state)
Canada	0	2	16	26	<1	0	0
United States of America	0	1	15	25	2	0	0
TBA level	**0**	**2**	**16**	**26**	<1	**0**	**0**

Key parameters table from Global Inventory

	Distance from ground surface to groundwater table (m)	Depth to top of aquifer formation (m)	Full vertical thickness of the aquifer (system)* (m)	Degree of confinement	Predominant aquifer lithology	Predominant type of porosity (or voids)	Secondary Porosity	Transmissivity (m^2/d)
Canada	30	200	100			High primary porosity fine/ medium sedimentary deposits	No secondary porosity	7
United States of America								
TBA level								

* Including aquitards/aquicludes

X A value was provided in the questionnaire, but it was considered un-realistic and therefore removed from the table.

Aquifer description

Only Canada has provided the information so most of the values relate to the part of the aquifer that falls within Canada.

Aquifer geometry

It is a single layered system. The average distance to the groundwater table is 30m and the average depth to the top of the aquifer 200m. The total vertical thickness of the aquifer system is 100m. The aquifer is mostly confined. The depth information and the piezometric map (See appendix) also indicate artesian conditions.

Hydrogeological aspects

There is no information on the aquifer lithology, but it is reported that the aquifer has high primary porosity fine/medium sedimentary deposits and no secondary porosity. The average aquifer transmissivity is estimated as $7m^2/d$, going to a maximum of $620m^2/day$. The average annual aquifer recharge is not known. The total groundwater volume is 40 km^3.

20N - Milk River

Linkages with other water systems

Recharge to the aquifer system is from precipitation on the aquifer area. There is no information on the discharge mechanism.

Environmental aspects

There is no information on the natural quality of the groundwater. Some pollution has been identified, but the extent and origin has not been reported on. No information is available on the occurrence of shallow groundwater and on groundwater dependent ecosystems.

Socio-economic aspects

No information is available on annual groundwater abstraction or fresh water abstraction.

Legal and Institutional aspects

Canada reports that no Bi-lateral Agreement exists. No information is provided on how groundwater is managed nationally.

Emerging issues

Information is too limited to draw any conclusions from.

Contributors to Global Inventory

Name	Organisation	Country	E-mail	Role
Alberto Manganelli		Uruguay	albertomanganelli@yahoo.com	Regional coordinator
Marie-Amélie Petre	INRS-Centre ETE - University of Quebec	Canada	marie-amelie.petre@ete.inrs.ca	Contributing national expert
Alfonso Rivera	Geological Survey of Canada	Canada	arivera@nrcan.gc.ca	Contributing national expert
Randall Hanson	U.S. Geological Survey	United States	rthanson@usgs.gov	Contributing national expert
Joanna Thamke	US Geological Survey	United States	jothamke@usgs.gov	Contributing national expert

Considerations and recommendations

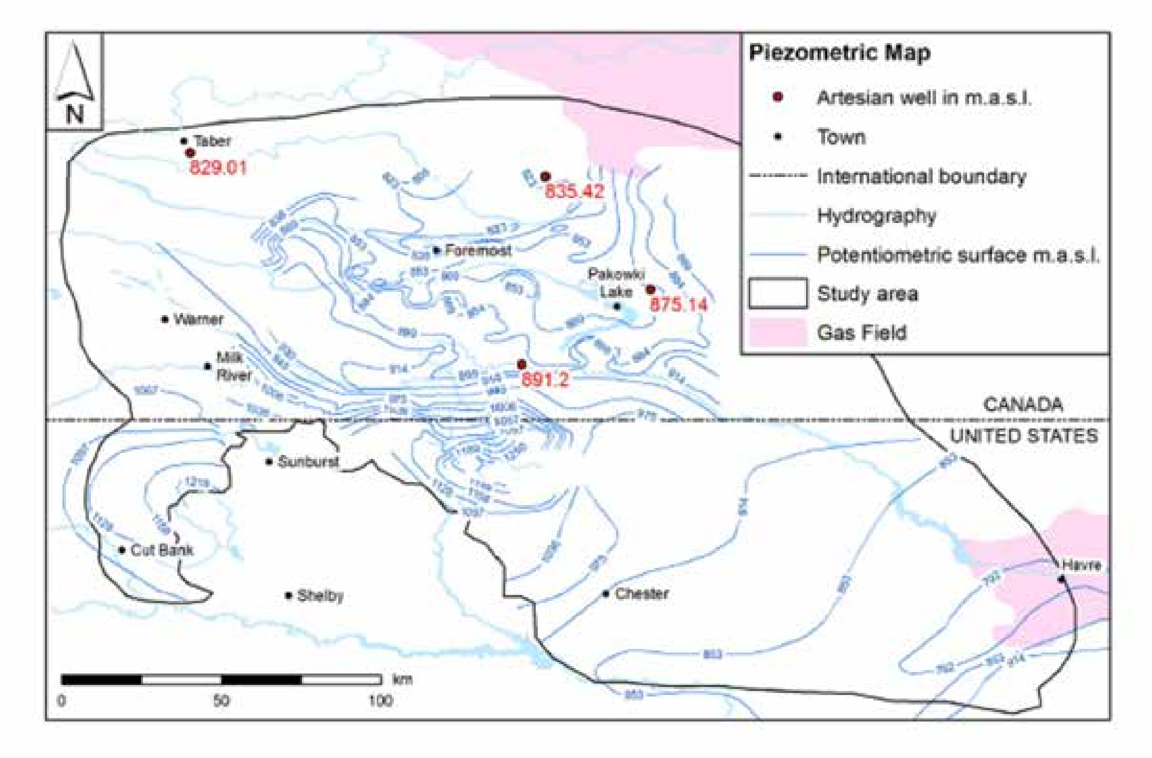
Most data in the tables and text above have been provided by national and regional experts (listed above) or have been derived from the global WaterGAP model. See colophon for more information, including references to data from other sources.

The TBA system could not be described fully, because only one of the TBA countries provided adequate numerical information.

Data gaps and also differences between data from national experts (Global Inventory) and data derived from WaterGAP highlight the need for further research on transboundary aquifers.

20N - Milk River

Appendix: 20N



Milk River – Piezometric Map

Colophon

This Transboundary Aquifers information sheet has been produced as part of the Groundwater Component of the GEF Transboundary Water Assessment Programme (GEF TWAP). **GEF TWAP** is the first truly global comparative assessment of transboundary groundwater, lakes, rivers, large marine ecosystems and the open ocean. More information on TWAP can be found on: www.geftwap.org . **The Groundwater component** of TWAP carried out a global comparison of 199 transboundary aquifers and the groundwater systems of 41 Small Island Developing States. The data used to compile this transboundary aquifer information sheet has been made available by national and regional experts from countries involved in the TWAP Groundwater project. For aquifers larger than 20 000 km2 and which are not overlapping, additional data are available from modelling done by the Goethe University Frankfurt (Germany) as part of TWAP Groundwater. All data were compiled by UNESCO-IHP and the International Groundwater Resources Assessment Centre (IGRAC – UNESCO Category II Institute). Values given in the fact-sheet represent an approximate guide only and should not replace data obtained from recent local assessments. The editors of this information sheet are not responsible for the quality of the data.

For more information on TWAP Groundwater and for more data, please have a look at the TWAP Groundwater Information Management System which is accessible via www.twap.isarm.org or www.un-igrac.org.

Request:
If you have additional data or information about this transboundary aquifer that can improve the quality of this information sheet and the underlying database, please contact us via email at info@un-igrac.org. If appropriate, the information will be uploaded to the database of transboundary aquifers and will also be used in new versions of this information sheet.

References:

- Population: Population has been calculated based on the aquifer map and grid information on population. Source population data: Center for International Earth Science Information Network - CIESIN - Columbia University, United Nations Food and Agriculture Programme - FAO, and Centro Internacional de Agricultura Tropical - CIAT. 2005. Gridded Population of the World, Version 3 (GPWv3): Population Count Grid, Future Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H42B8VZZ. Accessed Jan 2015.
- Rainfall: Average rainfall per TBA has been calculated based on the aquifer map and grid data for precipitation. Source precipitation data: Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated

20N - Milk River

climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978. Grid data download from www.worldclim.org (2015): Data for current conditions (~1950-2000), ESRI grids, 30 arc seconds, Precipitation.
- Climate: Climate indicates the major climate zone which occurs in the aquifer area. If more than 1 climate zone is present the zone with the largest surface area was selected. Source climate data: ArcGIS Online (2015), Simplified World Climate zones. Owner: Mapping Our World GIS Education. Original map: National Geographic World Atlas for Young Explorers (1998).
- All other data: TWAP Groundwater (2015).

Version: October 2015

6N - Northern Great Plains

Geography

Total area TBA (km^2): 770 000

No. countries sharing: 2

Countries sharing: Canada, United States of America

Population: 2 000 000

Climate zone: Humid Continental

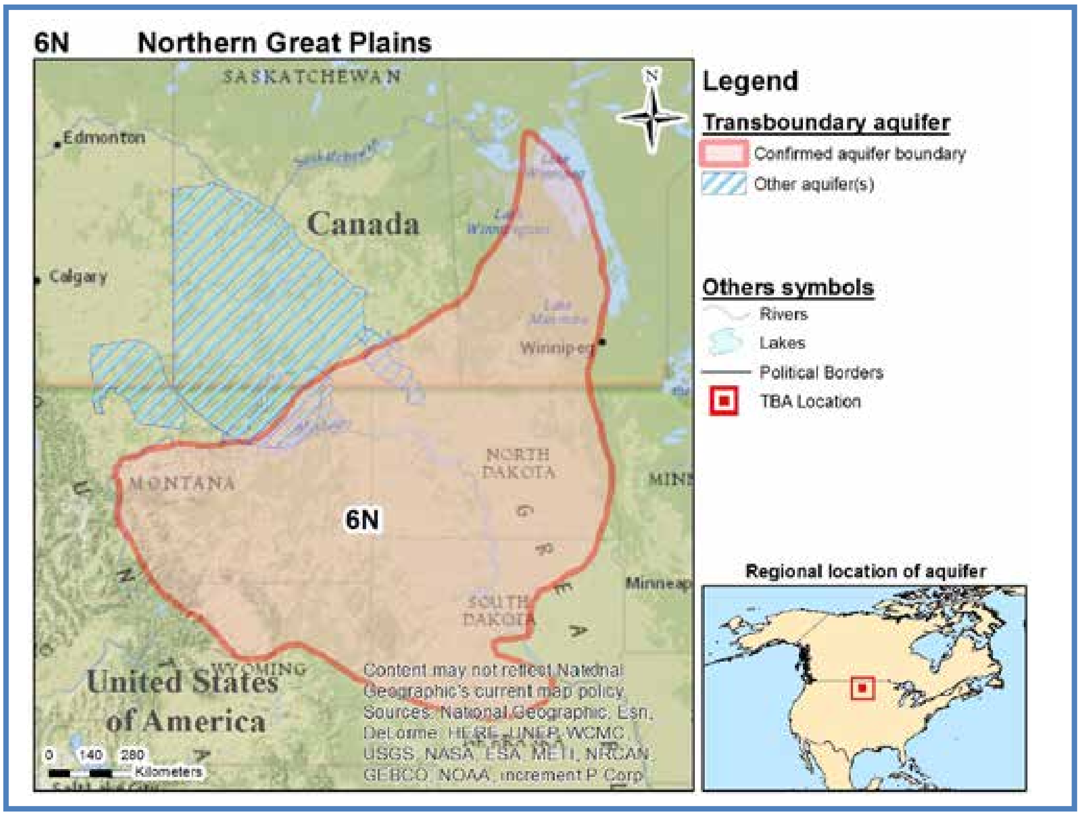
Rainfall (mm/yr): 430

Hydrogeology

Aquifer type: Data not available

Degree of confinement: Data not available

Main Lithology: Data not available



No cross-section available

Map and cross-section are only provided for illustrative purposes. Dimensions are only approximate.

6N - Northern Great Plains

TWAP Groundwater Indicators from Global Inventory

No data available.

TWAP Groundwater Indicators from WaterGAP model

	Recharge, incl. recharge from irrigation (mm/yr)	Renewable groundwater per capita			Human dependency on groundwater (%)	Human dependency on groundwater for domestic water supply (%)	Human dependency on groundwater for irrigation (%)	Human dependency on groundwater for industrial water use(%)
		Current state (m^3/y/capita)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)				
Canada	43	13 000	5	-3	10	46	48	0
United States of America	46	20 000	5	-4	14	60	16	1
TBA level	**45**	**18 000**	**5**	**-4**	**14**	**56**	**17**	**1**

	Groundwater depletion (mm/y)	Population density			Groundwater development stress		
		Current state (Persons/km2)	Projection 2030 (% change to current state)	Projection 2050 (% change to current state)	Current state (%)	Projection 2030 (% point change to current state)	Projection 2050 (% point change to current state)
Canada	0	4	16	26	2	0	0
United States of America	0	2	15	25	5	0	0
TBA level	**0**	**3**	**15**	**25**	**4**	**0**	**0**

Key parameters table from Global Inventory

No data available.

Aquifer description

No data available.

Contributors to Global Inventory

No contributions.

Considerations and recommendations

Canada and the United States of America did not provide data to the global inventory. This unfortunately presents a major gap in the first global transboundary groundwater assessment. The only information that could be presented here has been derived from the global WaterGAP model. See colophon for more information, including references to data from other sources.

6N - Northern Great Plains

Request:

If you have data or information about this transboundary aquifer that can improve the quality of this information sheet and the underlying database, please contact us via email at info@un-igrac.org. If appropriate, the information will be uploaded to the database of transboundary aquifers and will also be used in new versions of this information sheet.

Colophon

This Transboundary Aquifers information sheet has been produced as part of the Groundwater Component of the GEF Transboundary Water Assessment Programme (GEF TWAP). **GEF TWAP** is the first truly global comparative assessment of transboundary groundwater, lakes, rivers, large marine ecosystems and the open ocean. More information on TWAP can be found on: www.geftwap.org . **The Groundwater component** of TWAP carried out a global comparison of 199 transboundary aquifers and the groundwater systems of 41 Small Island Developing States. The data used to compile this transboundary aquifer information sheet has been made available by national and regional experts from countries involved in the TWAP Groundwater project. For aquifers larger than 20 000 km2 and which are not overlapping, additional data are available from modelling done by the Goethe University Frankfurt (Germany) as part of TWAP Groundwater. All data were compiled by UNESCO-IHP and the International Groundwater Resources Assessment Centre (IGRAC – UNESCO Category II Institute). Values given in the fact-sheet represent an approximate guide only and should not replace data obtained from recent local assessments. The editors of this information sheet are not responsible for the quality of the data.

For more information on TWAP Groundwater and for more data, please have a look at the TWAP Groundwater Information Management System which is accessible via www.twap.isarm.org or www.un-igrac.org.

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- Rainfall: Average rainfall per TBA has been calculated based on the aquifer map and grid data for precipitation. Source precipitation data: Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978. Grid data download from www.worldclim.org (2015): Data for current conditions (~1950-2000), ESRI grids, 30 arc seconds, Precipitation.
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- All other data: TWAP Groundwater (2015).

Version: October 2015

Transboundary Lakes / Reservoirs of Northern America

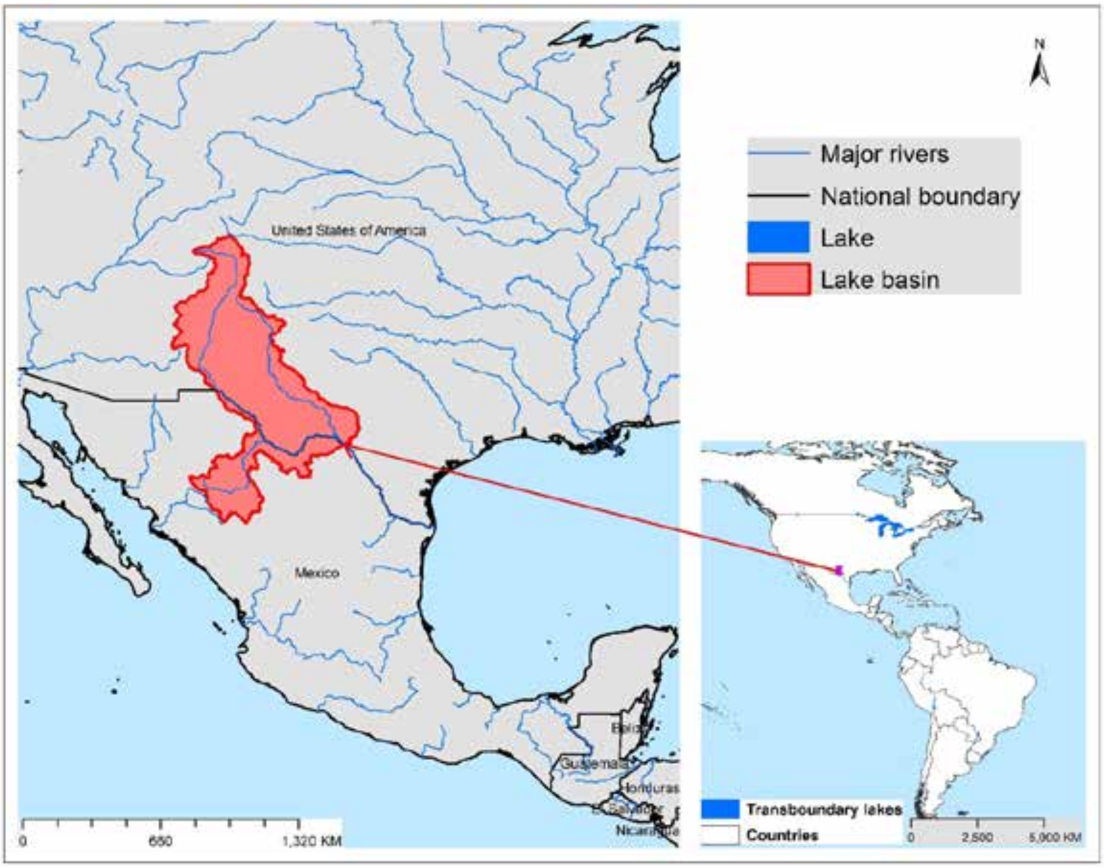
1. Lake Amistad
2. Lake Champlain
3. Lake Erie
4. Lake Falcon
5. Lake Huron
6. Lake Michigan
7. Lake Ontario
8. Lake Superior

ILEC
The Meadows Center for Water and the Environment
Texas State University
SHIGA UNIVERSITY

Lake Amistad

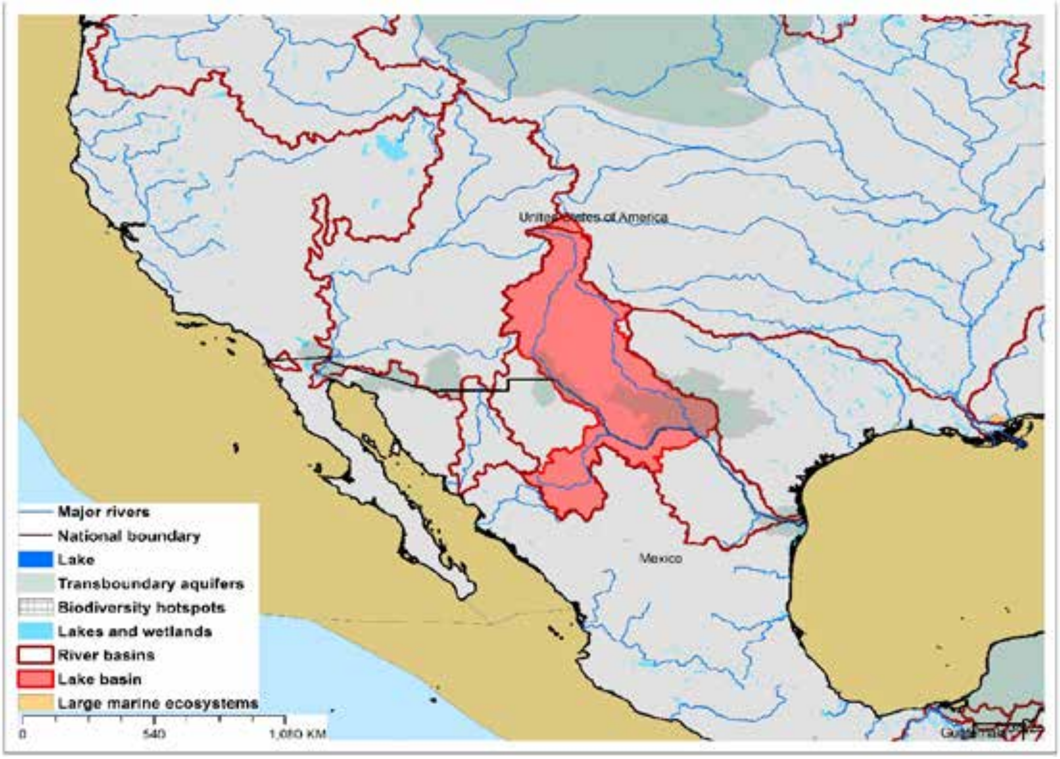
Geographic Information

Lake Amistad, considered an oasis in the desert by some, is a reservoir on the transboundary Rio Grande at its confluence with the Devils River northwest of Del Rio, Texas. Its drainage basin includes a vast area of West Texas and Northeastern Mexico. It was constructed by Mexico and the United States to jointly manage allocation of the waters of the transboundary portion of the Rio Grande between Texas and Mexico, as specified in the 1944 Treaty between the two countries. It is also used for flood control, water conservation, irrigation, and hydropower production, as well as providing year-round recreational opportunities (boating, fishing, swimming, scuba diving, water skiing). The area covered by the reservoir is rich in archaeology and rock art, having previously been inhabited by Indigenous Americans living in caves along the river. The reservoir area also contains a wide variety of plant and animal life.

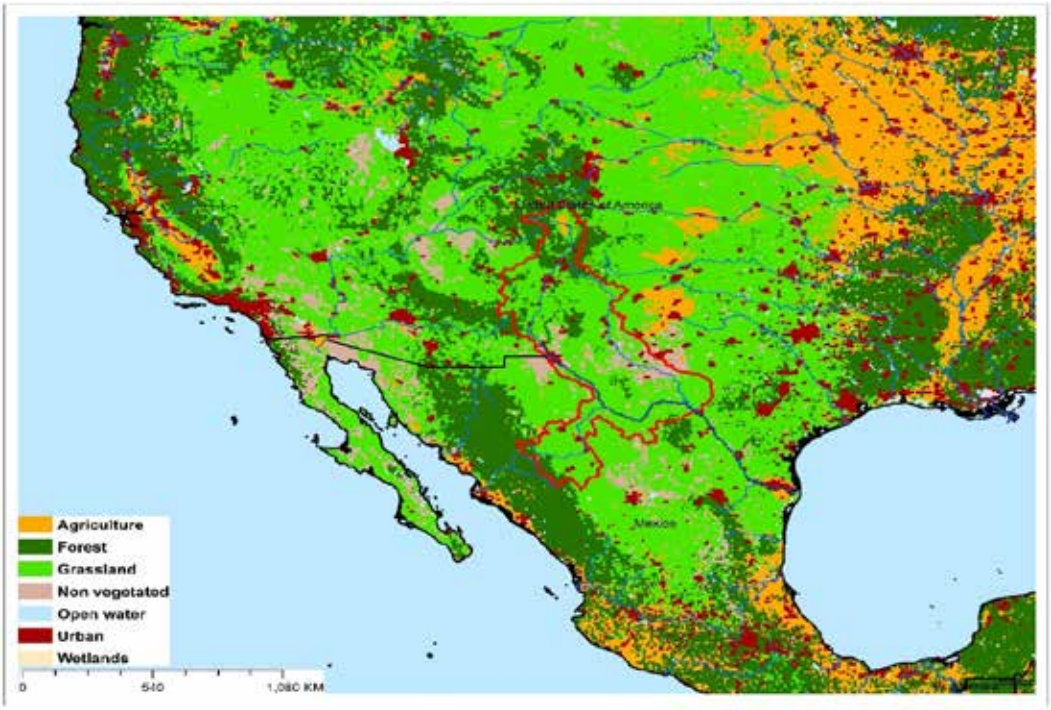


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	4,724,154
River Basin	Rio Grande	**Lake Basin Population Density (2010; # km^{-2})**	13.8
Riparian Countries	Mexico, USA	**Average Basin Precipitation (mm yr^{-1})**	360.2
Basin Area (km^2)	375,660	**Shoreline Length (km)**	232.0
Lake Area (km^2)	131.3	**Human Development Index (HDI)**	0.86
Lake Area:Lake Basin Ratio	0.0003	**International Treaties/Agreements Identifying Lake**	Yes

Lake Amistad Basin Characteristics



(a) Lake Amistad basin and associated transboundary water systems



(b) Lake Amistad basin land use

Lake Amistad Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Amistad and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Amistad threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Amistad and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Amistad Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank	Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank	Human Development Index (HDI) Score	Relative HDI Rank
0.49	47	0.61	26	0.86	45

It is emphasized that the Lake Amistad rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Amistad indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Amistad, which is meant to describe its biodiversity sensitivity to basin-derived degradation, places the lake in a medium threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Amistad basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Amistad Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

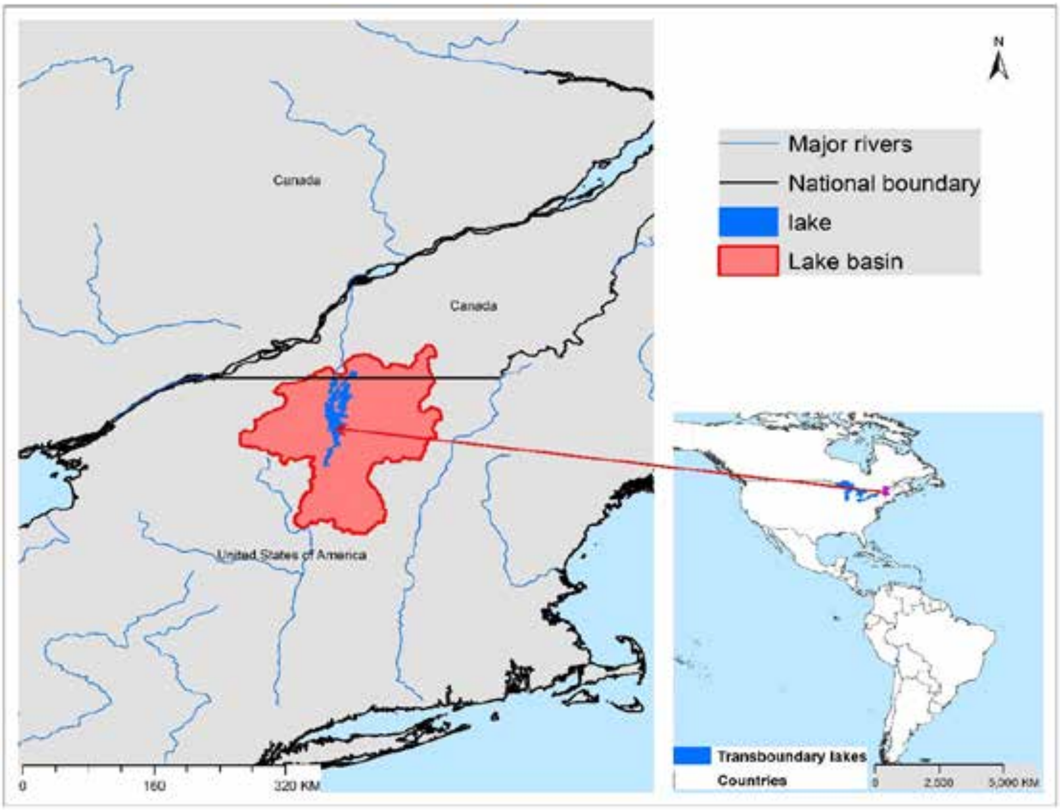
Adj-HWS Rank	HDI Rank	RvBD Rank		Sum Adj-HWS + RvBD	Relative Threat Rank		Sum Adj-HWS + HDI	Relative Threat Rank		Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
47	**45**	**26**		**73**	**40**		**47**	**40**		**118**	**42**

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Amistad in the lower third of the threat ranks. The relative threat is similar when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Amistad exhibits an overall moderately low threat ranking.

Interactions between the ranking parameters for Lake Amistad indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Amistad must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Amistad basin? Accurate answers to such questions for Lake Amistad, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

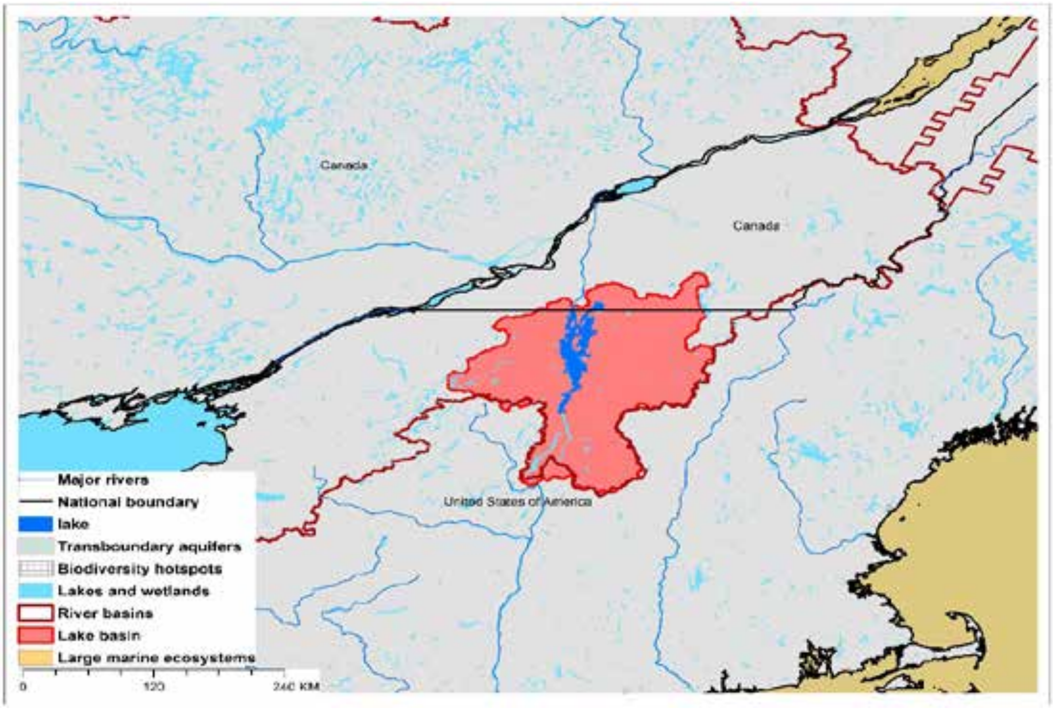
Lake Champlain Geographic Information

Lake Champlain is one of many freshwater lakes located in an arc from Labrador, Canada, through the northern USA. Although smaller than the Laurentian Great Lakes, it is a large lake, historically an important northern gateway to the Iroquois (native Americans) lands around the lake. Its major ports were of commercially and militarily important in the 18th and 19th Centuries, being used today primarily by small craft, ferries and lake cruise ships. It is connected to the St. Lawrence River via the Richelieu River, and to the Hudson River by the Champlain Canal. It is used for swimming, boating and fishing, considered a world class salmonid fishery. It also provides habitat and resting areas for more than 300 bird species. Its major pollution sources are agricultural and urban runoff from its drainage basin, which contribute significantly to the lake's eutrophication. A plan developed by the riparian countries to address it is considered a model for interstate and international cooperation.

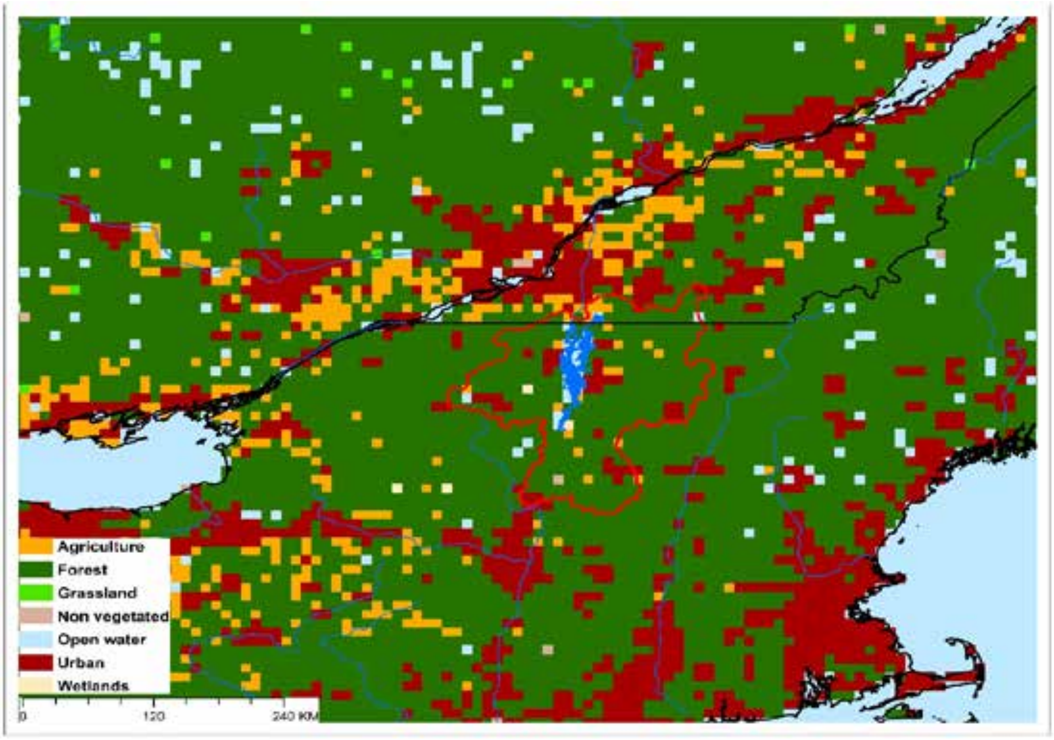


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	661,788
River Basin	St. Lawrence	**Lake Basin Population Density (2010; # km^{-2})**	29.9
Riparian Countries	Canada, USA	**Average Basin Precipitation (mm yr^{-1})**	1,000
Basin Area (km^2)	22,008	**Shoreline Length (km)**	865.6
Lake Area (km^2)	1,099	**Human Development Index (HDI)**	0.93
Lake Area:Lake Basin Ratio	0.050	**International Treaties/Agreements Identifying Lake**	Yes

Lake Champlain Basin Characteristics



(a) Lake Champlain basin and associated transboundary water systems



(b) Lake Champlain basin land use

Lake Champlain Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Champlain and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Champlain threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Champlain and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Champlain Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank	Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank	Human Development Index (HDI) Score	Relative HDI Rank
0.29	**53**	**0.51**	**38**	**0.94**	**53**

It is emphasized that the Lake Champlain rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Champlain indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Champlain, which is meant to describe its biodiversity sensitivity to basin-derived degradation, places the lake in a moderately low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Champlain basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Champlain Threat Ranks, Based on Multiple Ranking Criteria

***(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)***

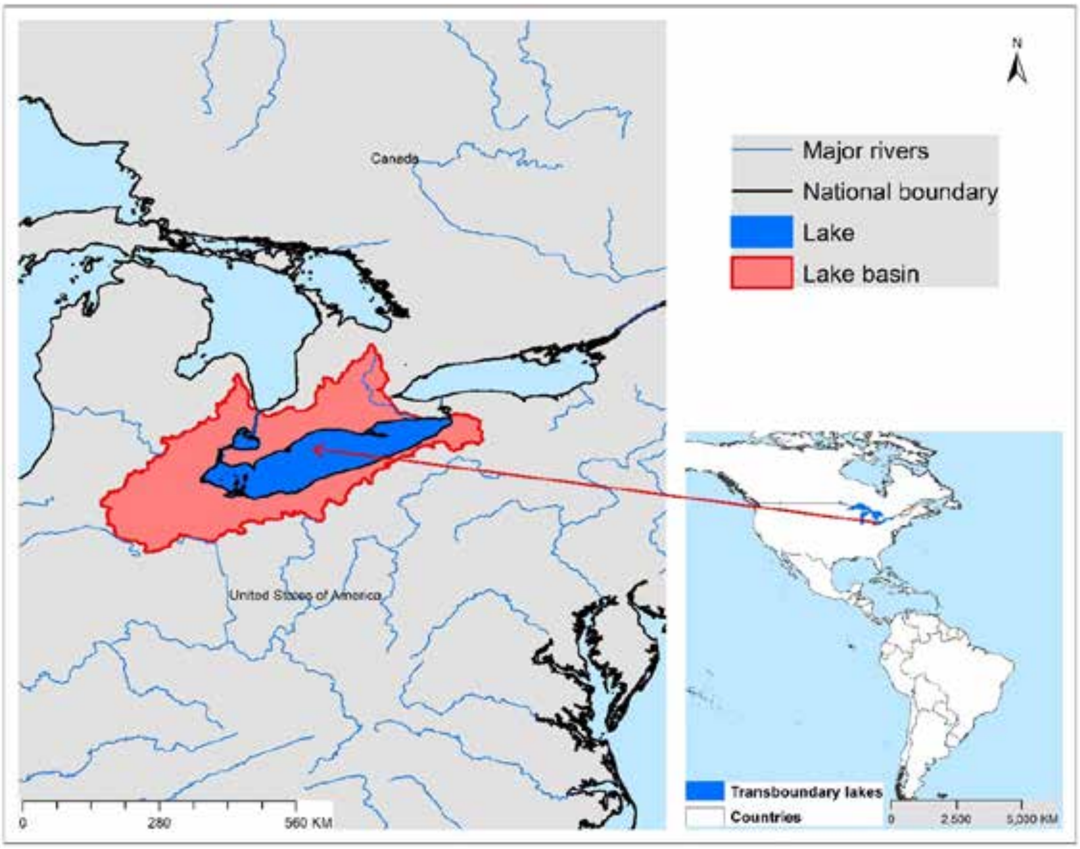
Adj-HWS Rank	HDI Rank	RvBD Rank		Sum Adj-HWS + RvBD	Relative Threat Rank		Sum Adj-HWS + HDI	Relative Threat Rank		Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
53	52	41		94	49		105	53		146	52

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Champlain in the lower quarter of the threat ranks. The relative threat is slightly increased when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Champlain exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Champlain indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Champlain must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Champlain basin? Accurate answers to such questions for Lake Champlain, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

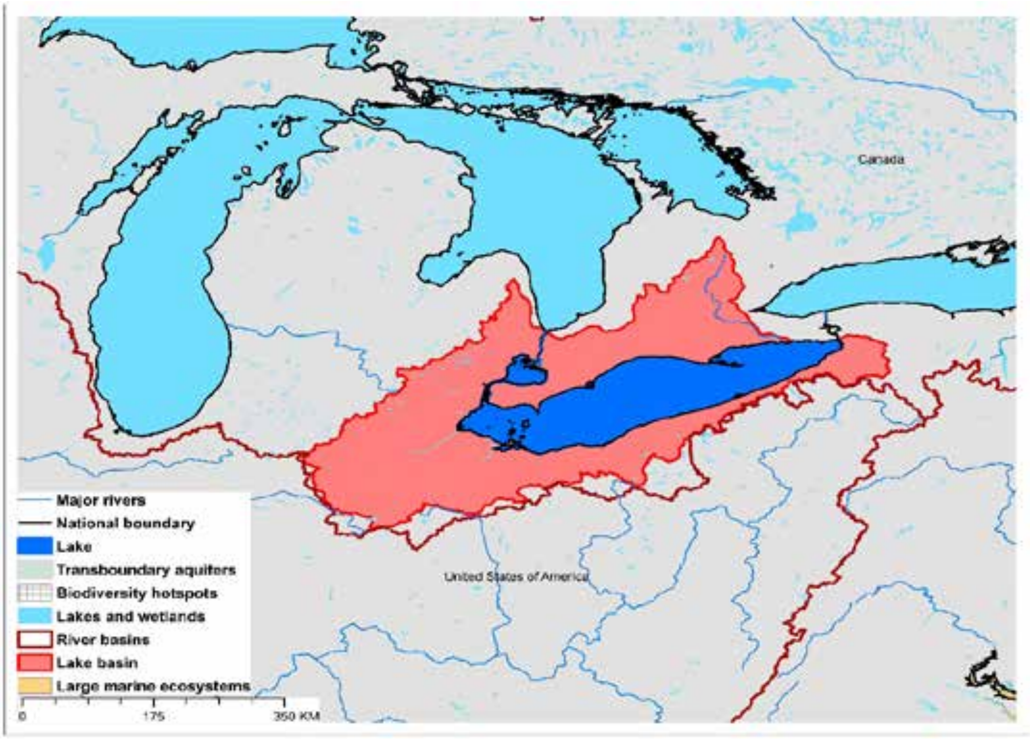
Lake Erie Geographic Information

Lake Erie is the fourth largest of the five Laurentian Great Lakes, and the thirteenth largest in the world (by area). It also is the southernmost, shallowest, warmest and most biologically productive, with the smallest water volume (484 km^3) of the Great Lakes. Its shallow depth makes it susceptible to wind-driven fluctuations in water level. It receives inflows from upstream Lakes Superior, Michigan and Huron, and drains to Lake Ontario via Niagara Falls. It has multiple water uses, including drinking and agricultural water supply, fishing, water sports, hydropower production and commercial shipping. Its environmental health has been of continuing concern, including overfishing, invasive species, urban, industrial and agricultural pollution and eutrophication. Originally managed within the context of the 1909 Boundary Waters Treaty between the USA and Canada, increasing eutrophication of Lake Erie was the impetus for the Great Lakes Water Quality Agreement between the two countries, including concerted efforts directed to controlling non-point source pollution of all the Great Lakes.

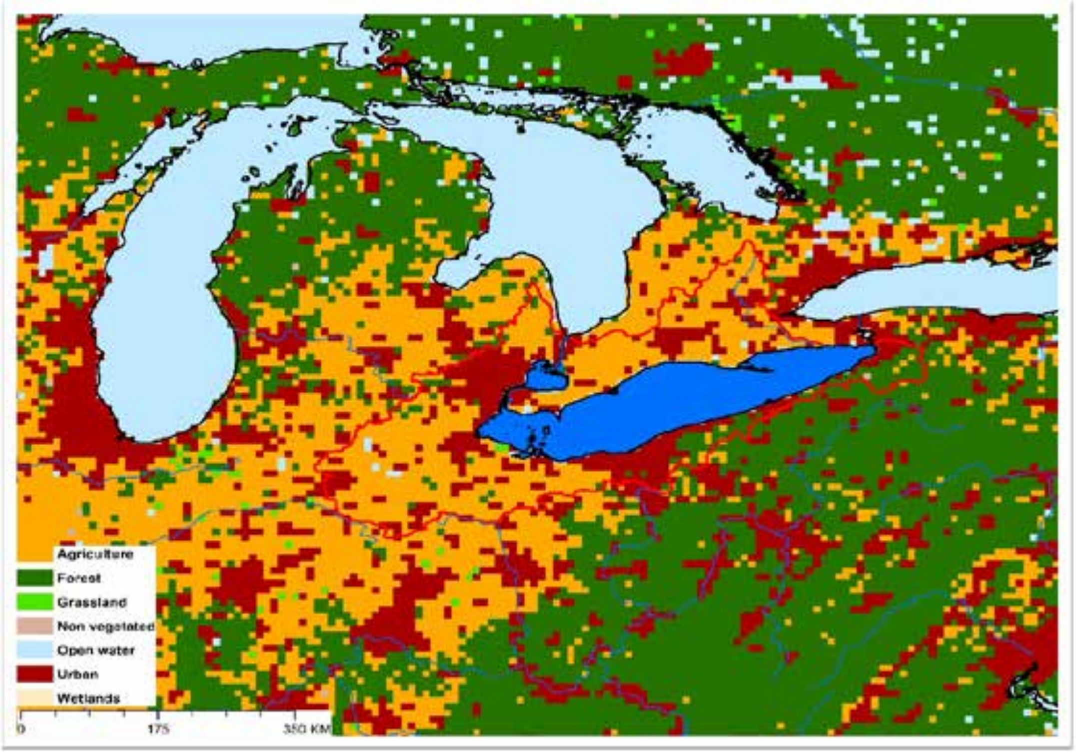


TWAP Regional Designation	Northern America		**Lake Basin Population (2010)**	13,804,450
River Basin	St. Lawrence		**Lake Basin Population Density (2010; # km^{-2})**	113.7
Riparian Countries	USA, Canada		**Average Basin Precipitation (mm yr^{-1})**	909.1
Basin Area (km^2)	102,670		**Shoreline Length (km)**	2,036
Lake Area (km^2)	26,560		**Human Development Index (HDI)**	0.93
Lake Area:Lake Basin Ratio	0.259		**International Treaties/Agreements Identifying Lake**	Yes

Lake Erie Basin Characteristics



(a) Lake Erie basin and associated transboundary water systems



(b) Lake Erie basin land use

Lake Erie Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Erie and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Erie threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Erie and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Erie Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank	Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank	Human Development Index (HDI) Score	Relative HDI Rank
0.51	**44**	**0.43**	**49**	**0.93**	**51**

It is emphasized that the Lake Erie rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Erie indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Erie, which is meant to describe its biodiversity sensitivity to basin-derived degradation, also places the lake in a low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Erie basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Erie Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj-HWS + RvBD	Relative Threat Rank	Sum Adj-HWS + HDI	Relative Threat Rank	Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
45	51	49	94	51	96	48	145	51

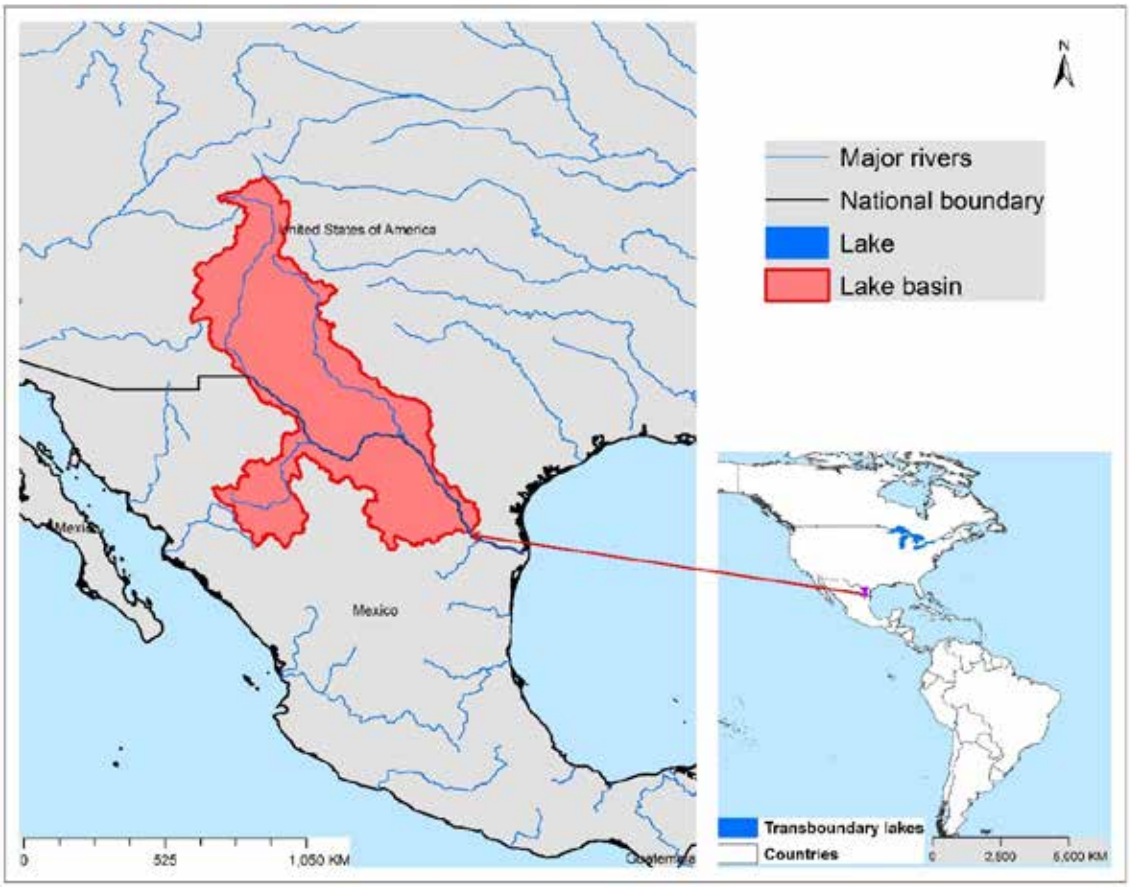
When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Erie in the lower quarter of the threat ranks. The relative threat is slightly reduced when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Erie exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Erie indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Erie must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Erie basin? Accurate answers to such questions for Lake Erie, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

Falcon Lake

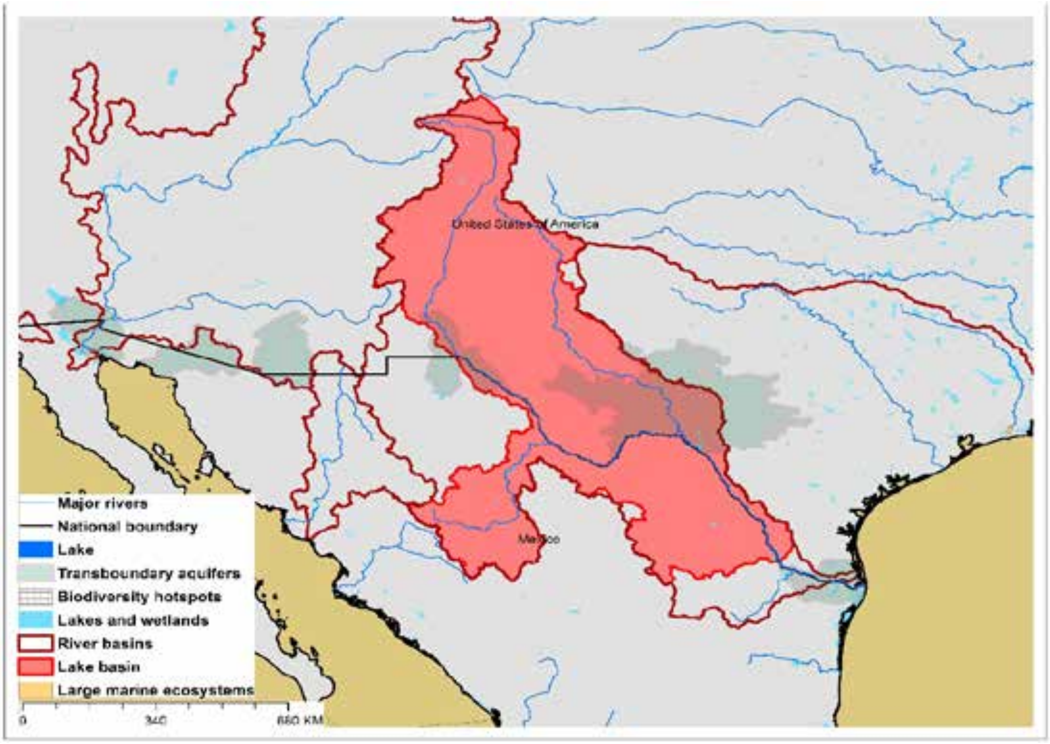
Geographic Information

Falcon Lake is an international reservoir on the transboundary Rio Grande southeast of Laredo, Texas and Nuevo Laredo, Tamaulipas, Mexico. Along with upstream Lake Amistad, which is included in its drainage basin, it was constructed by Mexico and the United States to jointly manage allocation of the waters of the transboundary portion of the Rio Grande between Texas and Mexico, as specified in the 1944 Treaty between the two countries. Its functions also include water conservation, agricultural irrigation, flood control, water sports, and hydropower production. It is especially important in regard to providing irrigation water for the major agricultural activities on both sides of the border on the lower Rio Grande. It also is a popular fishing location. At the same time, there have been episodes of piracy and armed robbery of boaters enjoying the reservoir.

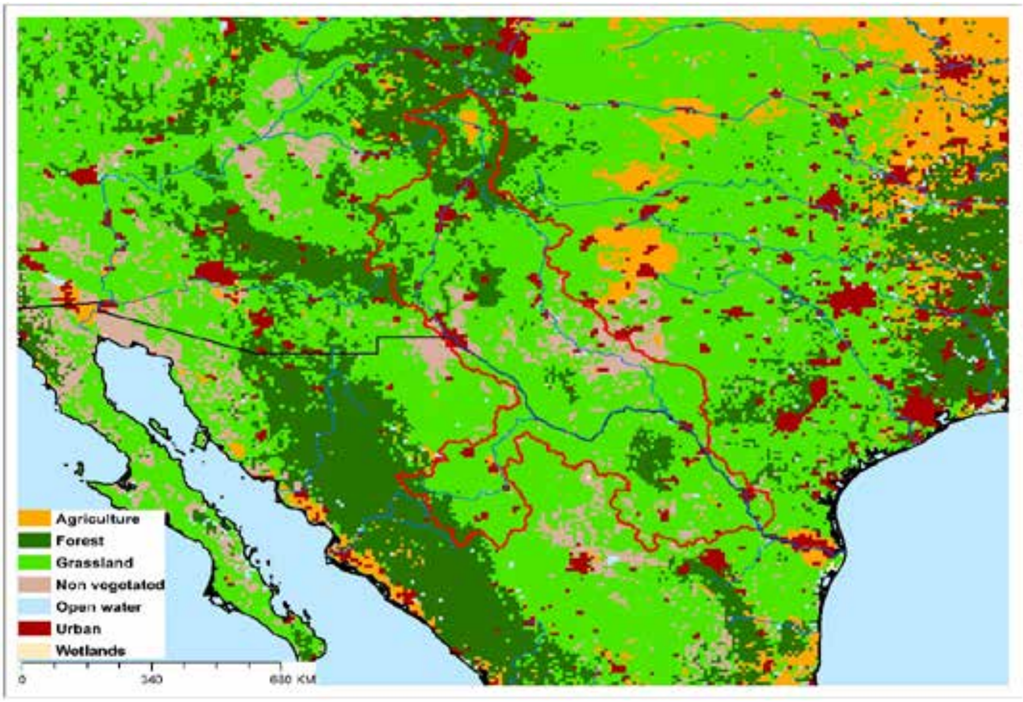


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	6,364,997
River Basin	Rio Grande	**Lake Basin Population Density (2010; # km^{-2})**	14.0
Riparian Countries	Mexico, USA	**Average Basin Precipitation (mm yr^{-1})**	371.2
Basin Area (km^2)	459,490	**Shoreline Length (km)**	301.1
Lake Area (km^2)	120.6	**Human Development Index (HDI)**	0.85
Lake Area:Lake Basin Ratio	0.0002	**International Treaties/Agreements Identifying Lake**	Yes

Falcon Lake Basin Characteristics



(a) Falcon Lake basin and associated transboundary water systems



(b) Falcon Lake basin land use

Falcon Lake Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Falcon Lake and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Falcon Lake threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Falcon Lake and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Falcon Lake Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank		Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank		Human Development Index (HDI) Score	Relative HDI Rank
0.50	**46**		**0.38**	**53**		**0.85**	**44**

It is emphasized that the Falcon Lake rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Falcon Lake indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Falcon Lake, which is meant to describe its biodiversity sensitivity to basin-derived degradation, also places the lake in a low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Falcon Lake basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Falcon Lake Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

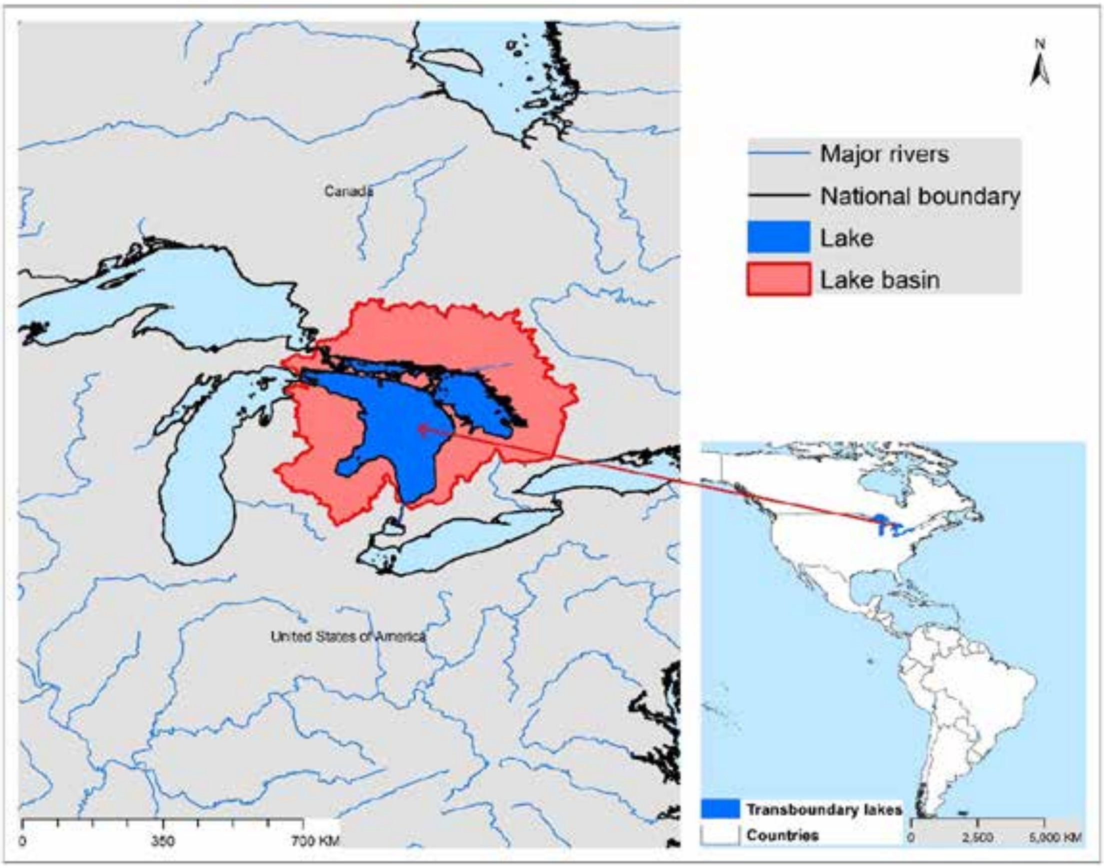
Adj-HWS Rank	HDI Rank	RvBD Rank		Sum Adj-HWS + RvBD	Relative Threat Rank		Sum Adj-HWS + HDI	Relative Threat Rank		Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
46	44	52		98	53		90	46		142	48

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Falcon Lake in the lower quarter of the threat ranks. The relative threat is further reduced when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Falcon Lake exhibits a low threat ranking.

Interactions between the ranking parameters for Falcon Lake indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Falcon Lake must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Falcon Lake basin? Accurate answers to such questions for Falcon Lake, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

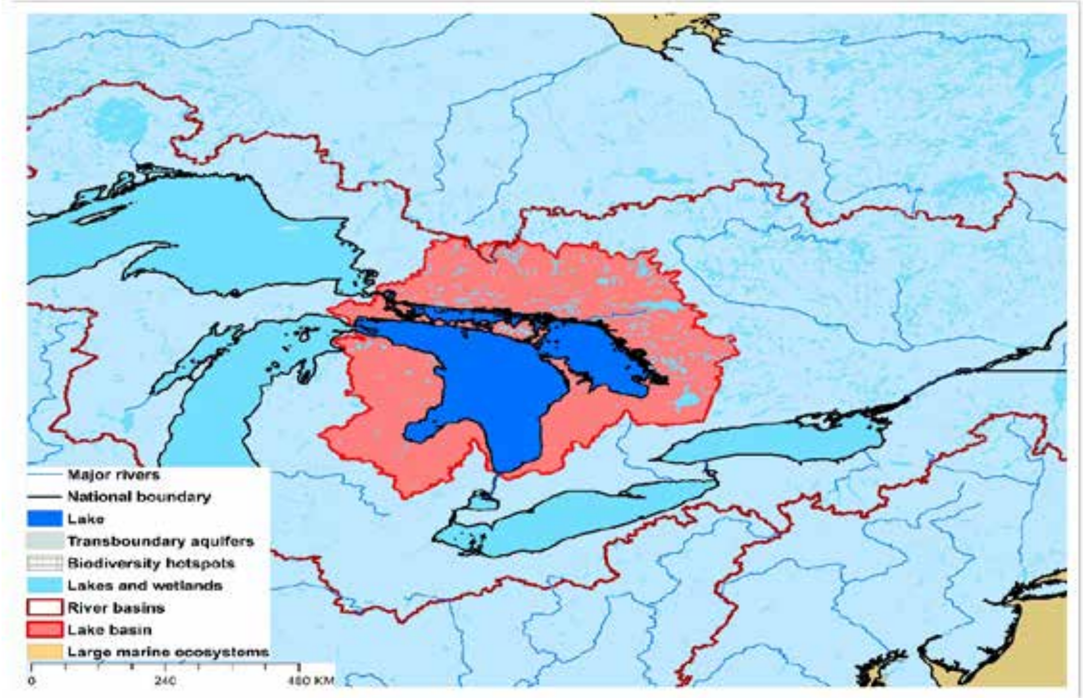
Lake Huron Geographic Information

Lake Huron is the second largest (by area) and third largest (by volume) of the five Laurentian Great Lakes, and the fourth largest (by area) in the world. With a water volume of 3,540 km^3, it also contains the world's largest freshwater island. With 30,000 islands, it has the largest shoreline length of the Great Lakes, and a relatively large drainage basin, compared to the other Great Lakes. It is hydrologically connected to Lake Michigan by the Straits of Mackinac, and lies at the same water level. If both lakes were considered an aggregated waterbody, it would be the world's largest freshwater lake. Its ecology has been degraded over time by a combination of overfishing, pollution and invasive species. Originally managed within the context of the 1909 Boundary Waters Treaty between the USA and Canada, the lake also is included in the Great Lakes Water Quality Agreement between the two countries, including concerted efforts directed to controlling non-point source pollution of all the Great Lakes.

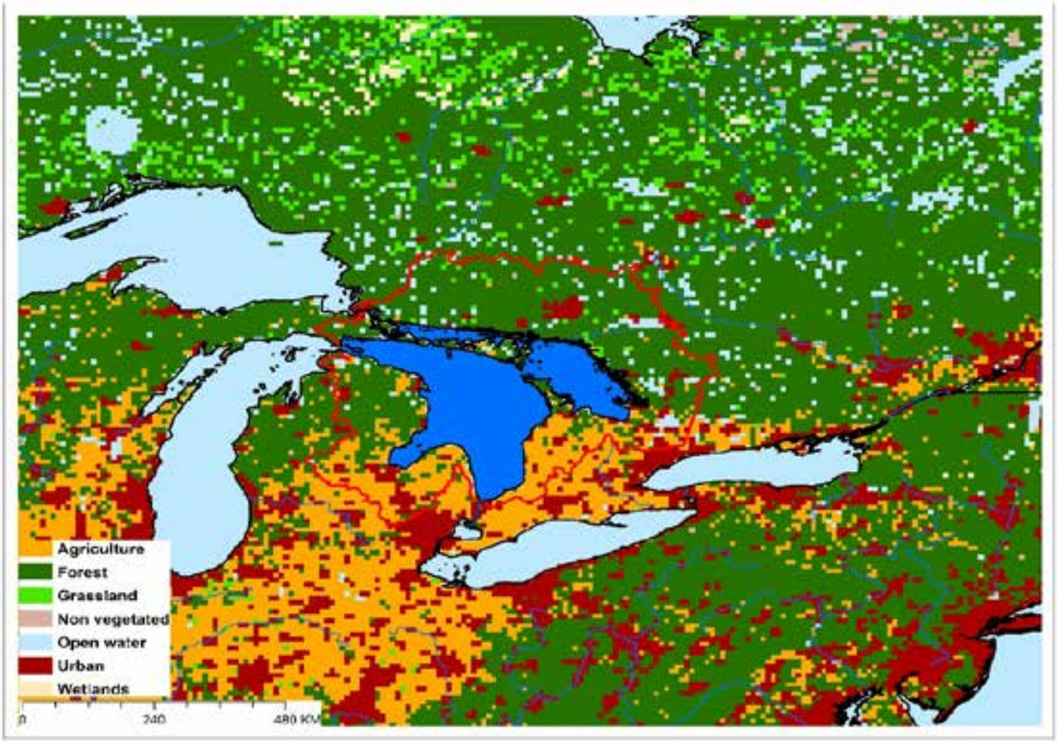


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	8,365,188
River Basin	St. Lawrence	**Lake Basin Population Density (2010; # km^{-2})**	48.7
Riparian Countries	USA, Canada	**Average Basin Precipitation (mm yr^{-1})**	828.2
Basin Area (km^2)	175,435	**Shoreline Length (km)**	2,367
Lake Area (km^2)	58,535	**Human Development Index (HDI)**	0.94
Lake Area:Lake Basin Ratio	0.334	**International Treaties/Agreements Identifying Lake**	Yes

Lake Huron Basin Characteristics



(a) Lake Huron basin and associated transboundary water systems



(b) Lake Huron basin land use

Lake Huron Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Huron and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Huron threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Huron and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Huron Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank		Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank		Human Development Index (HDI) Score	Relative HDI Rank
0.42	**51**		**0.53**	**36**		**0.93**	**50**

It is emphasized that the Lake Huron rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Huron indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Huron, which is meant to describe its biodiversity sensitivity to basin-derived degradation, places the lake in a moderately low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Huron basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Huron Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

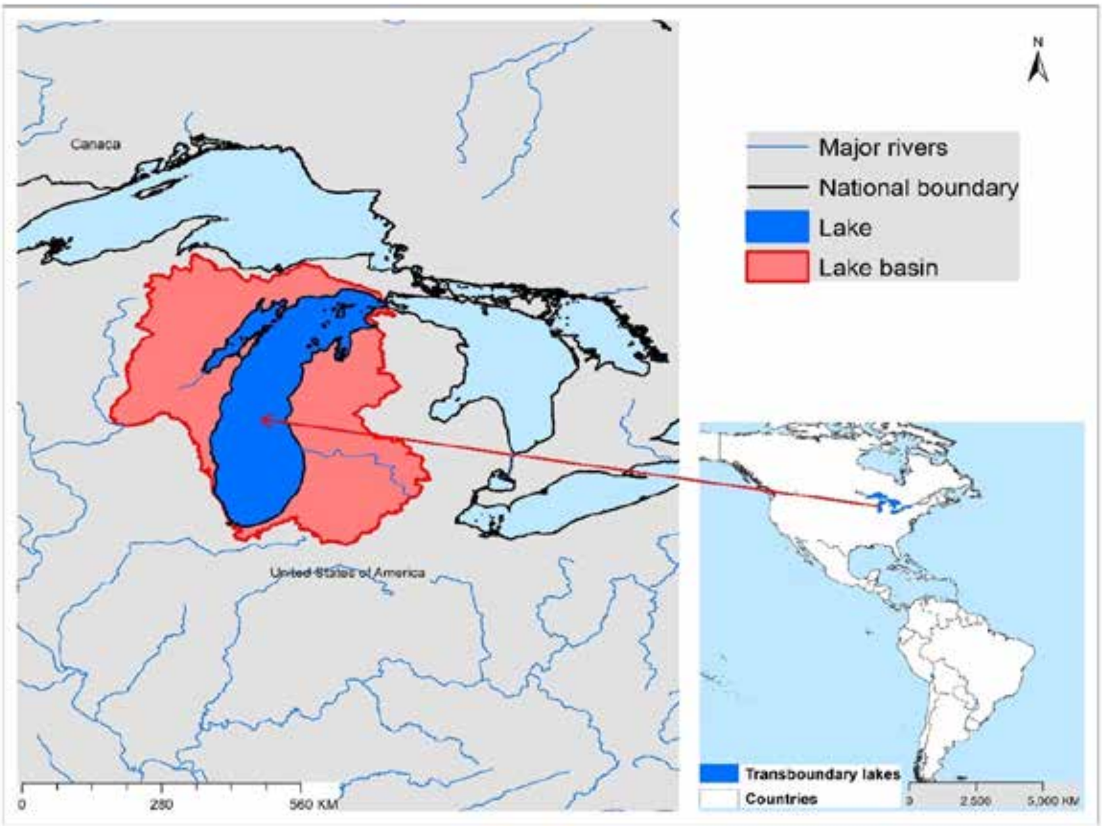
Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj-HWS + RvBD	Relative Threat Rank	Sum Adj-HWS + HDI	Relative Threat Rank	Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
51	**50**	**36**	**87**	**45**	**101**	**51**	**137**	**46**

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Huron in the lower quarter of the threat ranks. The relative threat is similar when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Huron exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Huron indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Huron must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Huron basin? Accurate answers to such questions for Lake Huron, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

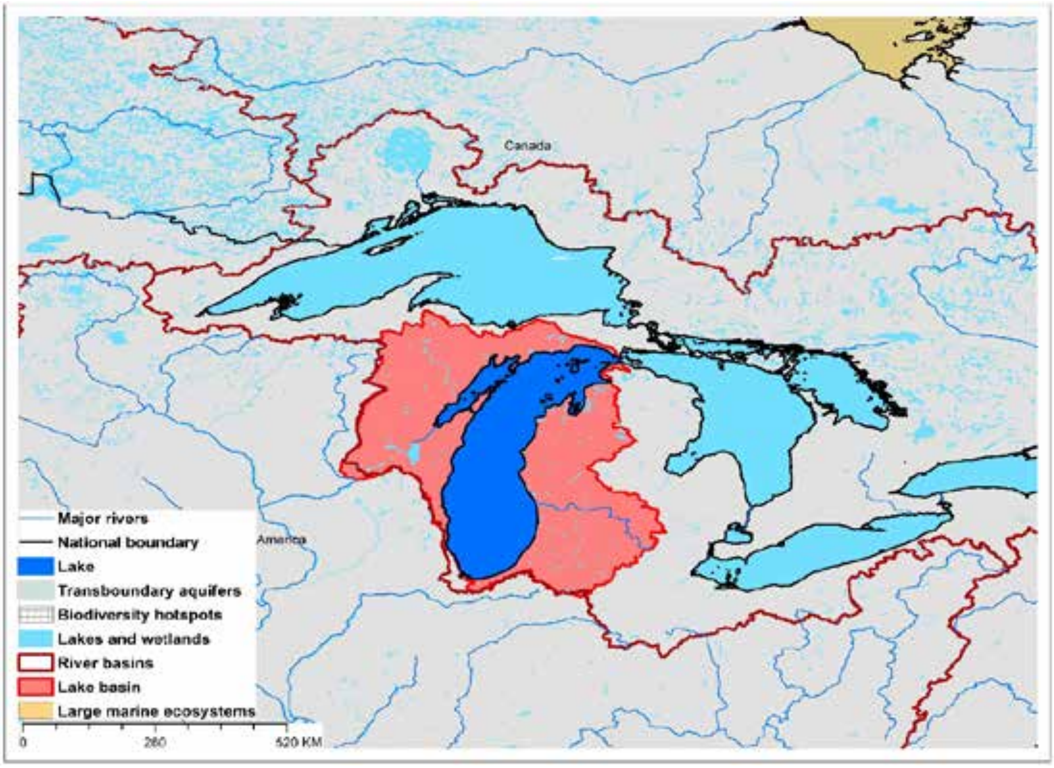
Lake Michigan — Geographic Information

Lake Michigan is the second largest (by volume), and third largest of the Laurentian Great Lakes and sixth largest of the world's lakes (by area). Lying entirely within the USA, it is the largest lake lying entirely in one country (by area), although part of the transboundary Great Lakes system under the Boundary Waters Treaty of 1909 between the USA and Canada. With a volume of 4,920 km³, it is hydrologically connected to Lake Huron by the Straits of Mackinac, lying at the same water level. If both lakes were considered an aggregated waterbody, it would be the world's largest freshwater lake. It also became a part of the waterways leading the Great Lakes to the Mississippi River and ultimately to the Gulf of Mexico. It has many sandy beaches, often being referred to as the 'Third Coast' of the USA after the Atlantic and Pacific Oceans. It nevertheless suffers from multiple environmental stresses, including pollution, invasive species and eutrophication. It is included in the Great Lakes Water Quality Agreement between the two countries, including concerted efforts directed to controlling non-point source pollution of all the Great Lakes.

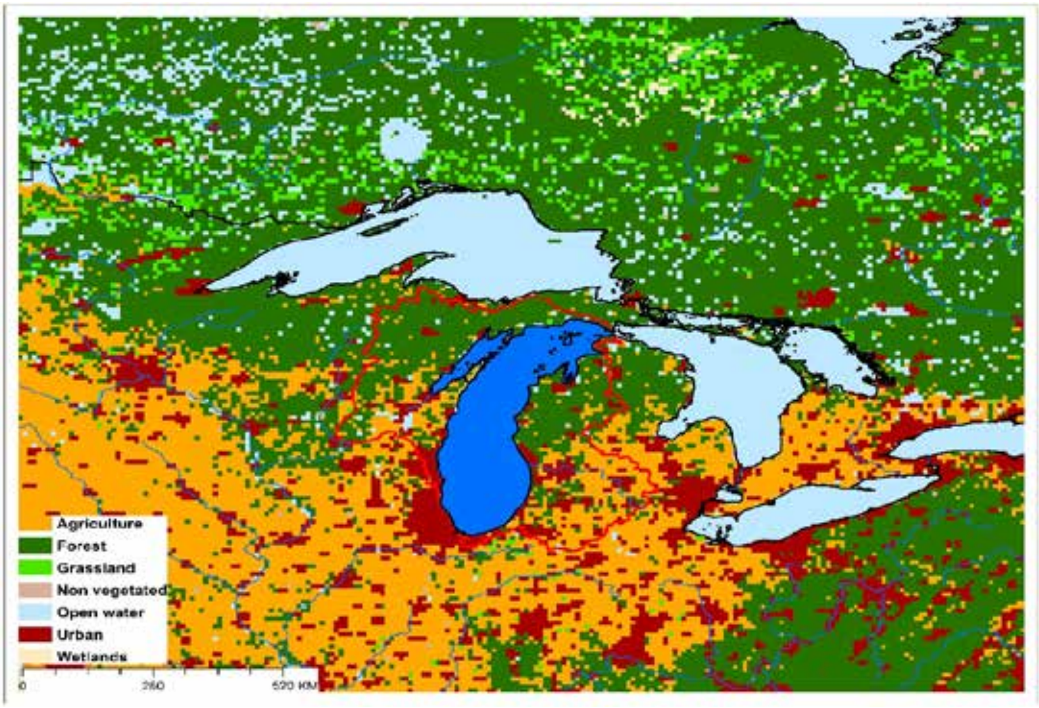


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	8,365,188
River Basin	St. Lawrence	**Lake Basin Population Density (2010; # km^{-2})**	48.7
Riparian Countries	USA, Canada	**Average Basin Precipitation (mm yr^{-1})**	828.2
Basin Area (km^{2})	175,435	**Shoreline Length (km)**	2,367
Lake Area (km^{2})	58,535	**Human Development Index (HDI)**	0.94
Lake Area:Lake Basin Ratio	0.334	**International Treaties/Agreements Identifying Lake**	Yes

Lake Michigan Basin Characteristics



(a) Lake Michigan basin and associated transboundary water systems



(b) Lake Michigan basin land use

Lake Michigan Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Michigan and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Michigan threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Michigan and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Michigan Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank		Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank		Human Development Index (HDI) Score	Relative HDI Rank
0.44	**50**		**0.44**	**48**		**0.94**	**53**

It is emphasized that the Lake Michigan rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Michigan indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Michigan, which is meant to describe its biodiversity sensitivity to basin-derived degradation, also places the lake in a low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Michigan basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Michigan Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

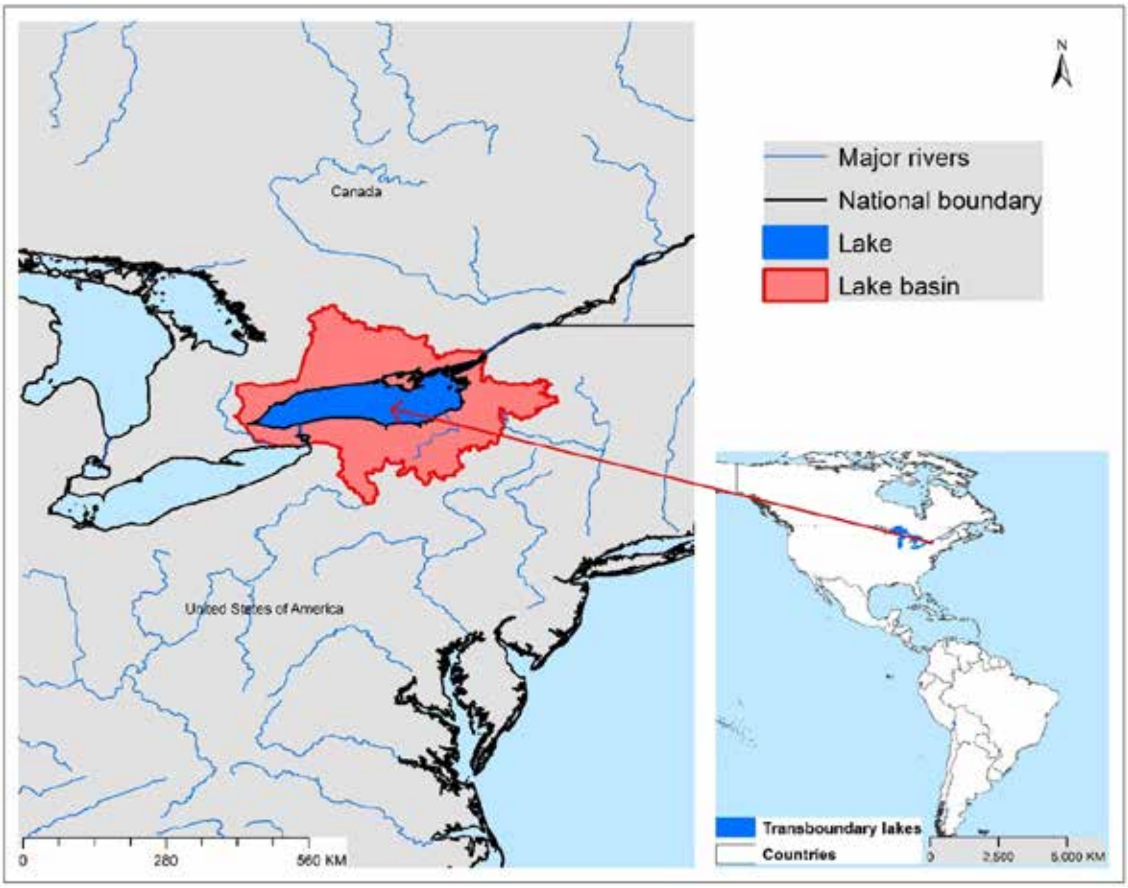
Adj-HWS Rank	HDI Rank	RvBD Rank		Sum Adj-HWS + RvBD	Relative Threat Rank		Sum Adj-HWS + HDI	Relative Threat Rank		Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
50	**53**	**48**		**98**	**52**		**103**	**52**		**151**	**53**

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Michigan in the lower quarter of the threat ranks. The relative threat is similar when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Michigan exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Michigan indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Michigan must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Michigan basin? Accurate answers to such questions for Lake Michigan, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

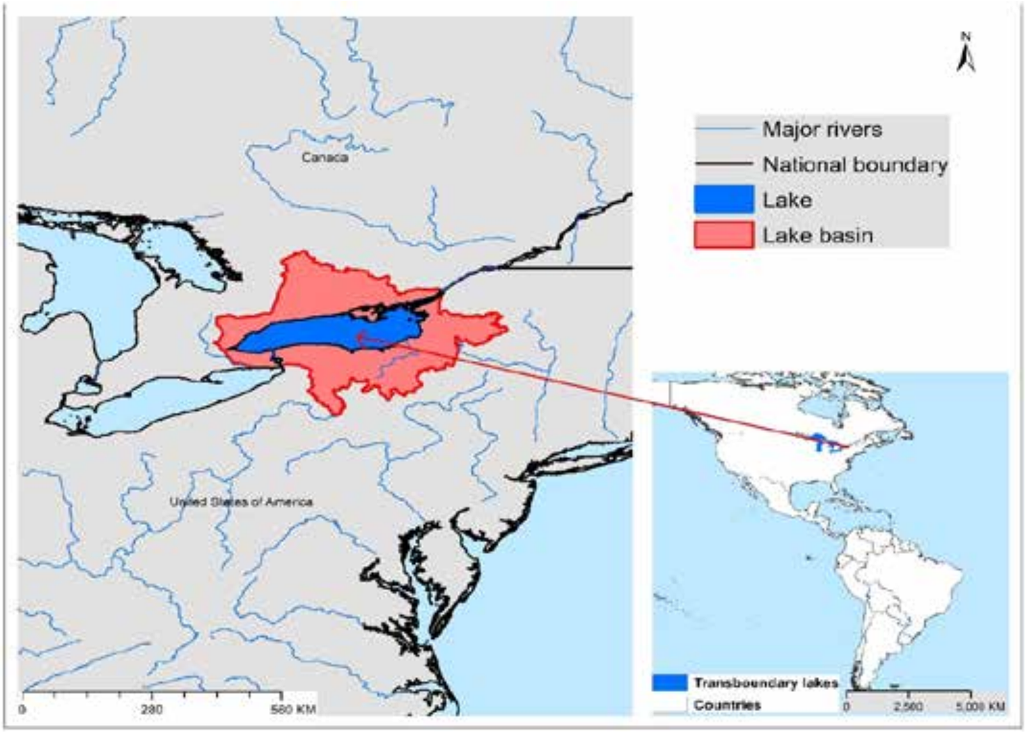
Lake Ontario Geographic Information

Lake Ontario, the most downstream of the five Laurentian Great Lakes, is also the most easterly and smallest (by area) of the lakes. Lying at a lower altitude than upstream Lake Erie, it receives inflow from the upstream Great Lakes via Niagara Falls, connecting Lakes Ontario and Erie. It is the fourteenth largest lake in the world, serving as the outlet to the Atlantic Ocean via the St. Lawrence River. With a volume of 1,639 km^3, its average depth is second only to Lake Superior. Its basin is largely rural, although located within Canada's most populous province. The lake has an important freshwater fishery, although its condition is impacted by industrial, agricultural and urban pollution, as well as invasive species (lamprey, zebra mussels). Considered within the context of the 1909 Boundary Waters Treaty between the USA and Canada, it also is included in the Great Lakes Water Quality Agreement between the two countries, including concerted efforts directed to controlling non-point source pollution of all the Great Lakes.

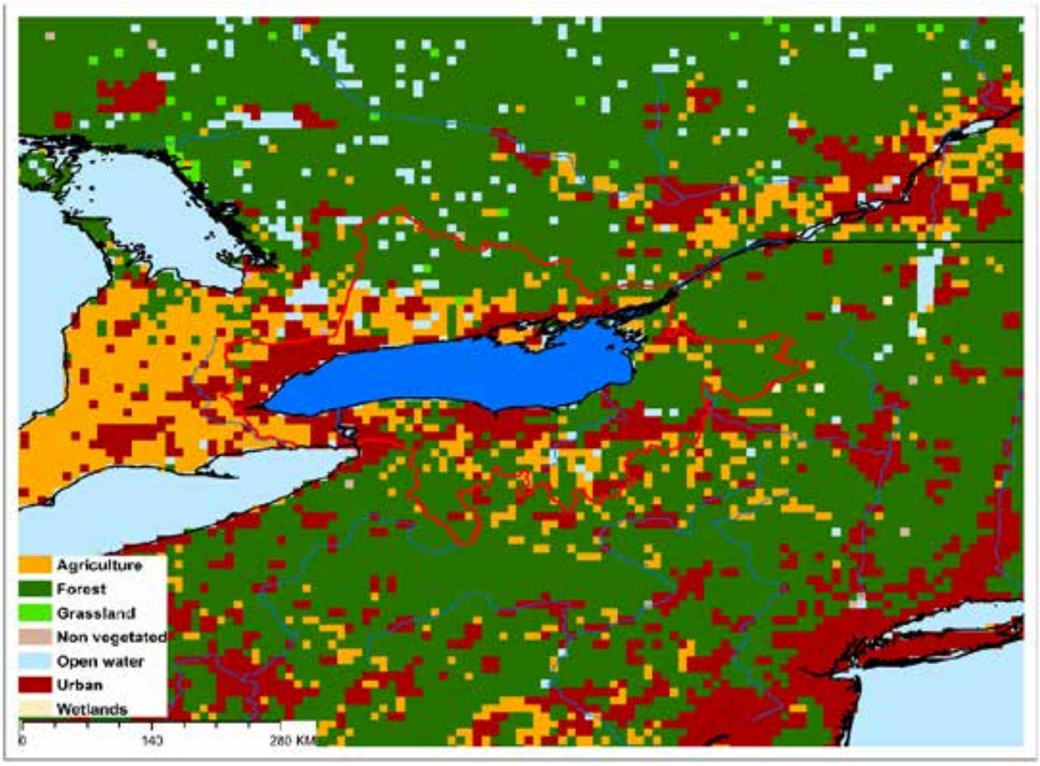


TWAP Regional Designation	Northern America		**Lake Basin Population (2010)**	10,394,370
River Basin	St. Lawrence		**Lake Basin Population Density (2010; # km^{-2})**	102.4
Riparian Countries	USA, Canada		**Average Basin Precipitation (mm yr^{-1})**	915.0
Basin Area (km^2)	84,681		**Shoreline Length (km)**	1,719
Lake Area (km^2)	19,062		**Human Development Index (HDI)**	0.92
Lake Area:Lake Basin Ratio	0.225		**International Treaties/Agreements Identifying Lake**	Yes

Lake Ontario Basin Characteristics



(a) Lake Ontario basin and associated transboundary water systems



(b) Lake Ontario basin land use

Lake Ontario Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Ontario and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Ontario threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Ontario and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Ontario Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank	Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank	Human Development Index (HDI) Score	Relative HDI Rank
0.48	**48**	**0.47**	**44**	**0.92**	**49**

It is emphasized that the Lake Ontario rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Ontario indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Ontario, which is meant to describe its biodiversity sensitivity to basin-derived degradation, also places the lake in a low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Ontario basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Ontario Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

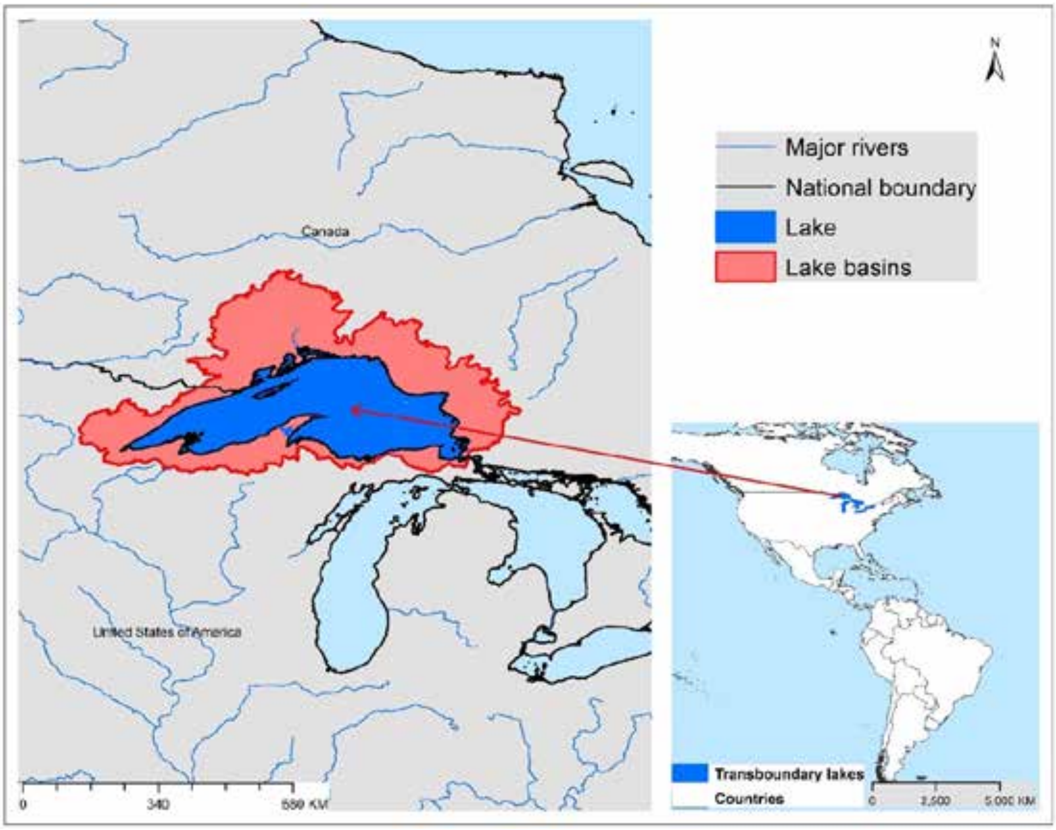
Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj-HWS + RvBD	Relative Threat Rank	Sum Adj-HWS + HDI	Relative Threat Rank	Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
48	**49**	**45**	**93**	**48**	**97**	**49**	**142**	**48**

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Ontario in the lower quarter of the threat ranks. The relative threat is similar when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Ontario exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Ontario indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Ontario must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Ontario basin? Accurate answers to such questions for Lake Ontario, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

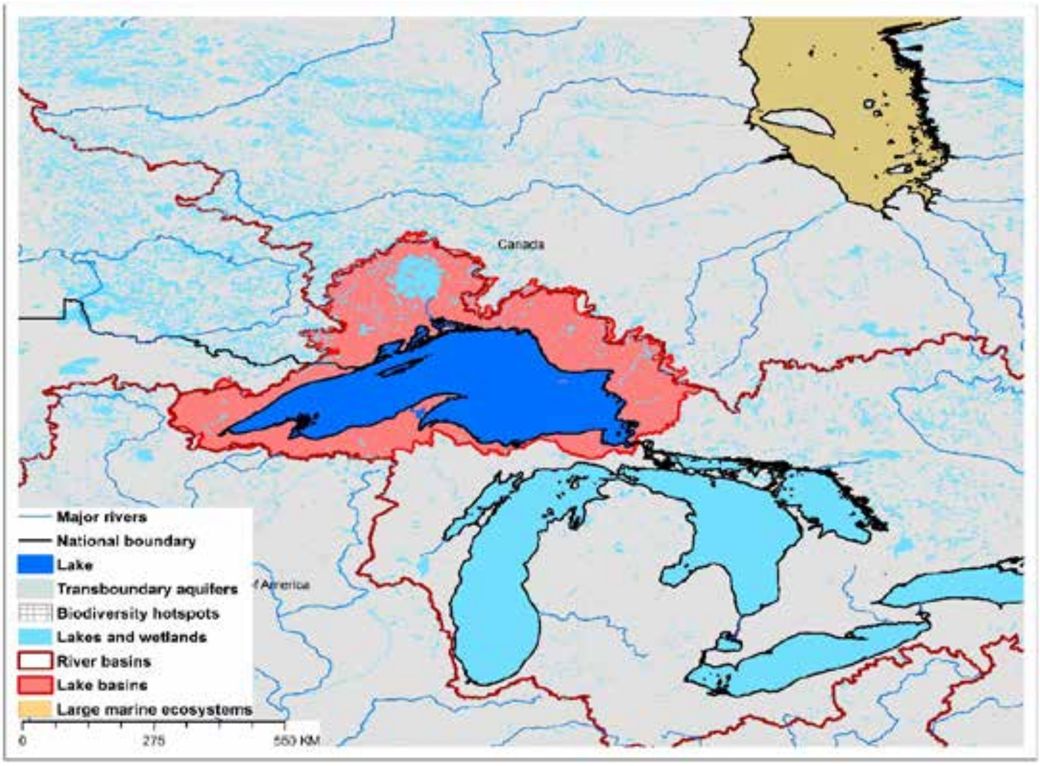
Lake Superior Geographic Information

Lake Superior is the largest (by area) and most upstream of the Laurentian Great Lakes, also being the largest lake in North America and third largest lake in the world (by volume), as well as the coldest and deepest Great Lake. Its water volume of 12,100 km^3 could cover the entire North and South American land masses to a depth of 30 cm. Its sparsely-populated drainage basin has much scenic beauty, and is economically dependent upon its natural resources. Locks and other control structures were previously installed at St. Mary's rapids between Lakes Superior and Huron to support transportation of iron ore, grain and other materials to downstream users. The lake is subject to major storms that regularly produce wave heights of more than 6 m, with many resulting ship wrecks. The lake is less biologically-productive than the other Great Lakes, although it is experiencing slowly-increasing eutrophication, as well as invasive species. It is included in the Great Lakes Water Quality Agreement between the USA and Canada, including concerted efforts directed to controlling non-point source pollution of all the Great Lakes.

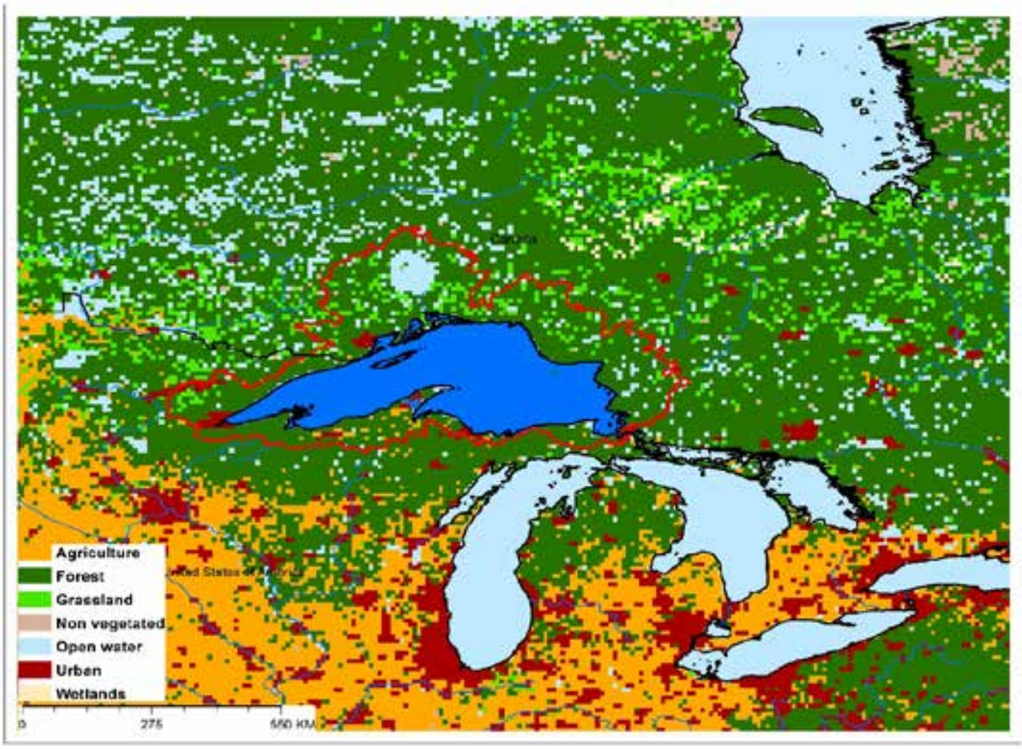


TWAP Regional Designation	Northern America	**Lake Basin Population (2010)**	700,331
River Basin	St. Lawrence	**Lake Basin Population Density (2010; # km^{-2})**	3.67
Riparian Countries	USA, Canada	**Average Basin Precipitation (mm yr^{-1})**	804.5
Basin Area (km^2)	217,624	**Shoreline Length (km)**	3,906
Lake Area (km^2)	85,894	**Human Development Index (HDI)**	0.93
Lake Area:Lake Basin Ratio	0.395	**International Treaties/Agreements Identifying Lake**	Yes

Lake Superior Basin Characteristics



(a) Lake Superior basin and associated transboundary water systems



(b) Lake Superior basin land use

Lake Superior Threat Ranking

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential threat risks be estimated on the basis of the characteristics of their drainage basins, rather than in-lake conditions. Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics.

The lake threat ranks were calculated with a spreadsheet-based interactive scenario analysis program, incorporating data and information about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services. These descriptive data for Lake Superior and the other transboundary lakes included lake and basin areas, population numbers and densities, areal extent of basin stressors on the lake, data grid size, and other components considered important from the perspective of the user of the data results. The scenario analysis program also provides a means to define the appropriate context and preconditions for interpreting the ranking results.

The Lake Superior threat ranks are expressed in terms of the Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and the Human Development Index (HDI) score, as well as combinations of these indices. However, it is emphasized that, being based on specific characteristics and assumptions regarding Lake Superior and its basin characteristics, the calculated threat scores represent only one possible set of lake threat rankings. Defining the appropriate context and preconditions for interpreting the lake rankings remains an important responsibility of those using the threat ranking results, including lake managers and decision-makers.

Table 1. Lake Superior Relative Threat Ranks, Based on Adjusted Human Water Security (Adj-HWS) and Reverse Biodiversity Threats, and Human Development Index (HDI) Score

(Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

Adjusted Human Water Security (Adj-HWS) Threat Score	Relative Adj-HWS Threat Rank		Reverse Biodiversity (RvBD) Threat Score	Relative RvBD Threat Rank		Human Development Index (HDI) Score	Relative HDI Rank
0.35	51		0.27	53		0.93	51

It is emphasized that the Lake Superior rankings above are discussed here within the context of the management and decision-making process, rather than as strict numerical ranks. Based on its geographic, population and socioeconomic assumptions used in the scenario analysis program, the calculated Adj-HWS score for Lake Superior indicates a low threat rank compared to other priority transboundary lakes.

The Reverse Biodiversity (RvBD) for Lake Superior, which is meant to describe its biodiversity sensitivity to basin-derived degradation, also places the lake in a low threat rank, compared to the other transboundary lakes. Management interventions directed to improving the biodiversity status must be viewed with caution, however, since we lack sufficient knowledge and experience to accurately predict the ultimate impacts of biodiversity manipulations and preservation efforts. Further, the RvBD scores indicate the relative sensitivity of a lake basin to human activities, and high threat scores *per se* do not necessarily justify management interventions. Such interventions may actually increase biodiversity degradation, noting that many developed countries have already fundamentally degraded their biodiversity because of economic development activities. Thus, activities undertaken to address the Adj-HWS threats may actually degrade the biodiversity status and resources, even if the health and socioeconomic conditions of the lake basin stakeholders are improved as a result of better conditions, thereby increasing stakeholder resource consumption.

The relative Human Development Index (HDI) places the Lake Superior basin in a low threat rank in regard to its health, educational and economic conditions.

Table 2. Lake Superior Threat Ranks, Based on Multiple Ranking Criteria

(Scores for Adj-HWS, RvBD and HDI ranks are presented in Table 1; the ranks may differ in some cases because of rounding of tied threat scores; Estimated risks: red – highest; orange – moderately high; yellow – medium;
green – moderately low; blue – low)

Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj-HWS + RvBD	Relative Threat Rank	Sum Adj-HWS + HDI	Relative Threat Rank	Sum Adj-HWS + RvBD + HDI	Overall Threat Rank
51	53	51	104	53	102	53	155	53

When multiple ranking criteria are considered together in the threat rank calculations, the Adj-HWS and HDI scores considered together place Lake Superior in the lower quarter of the threat ranks. The relative threat is similar when the Adj-HWS and RvBD threats are considered together. Considering all three ranking criteria together, Lake Superior exhibits a low threat ranking.

Interactions between the ranking parameters for Lake Superior indicate differing sensitivity to basin-derived stresses. Identifying potential management interventions needs for Lake Superior must be considered on the basis of educated judgement and accurate representations of its situation. A fundamental question will be how can one decide a given management intervention will produce the greatest benefit(s) for the greatest number of people in the Lake Superior basin? Accurate answers to such questions for Lake Superior, and other transboundary lakes, will require a case-by-case assessment approach that considers the specific lake situation and the anticipated improvements from specific management interventions, as well as interactions with water systems to which the lake is linked.

METHODOLOGY AND CAVEATS REGARDING TRANSBOUNDARY LAKE THREAT RANKS

A serious lack of global-scale uniform data on the TWAP transboundary in-lake conditions required their potential risks be estimated on the basis of the characteristics of their drainage basins, rather than analysis of their in-lake conditions. The lake threat ranks were calculated with a scenario analysis program that allowed incorporation of specific assumptions and preconditions about the nature and magnitude of their basin-derived stresses, and their possible impacts on the sustainability of their ecosystem services, as defined by the user of the ranking results. Because the transboundary lake threat ranks are based on specific lake and basin assumptions, therefore, the calculated rankings represent only one possible set of lake rankings.

Using basin characteristics to rank transboundary lake threats precludes consideration of the unique features that can buffer their in-lake responses to basin-derived disturbances, including an integrating nature for all inputs, long water retention times, and complex, non-linear response dynamics. A global overview of river basin threats based on 23 basin-scale drivers under four thematic areas (catchment disturbance; pollution; water resource development; biotic factors) was modified for the transboundary lakes assessment. The driver weights were initially based on collective opinions of experts exhibiting a range of disciplinary expertise, subsequently being refined with inputs from lake scientists and managers participating in ILEC's 15th World Lake Conference.

A spreadsheet-based, interactive scenario analysis program was used to rank the transboundary lake threats. The lake basin characteristics were determined by superimposing the lake basins over the river basin grids, and scaling the driver data to lake basin scale. Selected basin drivers, weights and preconditions were used in the scenario analysis program to calculate the relative lake threat ranks, expressed in terms of the Incident (HWS) and Adjusted (Adj-HWS) Human Water Security and Incident Biodiversity (BD) threats.

The transboundary lake analyses incorporated several assumptions and preconditions. Small transboundary lakes (area <5 km^2), sparse basin populations (< 5 persons km^{-1}), or that were frozen over for major portions of the year (annual air temperature <5 ^{o}C), were eliminated from the analyses. The areal extent of the influences of the basin drivers was addressed with a sensitivity analysis that indicated an areal band of 100 km^2 around a lake, appropriately clipped for the surrounding basin, was a realistic upper boundary for the scenario analysis program. The river basin grid size was problematic in that some grids (30' grid [0.5^o]) were often larger than those of some transboundary lake basins, and about 10% of the transboundary lakes lacked driver data for some grids. Based on these considerations, a final list of 53 priority transboundary lakes was selected for the scenario analysis program calculations of relative threat scores.

Insights obtained from lake scientists and managers participating in the 15th World Lake Conference helped address some of these concerns. Region-specific lake questionnaires also were distributed in some cases, obtaining both quantitative and qualitative data regarding the transboundary lakes and their basins.

These various factors and concerns indicate the transboundary lake threat ranks must be considered within the context of the specific basin conditions and assumptions used to derive them, since they represent only one possible set of lake threat rankings. Other factors such as lake and basin area, basin population and density, regional location, per capita Gross National Income (GNI), and Human

Development Index (HDI) could produce markedly different ranking results. Defining the appropriate context and preconditions for interpreting the lake ranking results, a task beyond the scope of this analysis, remains an important responsibility of those using the results, including lake managers and decision-makers.

The calculated ranks of the priority transboundary lakes, based on the specific assumptions and preconditions regarding the lakes and their drainage basins, is expressed below in terms of Adjusted Human Water Security (Adj-HWS) threats, Reverse Biodiversity (RvBD) threats, and Human Development Index (HDI) status. The Incident Human Water Security (HWS) score would suggest the current threat ranks of the lakes. However, for identifying needed management interventions, the ability of the basin countries to undertake investments to reduce identified transboundary water threats (i.e., water supply stabilization, improved water services, etc.) is also a relevant factor. This ability is considered within the context of the Adj-HWS threat. Countries less able to make such investments, mainly developing countries, exhibited higher Adj-HWS threats. Thus, the Adj-HWS threat ranks provide a more realistic picture of the transboundary lakes most in need of catalytic funding for management interventions than those with lower Adj-HWS scores.

Our more limited knowledge and experience regarding the ultimate outcomes of ecosystem restoration and conservation activities precluded a BD metric identical to the Adj-HWS threat. The Adj-HWS threat rank is meant to identify the transboundary lakes in most need of management interventions from a water investment perspective. The native biodiversity of most developed countries, however, has already been largely degraded as a result of their economic development activities. Thus, the preservation of those ecosystems still exhibiting the most pristine or undisturbed conditions should be the major BD management intervention goal. To address this goal, a RvBD threat was developed as a BD surrogate to define relative BD threats. It was calculated as 1-BD score, with the resulting RvBD score indicating the relative 'pristineness' of a lake in regard to its biodiversity status. The higher RvBD scores calculated with this normalization procedure identify the transboundary lakes most likely to be sensitive to BD degradation and, therefore, the lakes most in need of management attention.

The Human Development Index (HDI) is a composite statistic used by the United Nations Development Programme (UNDP) to reflect the relative life expectancy, education level, and per capita income of a country. A country whose inhabitants exhibit longer life spans, higher education levels, and higher per capita GDPs typically exhibit higher HDI scores, suggesting a higher overall condition of its citizens. It is meant to indicate that economic growth alone is not the sole criteria to assessment of a country, but that the status of its citizens and their capabilities also are important defining factors, therefore being an indication of potential human development.

Along with the assumptions and preconditions defining specific lake basin characteristics, these three criteria were major indicators considered within the context of the scenario analysis program to calculate the relative threat ranks of the transboundary lakes, as presented in the transboundary lake profile sheets.

Transboundary Lakes Ranked on Basis of (a) Incident Human Water Security [HWS] Threats, (b) Adjusted Human Water Security [Adj-HWS] Threats, and (c) Incident Biodiversity [BD] Threats

(Cont., continent; Eur, Europe; N.Am, North America; Afr., Africa; S.Am, South America;
Estimated risks: red – highest; orange – moderately high; yellow – medium; green – moderately low; blue – low)

(A) Lakes Ranked on Basis of Adjusted Human Water Security (Adj-HWS) Threats

Lake	Cont.	Surface Area (km^2)	Adj-HWS Threat Score	Rank
Sistan	Asia	488.2	0.98	1
Ihema	Afr.	93.2	0.97	2
Azuei	S.Am	117.3	0.96	3
Rweru/Moero	Afr.	125.6	0.96	4
Cohoha	Afr.	64.8	0.96	5
Edward	Afr.	2232.0	0.94	6
Natron/Magadi	Afr.	560.4	0.93	7
Abbe/Abhe	Afr.	310.6	0.93	8
Victoria	Afr.	66841.5	0.91	9
Albert	Afr.	5502.3	0.91	10
Kivu	Afr.	2371.1	0.91	11
Malawi/Nyasa	Afr.	29429.2	0.91	12
Dead Sea	Eur	642.7	0.90	13
Turkana	Afr.	7439.2	0.90	14
Aras Su Qovsaginin Su Anbari	Asia	52.1	0.89	15
Mangla	Asia	85.4	0.87	16
Galilee	Eur	162.0	0.87	17
Darbandikhan	Asia	114.3	0.87	18
Selingue	Afr.	334.4	0.87	19
Shardara/Kara-Kul	Asia	746.1	0.86	20
Nasser/Aswan	Afr.	5362.7	0.86	21
Chilwa	Afr.	1084.2	0.86	22
Josini/Pongola-poort Dam	Afr.	128.6	0.85	23

(B) Lakes Ranked on Basis of Reverse Biodiversity (RvBD) Threats

Lake	Cont.	Surface area (km^2)	RvBD Threat Score	Rank
Lake Congo River	Afr.	306.0	0.80	1
Sarygamysh	Asia	3777.7	0.75	2
Chiuta	Afr.	143.3	0.74	3
Mweru	Afr.	5021.5	0.72	4
Aral Sea	Asia	23919.3	0.72	5
Tanganyika	Afr.	32685.5	0.71	6
Abbe/Abhe	Afr.	310.6	0.71	7
Titicaca	S.Am	7480.0	0.71	8
Chilwa	Afr.	1084.2	0.70	9
Salto Grande	S.Am	532.9	0.70	10
Turkana	Afr.	7439.2	0.70	11
Cahora Bassa	Afr.	4347.4	0.69	12
Chungarkkota	S.Am	52.6	0.69	13
Malawi/Nyasa	Afr.	29429.2	0.68	14
Nasser/Aswan	Afr.	5362.7	0.68	15
Selingue	Afr.	334.4	0.68	16
Kivu	Afr.	2371.1	0.67	17
Natron/Magadi	Afr.	560.4	0.67	18
Lago de Yacyreta	S.Am	1109.4	0.66	19
Kariba	Afr.	5258.6	0.66	20
Edward	Afr.	2232.0	0.65	21
Aby	Afr.	438.8	0.65	22
Chad	Afr.	1294.6	0.64	23

(C) Lakes Ranked on Basis of Human Development Index (HDI) Scores

Lake	Cont.	Surface area (km^2)	HDI Score	Rank
Lake Congo River	Afr	306.0	0.34	1
Selingue	Afr	334.4	0.36	2
Rweru/Moero	Afr	125.6	0.36	3
Cohoha	Afr	64.8	0.38	4
Kivu	Afr	2371.1	0.38	5
Mweru	Afr	5021.5	0.38	6
Abbe/Abhe	Afr	310.6	0.40	7
Tanganyika	Afr	32685.5	0.40	8
Turkana	Afr	7439.2	0.41	9
Chiuta	Afr	143.3	0.41	10
Chilwa	Afr	1084.2	0.41	11
Malawi/Nyasa	Afr	29429.2	0.42	12
Edward	Afr	2232.0	0.43	13
Nasser/Aswan	Afr	5362.7	0.43	14
Cahora Bassa	Afr	4347.4	0.43	15
Chad	Afr	1294.6	0.43	16
Kariba	Afr	5358.6	0.43	17
Ihema	Afr	93.2	0.44	18
Sistan	Asia	488.2	0.46	19
Albert	Afr	5502.3	0.46	20
Azuei	S.Am,	117.3	0.46	21
Victoria	Afr	66841.5	0.47	22
Natron/Magadi	Afr	560.4	0.51	23

	Afr.	143.3	0.85	24		Albert	Afr.	5502.3	0.63	24		**Aby**	**Afr**	**438.8**	**0.52**	**24**
Chad	Afr.	1294.6	0.84	25		Sistan	Asia	488.2	0.62	25		**Mangla**	**Asia**	**85.4**	**0.54**	**25**
Aral Sea	Asia	23919.3	0.84	26		Amistad	N.Am	131.3	0.61	26		**Aral Sea**		**23919.3**	**0.60**	**26**
Tanganyika	Afr.	32685.5	0.84	27		Caspian Sea	Asia	377543.2	0.60	27		**Josini/Pongola-poort Dam**	**Afr**	**128.6**	**0.61**	**27**
Aby	Afr.	438.8	0.83	28		Cohoha	Afr.	64.8	059	28		**Shardara/Kara-kul**	**Asia**	**746.1**	**0.65**	**28**
Cahul	Eur	89.0	0.82	29		Itaipu	S.Am	1154.1	0.58	29		**Sarygamysh**	**Asia**	**3777.7**	**0.67**	**29**
Chungarkkota	S.Am	52.6	0.82	30		Rweru/Moero	Afr.	125.6	0.58	30		**Darbandikhan**	**Asia**	**114.3**	**0.68**	**30**
Titicaca	S.Am	7480.0	0.82	31		Azuei	S.Am	117.3	0.57	31		**Cahul**	**Eur**	**89.0**	**0.69**	**31**
Sarygamysh	Asia	3777.7	0.82	32		Ihema	Afr.	93.2	0.56	32		**Titicaca**	**S.Am**	**7480.0**	**0.71**	**32**
Mweru	Afr.	5021.5	0.81	33		Victoria	Afr.	66841.5	0.56	33		**Chungarkkota**	**S.Am**	**52.6**	**0.71**	**33**
Cahora Bassa	Afr.	4347.4	0.78	34		Scutari/Skadar	Eur	381.5	0.55	34		**Dead Sea**	**Eur**	**642.7**	**0.72**	**34**
Itaipu	S.Am	1154.1	0.75	35		Shardara/Kara-Kul	Asia	746.1	0.54	35		**Lago de Yacyreta**	**S.Am**	**1109.4**	**0.73**	**35**
Kariba	Afr.	5258.6	0.75	36		Huron	N.Am	60565.2	0.53	36		**Aras Su Qovsaginin Su Anbari**	**Asia**	**52.1**	**0.73**	**36**
Lago de Yacyreta	S.Am	1109.4	0.75	37		Josini/Pongola-poort Dam	Afr.	128.6	0.52	37		**Itaipu**	**S.Am**	**1154.1**	**0.73**	**37**
Lake Congo River	Afr.	306.0	0.75	38		Champlain	N.Am	1098.9	0.51	38		**Salto Grande**	**S.Am**	**532.9**	**0.74**	**38**
Caspian Sea	Asia	377543.2	0.73	39		Ohrid	Eur	354.3	0.51	39		**Ohrid**	**Eur**	**354.3**	**0.74**	**39**
Salto Grande	S.Am	532.9	0.67	40		Macro Prespa	Eur	263.0	0.51	40		**Macro Prespa**	**Eur**	**263.0**	**0.75**	**40**
Scutari/Skadar	Eur	381.5	0.62	41		Dead Sea	Eur	642.7	0.51	41		**Caspian Sea**	**Asia**	**377543.2**	**0.77**	**41**
Neusiedler/Ferto	Eur	141.9	0.58	42		Maggiore	Eur	211.4	0.49	42		**Scutari/Skadar**	**Eur**	**381.5**	**0.78**	**42**
Szczecin Lagoon	Eur	822.4	0.53	43		Szczecin Lagoon	Eur	822.4	0.49	43		**Szczecin Lagoon**	**Eur**	**822.4**	**0.83**	**43**
Erie	N.Am	26560.8	0.51	44		Ontario	N.Am	19062.2	0.47	44		**Falcon**	**N.Am**	**120.6**	**0.85**	**44**
Macro Prespa)	Eur	263.0	0.51	45		Aras Su Qovsaginin Su Anbari	Asia	52.1	0.47	45		**Amistad**	**N.Am**	**131.3**	**0.86**	**45**
Falcon	N.Am	120.6	0.50	46		Darbandikhan	Asia	114.3	0.46	46		**Galilee**	**Eur**	**162.0**	**0.88**	**46**
Amistad	N.Am	131.3	0.49	47		Galilee	Eur	162.0	0.45	47		**Neusiedler/Ferto**	**Eur**	**141.9**	**0.88**	**47**
Ontario	N.Am	19062.2	0.48	48		Michigan	N.Am	58535.5	0.44	48		**Lake Maggiore**	**Eur**	**211.4**	**0.89**	**48**
Ohrid	Eur	354.3	0.47	49		Erie	N.Am	26560.8	0.43	49		**Ontario**	**N.Am**	**19062.2**	**0.92**	**49**
Michigan	N.Am	58535.5	0.44	50		Neusiedler/Ferto	Eur	141.9	0.39	50		**Huron**	**N.Am**	**60565.2**	**0.93**	**50**
Huron	N.Am	60565.2	0.42	51		Cahul	Eur	89.0	0.39	51		**Erie**	**N.Am**	**26560.8**	**0.93**	**51**
Maggiore	Eur	211.4	0.33	52		Mangla	Asia	85.4	0.38	52		**Champlain**	**N.Am**	**1098.9**	**0.94**	**52**
Champlain	N.Am	1098.9	0.29	53		Falcon	N.Am	120.6	0.38	53		**Michigan**	**N.Am**	**58535.5**	**0.94**	**53**

Transboundary Lake Threat Ranks by Multiple Ranking Criteria

(Cont., continent; Eur, Europe; N.Am, North America; Afr, Africa; S.Am, South America;
Adj-HWS, Adjusted Human Water Security threat; HWS, Incident Human Water Security threat; BD, Incident Biodiversity threat;
HDI, Human Development Index, RvBD, surrogate for 'Adjusted' Biodiversity threat;
Estimated risks: Red – highest; Orange – moderately high; Yellow – medium; Green – moderately low; Blue – low)

Cont.	Lake Name	Adj-HWS Threat	RvBD Threat	HDI	Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj-HWS + RvBD	Relative Rank	Sum Adj-HWS + HDI	Relative Rank	Sum Adj-HWS + RvBD + HDI	Overall Rank
Afr	Abbe/Abhe	0.93	0.71	0.40	7	7	7	14	1	14	3	21	1
Afr	Turkana	0.90	0.70	0.41	13	10	9	22	2	23	10	32	2
Afr	Selingue	0.87	0.68	0.36	16	2	15	31	11	18	5	33	3
Afr	Malawi/Nyasa	0.91	0.68	0.42	9	12	14	23	3	21	9	35	4
Afr	Chiuta	0.85	0.74	0.41	23	9	3	26	5	32	15	35	4
Afr	Cohoha	0.96	0.59	0.38	3	4	28	31	2	7	1	35	4
Afr	Kivu	0.91	0.67	0.38	12	6	18	30	8	18	4	36	7
Afr	Rweru/Moero	0.96	0.58	0.36	4	3	30	34	16	7	2	37	8
Afr	Lake Congo River	0.75	0.78	0.34	35	1	1	36	18	36	19	37	8
Afr	Tanganyika	0.84	0.71	0.40	26	8	6	32	14	34	17	40	10
Afr	Edward	0.94	0.65	0.43	6	13	22	28	7	19	6	41	11
Afr	Chilwa	0.86	0.70	0.41	21	11	10	31	10	32	14	42	12
Afr	Mweru	0.81	0.72	0.38	33	5	4	37	21	38	20	42	12
Asia	Sistan	0.98	0.62	0.46	1	20	25	26	6	21	8	46	14
Afr	Natron/Magadi	0.93	0.67	0.51	8	23	17	25	4	31	13	48	15
Afr	Nasser/Aswan	0.86	0.68	0.43	20	16	16	36	19	36	18	52	16
Afr	Albert	0.91	0.63	0.46	10	19	24	34	15	29	12	53	17
Afr	Ihema	0.97	0.56	0.44	2	18	33	35	17	20	7	53	17
S.Am,	Azuei	0.96	0.57	0.46	5	21	31	36	20	26	11	57	19
Asia	Aral Sea	0.84	0.62	0.60	27	26	5	32	13	53	31	58	20
Asia	Sarygamysh	0.82	0.75	0.67	29	29	2	31	9	58	32	60	21
Afr	Cahora Bassa	0.78	0.69	0.43	34	15	13	47	25	49	25	62	22
Afr	Victoria	0.91	0.56	0.47	11	22	32	43	24	33	16	65	23
Afr	Chad	0.84	0.64	0.43	25	17	23	48	26	42	21	65	23
Afr	Kariba	0.75	0.66	0.43	36	14	19	55	30	50	28	69	25

S.Am	Titicaca	0.82	0.71	0.71		32	32	8		40	22		25	35		72	26
Afr	Aby	0.83	0.65	0.52		28	24	21		49	27		52	30		73	27
S.Am	Chungarkkota	0.82	0.69	0.71		31	33	12		43	23		64	34		76	28
Asia	Shardara/Kara-kul	0.86	0.54	0.65		22	28	35		57	31		50	27		85	29
Eur	Dead Sea	0.90	0.51	0.72		14	34	38		52	29		48	24		86	30
Afr	Josini/Pongola-poort Dam	0.85	0.52	0.61		24	27	37		61	34		51	29		88	31
S.Am	Salto Grande	0.67	0.70	0.74		40	38	11		51	28		78	39		89	32
Asia	Darbandikhan	0.87	0.46	0.68		17	30	46		63	35		47	23		93	33
S.Am	Lago de Yacyreta	0.75	0.66	0.73		38	36	20		58	32		74	38		94	34
Asia	Aras Su Qovsaginin Su Anbari	0.89	0.47	0.73		15	35	44		59	33		50	26		94	34
Asia	Mangla	0.87	0.38	0.54		18	25	53		71	39		43	22		96	36
S.Am	Itaipu	0.75	0.58	0.73		37	37	29		66	37		74	37		103	37
Asia	Caspian Sea	0.73	0.60	0.77		39	41	27		66	36		80	40		107	38
Eur	Galilee	0.87	0.45	0.88		19	46	47		66	38		65	36		112	39
Eur	Cahul	0.82	0.39	0.69		30	31	51		81	42		61	33		112	39
Eur	Scutari/Skadar	0.62	0.55	0.78		41	42	34		75	41		83	41		117	41
N.Am	Amistad	0.49	0.61	0.86		47	45	26		73	40		47	40		118	42
Eur	Macro Prespa (Large Prespa)	0.51	0.51	0.75		44	40	40		84	43		84	42		124	43
Eur	Ohrid	0.47	0.51	0.74		49	39	39		88	46		88	44		127	44
Eur	Szczecin Lagoon	0.53	0.49	0.83		43	43	43		86	44		86	43		129	45
N.Am	Huron	0.42	0.53	0.93		51	50	36		87	45		101	51		137	46
Eur	Neusiedler/Ferto	0.58	0.39	0.88		42	47	50		92	47		89	45		139	47
N.Am	Ontario	0.48	0.47	0.92		48	49	45		93	48		97	49		142	48
Eur	Lake Maggiore	0.33	0.50	0.89		52	48	42		94	50		100	50		142	48
N.Am	Falcon	0.50	0.38	0.85		46	44	52		98	53		90	46		142	48
N.Am	Erie	0.51	0.43	0.93		45	51	49		94	51		96	48		145	51
N.Am	Champlain	0.29	0.51	0.94		53	52	41		94	49		105	53		146	52
N.Am	Michigan	0.44	0.44	0.94		50	53	48		98	52		103	52		151	53

Seawifs Project, NASA/Goddard Space Flight Center and ORBIMAGE

Transboundary River Basins of Northern America

1. Alsek Basin
2. Colorado Basin
3. Chilkat Basin
4. Columbia Basin
5. Fraser Basin
6. Firth Basin
7. Mississippi Basin
8. Nelson-Saskatchewan Basin
9. Rio Grande (North America) Basin
10. Skagit Basin
11. St. Croix Basin
12. St. John (North America) Basin
13. St. Lawrence Basin
14. Stikine Basin
15. Taku Basin
16. Tijuana Basin
17. Whiting Basin
18. Yaqui Basin
19. Yukon Basin

UNEP-DHI PARTNERSHIP
Centre on Water and Environment
UNEP DHI
IUCN
SIWI
CUNY The City University of New York
OSU Oregon State University
GLOBAL IGBP CHANGE International Geosphere-Biosphere Programme
Center for International Earth Science Information Network
Earth Institute | Columbia University
CESR Center for Environmental Systems Research
Delta Alliance

Alsek Basin

Geography

Total drainage area (km^2)	28,220
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	803
Country at mouth	United States
Average rainfall (mm/year)	1,552

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	2

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	3
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
ALSK_CAN		831.52			235.30	5.32
ALSK_USA		2,768.09			75.80	0.12
Total in Basin	34.13	1,209.34			311.10	5.44

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
ALSK_CAN	0.18	0.06	0.00	0.00	0	0.13	304.01	
ALSK_USA	0.10	0.00	0.01	0.00	0	0.09	502.63	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/
[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	0.28	0.06	0.01	0.00	0.00	0.22	353.01	0.00

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500 ,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000 .000 km^2)
ALSK_ CAN	26	0.93	1	0.02	1.05			0	51,958.38	0	0.00
ALSK_ USA	2	0.07	0	0.10	0.89			0	53,142.89	0	0.00
Total in Basin	28	1.00	1	0.03	1.05	0.00	0.00	0	52,250.62	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
ALSK_CAN	1	1	1		1		3	1	2	5	1	1	1	1	1
ALSK_USA	1	1	1		2				2	5	1	2	1	2	1
River Basin	1	1	1	2	2		3	1	2	5	1	1	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
ALSK_CAN	5	5	1	1			1	2	1
ALSK_USA	4	5	1	1			1	1	1
River Basin	5	5	1	1	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Country Boundaries Under TWAP

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Disputed areas

The GAUL project and original dataset maintains disputed areas in such a way to preserve national integrity for all disputing countries. The GAUL Set reports the international, first level and second level administrative boundaries delimiting, or falling within, the disputed areas in a way to enable the re-construction of the administrative units as they are specified by the individual disputing countries. Disputed areas are therefore shown as individual entities, not dependent from countries, with corresponding coding. Same approach has been taken by TWAP RB, reporting on disputed territories, as well as presentation of Basin Country Units.

Basin Delineation

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Colorado Basin

Geography

Total drainage area (km^2)	626,050
No. of countries in basin	2
BCUs in basin	Mexico (MEX), United States (USA)
Population in basin (people)	8,794,418
Country at mouth	Mexico
Average rainfall (mm/year)	339

Governance

No. of treaties and agreements[1]	21
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	11
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
CLDO_MEX		10.06				
CLDO_USA		41.01			2,042.20	92.61
Total in Basin	25.19	40.23			2,042.20	92.61

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
CLDO_MEX	3,160.74	3,034.55	3.31	18.72	21	83.38	11,483.49	
CLDO_USA	18,334.76	15,567.07	47.14	520.02	611	1,589.12	2,152.18	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	21,495.50	18,601.62	50.45	538.74	632.20	1,672.49	2,444.22	85.34

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
CLDO_MEX	6	0.01	275	44.90	1.26	0.00	100.00	1	10,307.28	0	0.00
CLDO_USA	620	0.99	8,519	13.74	0.89	4.16	95.84	15	53,142.89	82	132.28
Total in Basin	626	1.00	8,794	14.05	0.73	4.03	95.97	16	51,802.25	82	130.98

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CLDO_MEX	5	5	5		4	4	5	5	1	2	1	2	2	2	5
CLDO_USA	4	4	5		2	2	5	4	2	2	1	2	1	2	5
River Basin	5	4	5	1	2	2	5	4	1	2	1	2	1	2	5

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	**1.Environmental water stress**		**2.Human water stress**		**4.Nutrient pollution**		**16.Change in population density**		**11.Hydropolitical tension**
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
CLDO_MEX	5	5	5	5			1	2	2
CLDO_USA	5	5	4	4			1	1	1
River Basin	5	5	4	5	1	1	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	**Lake Influence Indicator**	**Delta Vulnerability Index**			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	5	4	1	2	5

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Chilkat Basin

Geography

Total drainage area (km^2)	3,967
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	1,204
Country at mouth	United States
Average rainfall (mm/year)	1,438

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	2

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	1
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
CLKT_CAN		1,207.89				
CLKT_USA		1,323.46			91.20	0.56
Total in Basin	4.98	1,254.39			91.20	0.56

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
CLKT_CAN	0.08	0.00	0.00	0.00	0	0.08	2,356.00	
CLKT_USA	0.22	0.00	0.01	0.00	0	0.21	187.45	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	0.30	0.00	0.01	0.00	0.00	0.29	248.99	0.01

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500 ,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000 .000 km^2)
CLKT_ CAN	2	0.45	0	0.02	1.05			0	51,958.38	0	0.00
CLKT_ USA	2	0.55	1	0.54	0.89	100.00	0.00	0	53,142.89	0	0.00
Total in Basin	4	1.00	1	0.30	0.73	97.16	0.00	0	53,109.27	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CLKT_CAN	1	1	1		1		3	1	2	5	1	1	1	1	1
CLKT_USA	1	1	1		2	1	3	1	2	5	1	2	1	2	1
River Basin	1	1	1	2	2	1	3	1	2	5	1	2	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
CLKT_CAN	5	5	1	1			1	2	1
CLKT_USA	4	5	1	1			1	1	1
River Basin	5	5	1	1	2	2	1	1	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Columbia Basin

Geography

Total drainage area (km^2)	653,255
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	7,489,336
Country at mouth	United States
Average rainfall (mm/year)	632

Governance

No. of treaties and agreements[1]	8
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	35
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
CLMB_CAN		608.32			1,897.59	41.96
CLMB_USA		315.08			2,938.11	119.37
Total in Basin	233.76	357.83			4,835.70	161.33

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
CLMB_CAN	398.60	210.86	2.71	32.78	55	97.37	840.87	
CLMB_USA	35,680.95	33,472.06	85.88	346.45	466	1,310.79	5,086.16	

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	36,079.55	33,682.92	88.58	379.23	520.66	1,408.16	4,817.46	15.43

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000 .000 km^2)
CLMB_CAN	103	0.16	474	4.61	1.05	0.00	100.00	1	51,958.38	11	106.98
CLMB_USA	550	0.84	7,015	12.75	0.89	7.70	92.30	6	53,142.89	114	207.11
Total in Basin	653	1.00	7,489	11.46	0.74	7.21	92.79	7	53,067.92	125	191.35

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CLMB_CAN	2	1	2		1	1	5	4	1	2	1	1	1	1	1
CLMB_USA	3	2	3		2	2	5	4	2	2	1	2	2	2	1
River Basin	3	2	3	2	2	2	5	5	1	2	1	2	2	2	1

Indicators

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Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
CLMB_CAN	5	5	1	1			1	2	1
CLMB_USA	4	4	2	2			1	1	1
River Basin	5	5	2	2	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	2				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

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Fraser Basin

Geography

Total drainage area (km^2)	231,593
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	1,180,759
Country at mouth	Canada
Average rainfall (mm/year)	774

Governance

No. of treaties and agreements[1]	1
No. of RBOs and Commissions[2]	0

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	29
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
FRSR_CAN		537.44			3,646.43	262.42
FRSR_USA						
Total in Basin	124.47	537.44			3,882.72	265.53

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
FRSR_CAN	1,878.09	380.99	9.50	258.61	619	610.42	1,600.12	
FRSR_USA								

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	1,878.09	380.99	9.50	258.61	618.57	610.42	1,590.58	1.51

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
FRSR_CAN	231	1.00	1,174	5.08	1.05	0.00	100.00	1	51,958.38	10	43.30
FRSR_USA	1	0.00	7	11.15	0.89	100.00	0.00	0	53,142.89	0	0.00
Total in Basin	232	1.00	1,181	5.10	1.15	0.60	99.40	1	51,965.44	10	43.18

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
FRSR_CAN	2	1	2		1	1	4	3	▨ 2	2	1	1	1	1	1
FRSR_USA		▨			2	3			▨ 1	2	1	2	1	2	1
River Basin	2	1	2	2	1	1	4	3	▨ 1	2	1	1	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
FRSR_CAN	4	5	1	1			1	2	▨ 1
FRSR_USA			▨	▨					▨ 1
River Basin	4	5	1	1	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	4				

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Firth Basin

Geography

Total drainage area (km²)	6,075
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	24
Country at mouth	Canada
Average rainfall (mm/year)	132

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	0
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
FRTH_CAN		70.03				
FRTH_USA		35.27				
Total in Basin	0.32	52.65			0.00	0.00

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
FRTH_CAN	0.01	0.00	0.00	0.00	0	0.00	547.20	
FRTH_USA	0.02	0.00	0.02	0.00	0	0.00	1,829.26	

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	0.03	0.00	0.02	0.00	0.00	0.01	1,165.15	0.01

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500 ,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000 .000 km^2)
FRTH_CAN	4	0.58	0	0.00	1.05			0	51,958.38	0	0.00
FRTH_USA	3	0.42	0	0.00	0.89			0	53,142.89	0	0.00
Total in Basin	6	1.00	0	0.00	0.94	0.00	0.00	0	52,529.35	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
FRTH_CAN	1	1	1		1				2	5	1	1	1	1	2
FRTH_USA	1	1	1		2				2	5	1	2	1	2	2
River Basin	1	1	1	1	2				2	5	1	2	1	2	2

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
FRTH_CAN	2	4	1	1			1	2	1
FRTH_USA	3	5	1	1			1	1	1
River Basin	3	5	1	1	1	1	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Mississippi Basin

Geography

Total drainage area (km^2)	3,208,233
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	78,173,975
Country at mouth	United States
Average rainfall (mm/year)	893

Governance

No. of treaties and agreements[1]	2
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	119
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
MISS_CAN		6.68				
MISS_USA		223.20			17,310.70	184.87
Total in Basin	709.76	221.23			17,310.70	184.87

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
MISS_CAN	439.62	192.49	5.84	236.83	0	4.46	32,956.93	
MISS_USA	207,572.72	94,185.26	1,337.32	90,416.34	6,078	15,555.97	2,655.72	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	208,012.34	94,377.74	1,343.16	90,653.17	6,077.84	15,560.43	2,660.89	29.31

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500 ,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000 .000 km^2)
MISS_CAN	26	0.01	13	0.50	1.05			0	51,958.38	2	75.53
MISS_USA	3,182	0.99	78,161	24.57	0.89	11.42	88.58	54	53,142.89	705	221.58
Total in Basin	3,208	1.00	78,174	24.37	0.72	11.41	88.57	54	53,142.69	707	220.37

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
MISS_CAN	3	3	5		1	5	5	3	1	2	1	1	1	1	3
MISS_USA	3	2	3		2	2	5	4	5	2	1	2	3	2	2
River Basin	3	2	3	4	2	3	5	5	4	2	1	2	3	2	2

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
MISS_CAN	4	4	3	3			1	2	1
MISS_USA	4	4	3	3			1	1	1
River Basin	4	4	3	3	4	4	1	1	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	3	4	1	2	2

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Nelson-Saskatchewan Basin

Geography

Total drainage area (km^2)	1,088,785
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	6,080,864
Country at mouth	Canada
Average rainfall (mm/year)	543

Governance

No. of treaties and agreements[1]	3
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	187
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
NELS_CAN		95.68			64,230.17	648.50
NELS_USA		77.24			3,249.32	54.09
Total in Basin	101.67	93.38			67,479.49	702.59

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
NELS_CAN	10,436.71	4,362.83	160.77	3,947.59	856	1,109.10	1,952.91	
NELS_USA	807.56	378.71	18.56	255.23	21	133.94	1,096.19	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	11,244.26	4,741.54	179.32	4,202.82	877.54	1,243.04	1,849.12	11.06

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
NELS_CAN	934	0.86	5,344	5.72	1.05	0.00	100.00	5	51,958.38	49	52.46
NELS_USA	155	0.14	737	4.76	0.89	29.46	70.54	0	53,142.89	41	264.93
Total in Basin	1,089	1.00	6,081	5.59	1.10	3.57	96.43	5	52,101.88	90	82.66

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
NELS_CAN	2	1	2		1	3	5	4	2	2	1	1	4	1	1
NELS_USA	2	1	2		2	3	5	4	2	2	1	2	1	2	3
River Basin	2	1	2	2	2	3	5	4	1	2	1	1	4	2	2

Indicators

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Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
NELS_CAN	2	2	1	1			1	2	1
NELS_USA	2	2	1	1			1	1	1
River Basin	2	2	1	1	2	3	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	5				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

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Rio Grande (North America) Basin

Geography

Total drainage area (km^2)	538,402
No. of countries in basin	2
BCUs in basin	Mexico (MEX), United States (USA)
Population in basin (people)	10,968,793
Country at mouth	Mexico
Average rainfall (mm/year)	440

Governance

No. of treaties and agreements[1]	23
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	12
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
RGNA_MEX		25.79			687.83	8.69
RGNA_USA		20.01			536.57	8.03
Total in Basin	12.11	22.50			1,224.40	16.72

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
RGNA_MEX	8,114.88	6,704.13	51.05	99.06	268	992.53	1,041.93	
RGNA_USA	10,744.97	8,783.00	42.04	611.59	357	951.57	3,378.38	

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	18,859.84	15,487.13	93.10	710.66	624.86	1,944.11	1,719.41	155.68

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
RGNA_MEX	224	0.42	7,788	34.81	1.26	0.00	100.00	17	10,307.28	10	44.69
RGNA_USA	315	0.58	3,181	10.11	0.89	7.48	92.52	4	53,142.89	25	79.45
Total in Basin	538	1.00	10,969	20.37	1.07	2.17	97.83	21	22,727.90	35	65.01

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RGNA_MEX	4	5	5		4	1	5	4	2	2	1	2	3	2	5
RGNA_USA	5	5	5		2	2	5	4	1	2	1	2	1	2	5
River Basin	5	5	5	3	3	2	5	4	1	2	1	2	2	3	5

Indicators

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Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
RGNA_MEX	5	5	5	5			1	2	2
RGNA_USA	5	5	5	5			1	2	1
River Basin	5	5	5	5	3	3	1	2	2

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	4	5	1	3	3

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Skagit Basin

Geography

Total drainage area (km^2)	8,207
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	78,441
Country at mouth	United States
Average rainfall (mm/year)	1,744

Governance

No. of treaties and agreements[1]	2
No. of RBOs and Commissions[2]	0

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	1
Large Marine Ecosystems	1

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All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
SKAG_CAN		1,275.07			0.89	0.07
SKAG_USA		1,279.14			40.41	3.23
Total in Basin	10.49	1,278.69			41.30	3.30

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
SKAG_CAN	3.74	2.04	0.09	0.00	0	1.62	9,680.58	
SKAG_USA	305.91	71.16	3.31	126.25	31	74.17	3,919.21	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	309.65	73.19	3.40	126.25	31.03	75.78	3,947.60	2.95

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
SKAG_CAN	1	0.13	0	0.37	1.05			0	51,958.38	0	0.00
SKAG_USA	7	0.87	78	10.90	0.89	11.27	88.73	0	53,142.89	4	558.47
Total in Basin	8	1.00	78	9.56	0.72	11.22	88.29	0	53,137.05	4	487.36

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
SKAG_CAN	1	1	2		1		4	3	1	2	1	1	1	1	1
SKAG_USA	2	1	2		2	2	4	4	2	2	1	2	1	2	2
River Basin	2	1	2	3	2	2	4	4	1	2	1	2	1	2	2

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
SKAG_CAN	3	4	1	1					1
SKAG_USA	4	4	1	1			1	1	1
River Basin	4	5	1	1	3	3	1	1	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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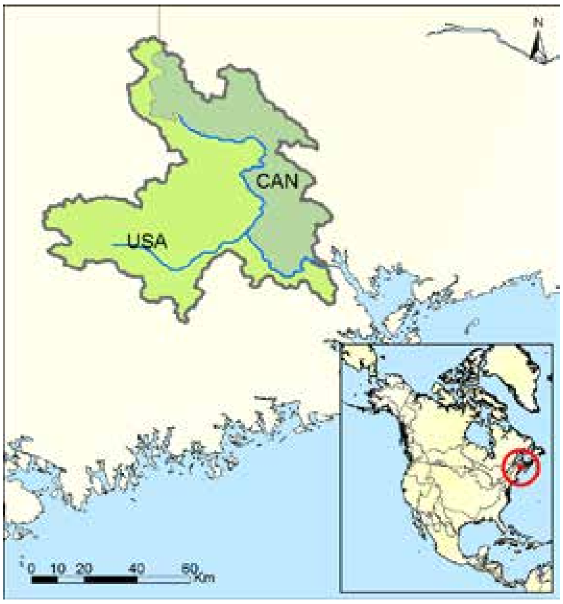
St. Croix Basin



Geography

Total drainage area (km^2)	3,942
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	17,804
Country at mouth	Canada, United States
Average rainfall (mm/year)	1,220

Governance

No. of treaties and agreements[1]	1
No. of RBOs and Commissions[2]	2

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	4
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
SCRO_CAN		540.79			74.68	0.53
SCRO_USA		649.29			214.02	1.40
Total in Basin	2.39	606.08			288.70	1.93

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
SCRO_CAN	10.68	3.54	0.03	0.39	2	5.19	1,133.38	
SCRO_USA	7.47	3.56	0.03	0.00	0	3.88	891.06	

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	18.15	7.10	0.07	0.39	1.52	9.07	1,019.26	0.76

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
SCRO_CAN	1	0.36	9	6.60	1.05	0.00	100.00	0	51,958.38	0	0.00
SCRO_USA	3	0.64	8	3.34	0.89	23.25	76.75	0	53,142.89	6	2,386.79
Total in Basin	4	1.00	18	4.52	0.95	10.95	89.05	0	52,516.21	6	1,522.17

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
SCRO_CAN	1	1	2		1	3	4	2	1	2	1	1	1	1	1
SCRO_USA	1	1	2		2	4	5	2	1	2	1	2	1	2	1
River Basin	1	1	2	4	2	4	4	2	1	2	1	2	1	2	1

Indicators

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Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
SCRO_CAN	2	3	1	1			1	2	1
SCRO_USA	2	2	1	1			1	1	1
River Basin	2	2	1	1	4	4	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	2				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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St. John (North America) Basin

Geography

Total drainage area (km^2)	55,056
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	397,500
Country at mouth	Canada
Average rainfall (mm/year)	1,201

Governance

No. of treaties and agreements[1]	3
No. of RBOs and Commissions[2]	0

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	7
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
SJNA_CAN		650.74			500.90	4.42
SJNA_USA		604.73			53.00	0.30
Total in Basin	35.09	637.43			553.90	4.72

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
SJNA_CAN	543.85	7.42	2.70	378.93	47	108.02	1,691.06	
SJNA_USA	40.33	4.42	0.71	17.99	1	16.28	531.33	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/
[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	584.18	11.84	3.40	396.92	47.72	124.30	1,469.63	1.66

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
SJNA_CAN	36	0.66	322	8.89	1.05	0.00	100.00	0	51,958.38	2	55.30
SJNA_USA	19	0.34	76	4.02	0.89	25.52	74.48	0	53,142.89	3	158.84
Total in Basin	55	1.00	398	7.22	1.07	4.87	95.13	0	52,184.55	5	90.82

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
SJNA_CAN	1	1	2		1	2	4	3	1	2	1	1	1	1	1
SJNA_USA	1	1	2		2	2	5	3	1	2	1	2	1	2	1
River Basin	1	1	2	3	2	2	4	3	1	2	1	2	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
SJNA_CAN	4	4	1	1			1	2	1
SJNA_USA	3	3	1	1			1	2	1
River Basin	4	4	1	1	3	3	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

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St. Lawrence Basin

Geography

Total drainage area (km^2)	1,057,304
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	45,877,260
Country at mouth	Canada
Average rainfall (mm/year)	1,010

Governance

No. of treaties and agreements[1]	25
No. of RBOs and Commissions[2]	3

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	86
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
SLAW_CAN		405.67			17,628.03	697.55
SLAW_USA		594.41			5,717.55	328.40
Total in Basin	517.70	489.64			262,849.40	23,119.86

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
SLAW_CAN	21,351.39	358.34	84.25	12,853.21	4,085	3,970.16	1,149.30	
SLAW_USA	34,230.37	1,177.23	104.40	26,135.59	2,200	4,612.83	1,253.88	

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Total in Basin	55,581.76	1,535.57	188.64	38,988.80	6,285.76	8,582.99	1,211.53	10.74

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
SLAW_CAN	570	0.54	18,578	32.57	1.05	0.00	100.00	16	51,958.38	53	92.92
SLAW_USA	487	0.46	27,299	56.07	0.89	4.86	95.14	21	53,142.89	123	252.61
Total in Basin	1,057	1.00	45,877	43.39	0.89	2.89	97.11	37	52,663.23	176	166.46

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SLAW_CAN	2	1	2		1	1	5	4	1	2	1	1	3	1	2
SLAW_USA	2	2	2		2	2	5	4	1	2	1	2	1	2	2
River Basin	2	1	2	3	2	2	5	4	1	2	1	2	2	2	2

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
SLAW_CAN	3	3	1	1			1	2	1
SLAW_USA	2	3	2	2			1	1	1
River Basin	3	3	1	1	3	3	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	5				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Stikine Basin

Geography

Total drainage area (km^2)	50,877
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	1,100
Country at mouth	United States
Average rainfall (mm/year)	827

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	2

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	0
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
STKN_CAN		758.72				
STKN_USA		1,966.66				
Total in Basin	44.46	873.84			0.00	0.00

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
STKN_CAN	3.06	0.17	0.00	2.59	0	0.30	4,071.77	
STKN_USA	0.26	0.00	0.01	0.00	0	0.26	751.40	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	3.32	0.17	0.01	2.59	0.00	0.55	3,016.96	0.01

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
STKN_CAN	50	0.98	1	0.02	1.05			0	51,958.38	0	0.00
STKN_USA	1	0.02	0	0.28	0.89			0	53,142.89	0	0.00
Total in Basin	51	1.00	1	0.02	1.02	0.00	0.00	0	52,334.67	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
STKN_CAN	1	1	1		1		1	2	2	5	1	1	1	1	1
STKN_USA	1	1	1		2		4	2	2	5	1	2	1	2	1
River Basin	1	1	1	2	2		1	2	1	5	1	1	1	2	1

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Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
STKN_CAN	4	5	1	1			1	2	1
STKN_USA	4	5	1	1					1
River Basin	4	5	1	1	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	1				

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17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Taku Basin

Geography

Total drainage area (km^2)	17,496
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	795
Country at mouth	United States
Average rainfall (mm/year)	984

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	2

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	0
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
TAKU_CAN		668.97				
TAKU_USA						
Total in Basin	11.70	668.97			0.00	0.00

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
TAKU_CAN	0.11	0.00	0.00	0.00	0	0.11	780.26	
TAKU_USA								

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	0.11	0.00	0.00	0.00	0.00	0.11	140.16	0.00

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
TAKU_CAN	17	0.96	0	0.01	1.05			0	51,958.38	0	0.00
TAKU_USA	1	0.04	1	0.85	0.89			0	53,142.89	0	0.00
Total in Basin	17	1.00	1	0.05	0.79	0.00	0.00	0	52,930.11	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TAKU_CAN	1	1	1		1		3	2	2	5	1	1	1	1	1
TAKU_USA		▨			2				2	5	1	2	1	2	
River Basin	1	1	1	2	2		3	2	2	5	1	2	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
TAKU_CAN	4	5	1	1			1	2	1
TAKU_USA			▨	▨			1	1	1
River Basin	4	5	1	1	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Tijuana Basin

Geography

Total drainage area (km^2)	4,430
No. of countries in basin	2
BCUs in basin	Mexico (MEX), United States (USA)
Population in basin (people)	1,067,632
Country at mouth	United States
Average rainfall (mm/year)	341

Governance

No. of treaties and agreements[1]	9
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	1
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
TIJU_MEX		68.21				
TIJU_USA		115.67				
Total in Basin	0.41	91.88			0.00	0.00

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
TIJU_MEX	572.25	287.83	2.12	0.00	71	211.08	619.48	
TIJU_USA	844.05	89.46	1.60	30.91	249	473.56	5,866.32	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/
[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	1,416.30	377.29	3.73	30.91	319.73	684.65	1,326.58	347.98

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
TIJU_MEX	3	0.72	924	289.21	1.26	0.00	100.00	1	10,307.28	2	626.17
TIJU_USA	1	0.28	144	116.42	0.89	5.27	94.73	0	53,142.89	2	1,618.36
Total in Basin	4	1.00	1,068	241.01	1.15	0.71	99.29	1	16,080.07	4	902.97

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
TIJU_MEX	5	5	4		4		3	4	2	2	1	2	1	2	5
TIJU_USA	5		3		2				2	2	1	2	1	2	5
River Basin	5	5	3	5	3		4	5	2	2	1	2	1	3	5

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Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
TIJU_MEX	5	5	5	5			1	2	1
TIJU_USA	5	5							1
River Basin	5	5	5	5	5	5	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	5				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

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Whiting Basin

Geography

Total drainage area (km^2)	2,474
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	520
Country at mouth	United States
Average rainfall (mm/year)	2,387

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	0
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
WHIT_CAN		2,177.29				
WHIT_USA		2,236.80				
Total in Basin	5.47	2,213.13			0.00	0.00

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
WHIT_CAN	0.13	0.00	0.00	0.00	0	0.12	5,577.81	
WHIT_USA	0.38	0.00	0.01	0.00	0	0.38	770.14	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	0.51	0.00	0.01	0.00	0.00	0.50	976.73	0.01

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
WHIT_CAN	2	0.79	0	0.01	1.05			0	51,958.38	0	0.00
WHIT_USA	1	0.21	0	0.94	0.89			0	53,142.89	0	0.00
Total in Basin	2	1.00	1	0.21	0.73	0.00	0.00	0	53,091.99	0	0.00

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	**Water Quantity**			**Water Quality**			**Ecosystems**			**Governance**			**Socioeconomics**		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
WHIT_CAN	1	1	1		1		3	1	2	5	1	1	1	1	1
WHIT_USA	1		1		2				2	5	1	2	1	2	1
River Basin	1	1	1	2	2		3	1	2	5	1	2	1	2	1

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	**1.Environmental water stress**		**2.Human water stress**		**4.Nutrient pollution**		**16.Change in population density**		**11.Hydropolitical tension**
Basin BCU	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**P-2030**	**P-2050**	**Projected**
WHIT_CAN	5	5	1	1			1	2	1
WHIT_USA	5	5							1
River Basin	5	5	1	1	2	2	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	**Lake Influence Indicator**	**Delta Vulnerability Index**			
Basin/Delta	**17**	**18**	**19**	**20**	**21**
River Basin	1				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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Yaqui Basin

Geography

Total drainage area (km^2)	72,879
No. of countries in basin	2
BCUs in basin	Mexico (MEX), United States (USA)
Population in basin (people)	559,911
Country at mouth	Mexico
Average rainfall (mm/year)	541

Governance

No. of treaties and agreements[1]	3
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	2
Large Marine Ecosystems	0

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
YAQU_MEX		50.21			292.70	1.91
YAQU_USA		31.37				
Total in Basin	3.59	49.29			292.70	1.91

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
YAQU_MEX	2,036.49	1,929.06	9.02	9.93	7	81.09	3,850.66	
YAQU_USA	83.90	79.91	0.18	0.00	0	3.81	2,702.74	

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[1] For details on Treaties and Agreements please see http://www.transboundarywaters.orst.edu/

[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	2,120.39	2,008.97	9.21	9.93	7.38	84.90	3,787.01	59.03

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/ km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
YAQU_MEX	69	0.94	529	7.70	1.26	0.00	100.00	0	10,307.28	3	43.67
YAQU_USA	4	0.06	31	7.42	0.89	9.77	90.23	0	53,142.89	0	0.00
Total in Basin	73	1.00	560	7.68	1.19	0.54	99.46	0	12,682.26	3	41.16

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
YAQU_MEX	3	2	3		4	1	5	3	1	3	2	2	1	2	3
YAQU_USA	5	5	4		2				1	3	2	2	1	2	5
River Basin	3	2	3	3	4	1	5	3	1	3	2	2	1	3	3

Indicators

1 - Environmental water stress **2** – Human water stress **3** – Agricultural water stress **4** – Nutrient pollution **5** – Wastewater pollution **6** – Wetland disconnectivity **7** – Ecosystem impacts from dams **8** – Threat to fish **9** – Extinction risk **10** – Legal framework **11** – Hydropolitical tension **12** – Enabling environment **13** – Economic dependence on water resources **14** – Societal well-being **15** – Exposure to floods and droughts

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Projected Indicator

Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
YAQU_MEX	5	5	3	3			1	2	3
YAQU_USA	5	5	5	5			1	1	2
River Basin	5	5	3	3	3	3	1	2	3

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	2				

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[3] Lined (or dotted) cells indicate a lower degree of confidence in results due to global modelling limitations and other gap-filling methods.

Indicators

17 – Lake influence indicator **18** – Relative sea level rise (RSLR) **19** – Wetland ecological threat **20** – Population pressure **21** – Delta governance

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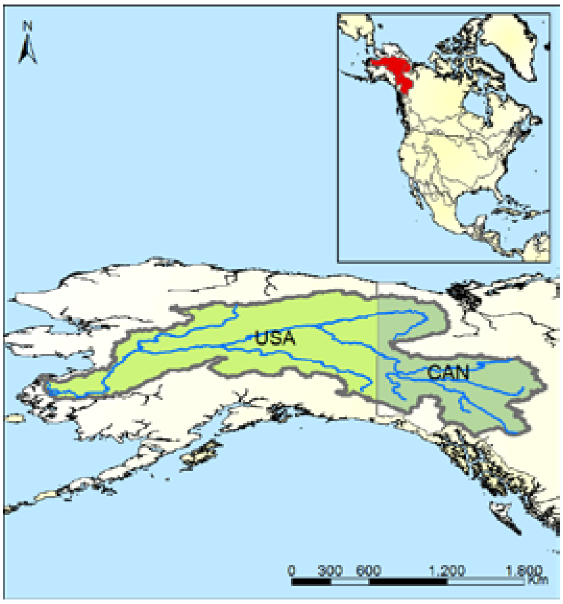
Yukon Basin



Geography

Total drainage area (km^2)	838,169
No. of countries in basin	2
BCUs in basin	Canada (CAN), United States (USA)
Population in basin (people)	140,462
Country at mouth	United States
Average rainfall (mm/year)	351

Governance

No. of treaties and agreements[1]	0
No. of RBOs and Commissions[2]	1

Geographical Overlap with Other Transboundary Systems

(No. of overlapping water systems)

Groundwater	
Lakes	18
Large Marine Ecosystems	1

A BCU (Basin Country Unit) is defined as the portion of a country within a particular river basin.
All BCUs have a BCU code which includes a Basin Code of four letters and a Country Code of three letters: XXXX-XXX

Water Resources

BCU	Annual Discharge (km^3/year)	Annual Runoff (mm/year)	Av. Groundwater Recharge (km^3/year)	Av. Groundwater Discharge (km^3/year)	Lake and Reservoir Surface Area (km^2)	Lake and Reservoir Volume (km^3)
YUKN_CAN		286.91			2,676.90	87.25
YUKN_USA		215.17			248.10	1.87
Total in Basin	204.00	243.39			2,925.00	89.12

Water Withdrawals

BCU	Total (km^3/year)	Irrigation (km^3/year)	Livestock (km^3/year)	Electricity (km^3/year)	Manufacture (km^3/year)	Domestic (km^3/year)	Per capita (m^3/year)	Total withdrawal as a % of Total Actual Renewable Water Resources (%)
YUKN_CAN	24.60	0.72	0.01	18.62	0	5.20	1,030.10	
YUKN_USA	46.85	2.15	2.06	17.12	4	21.64	401.83	

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[2] For details on River Basin Organisations (RBOs) and Commissions please visit http://www.transboundarywaters.orst.edu/

Total in Basin	71.45	2.86	2.07	35.74	3.94	26.84	508.64	0.04

Socioeconomic Geography

BCU	Area ('000 km^2)	BCU area in basin (%)	Population ('000 people)	Population density (people/km^2)	Annual pop. growth (%)	Rural population ratio (% pop. rural)	Urban population ratio (% pop. urban)	Large Cities (>500,000)	GDP per capita (USD)	No. of dams	Dam Density (No./000.000 km^2)
YUKN_CAN	333	0.40	24	0.07	1.05	0.00	100.00	0	51,958.38	1	3.00
YUKN_USA	505	0.60	117	0.23	0.89	33.51	66.49	0	53,142.89	0	0.00
Total in Basin	838	1.00	140	0.17	0.79	27.81	72.19	0	52,941.51	1	1.19

TWAP RB Assessment Results: BCU and Basin Relative Risk Category per Indicator[3]

Thematic group	Water Quantity			Water Quality			Ecosystems			Governance			Socioeconomics		
BCU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
YUKN_CAN	1	1	1		1	1	2	2	2	5	1	1	1	1	1
YUKN_USA	1	1	1		2	1	2	2	3	5	1	2	1	2	2
River Basin	1	1	1	1	2	1	2	2	2	5	1	2	1	2	2

Indicators

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Projected Indicator	1.Environmental water stress		2.Human water stress		4.Nutrient pollution		16.Change in population density		11.Hydropolitical tension
Basin BCU	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	P-2030	P-2050	Projected
YUKN_CAN	4	5	1	1			1	2	1
YUKN_USA	3	5	1	1			1	1	1
River Basin	4	5	1	1	1	1	1	2	1

TWAP RB Assessment results: Water System Linkages

Thematic group	Lake Influence Indicator	Delta Vulnerability Index			
Basin/Delta	17	18	19	20	21
River Basin	2	2	2	1	2

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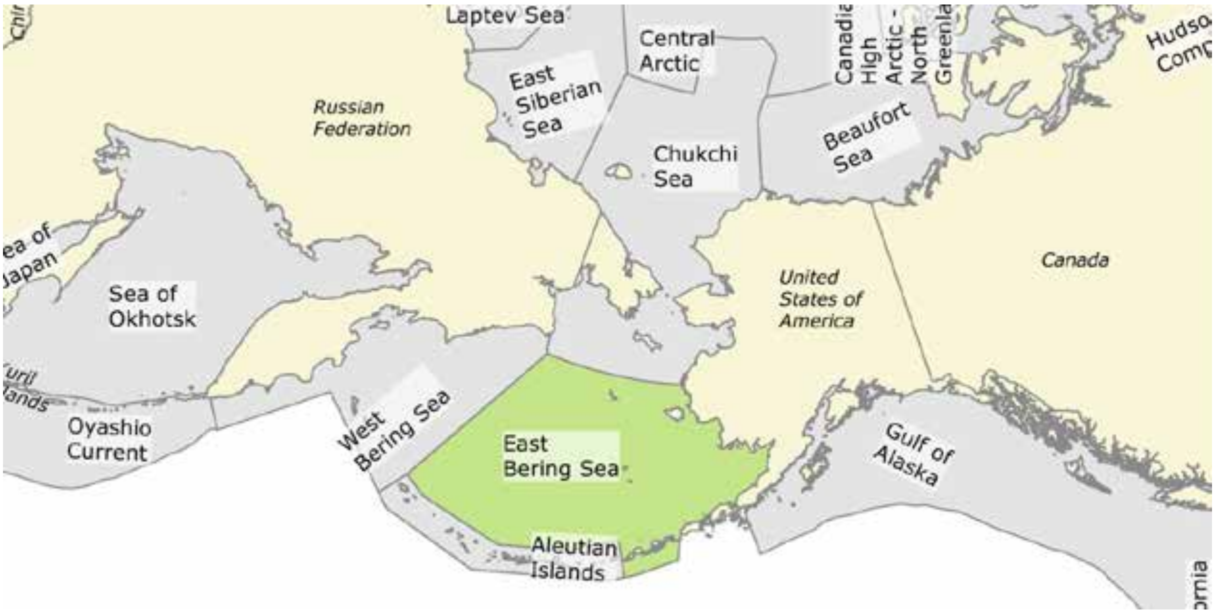
Large Marine Ecosystems of Northern America

1. East Bering Sea LME
2. Gulf of Alaska LME
3. California Current LME
4. Gulf of California LME
5. Gulf of Mexico LME
6. Southeast U.S. Continental Shelf LME
7. Northeast U.S. Continental Shelf LME
8. Scotian Shelf LME
9. Labrador-Newfoundland LME
10. Pacific Central-American Shelf LME
11. Caribbean Sea LME
12. Canadian Eastern Arctic - West Greenland LME
13. Greenland Sea LME
14. Northern Bering - Chukchi Seas LME
15. Beaufort Sea
16. Hudson Bay Complex LME
17. Central Arctic LME
18. Aleutian Islands LME
19. Canadian High Arctic - North Greenland LME

United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
Center for Marine Assessment and Planning, UCSB
DALHOUSIE UNIVERSITY Inspiring Minds
GLOBAL IGBP CHANGE International Geosphere-Biosphere Programme
UNEP WCMC
UBC
SEA AROUND US
CERMES
TAT Tokyo University of Agriculture and Technology

LME 01 – East Bering Sea

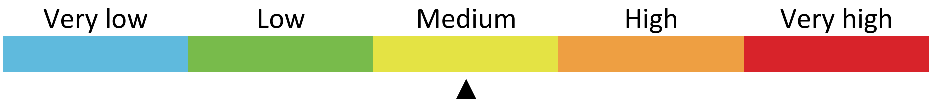


Bordering country: United States of America
LME Total area: 1,193,601 km^2

List of indicators

LME overall risk

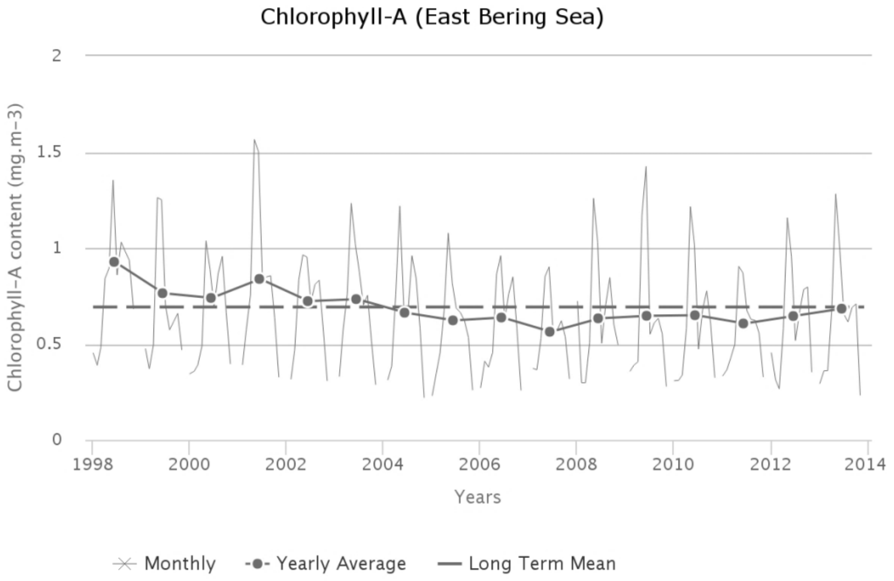
This LME falls in the cluster of LMEs that exhibit medium numbers of collapsed and overexploited fish stocks, as well as very high proportions of catch from bottom impacting gear.
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is medium.

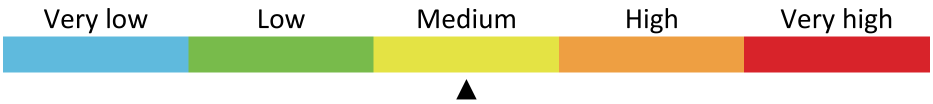


Productivity

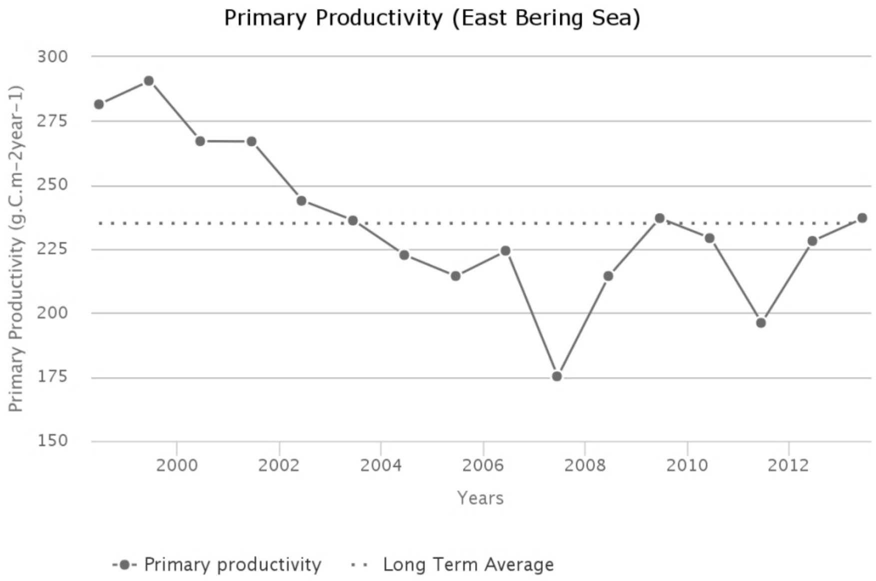
Chlorophyll-A

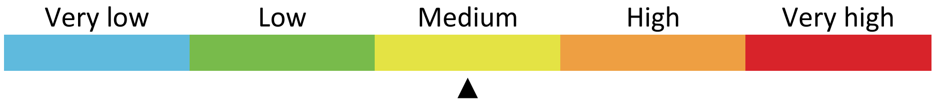
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (1.12 $mg.m^{-3}$) in May and a minimum (0.309 $mg.m^{-3}$) during November. The average CHL is 0.692 $mg.m^{-3}$. Maximum primary productivity (291 $g.C.m^{-2}.y^{-1}$) occurred during 1999 and minimum primary productivity (175 $g.C.m^{-2}.y^{-1}$) during 2007. There is a statistically insignificant decreasing trend in Chlorophyll of -19.1 % from 2003 through 2013. The average primary productivity is 235 $g.C.m^{-2}.y^{-1}$, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





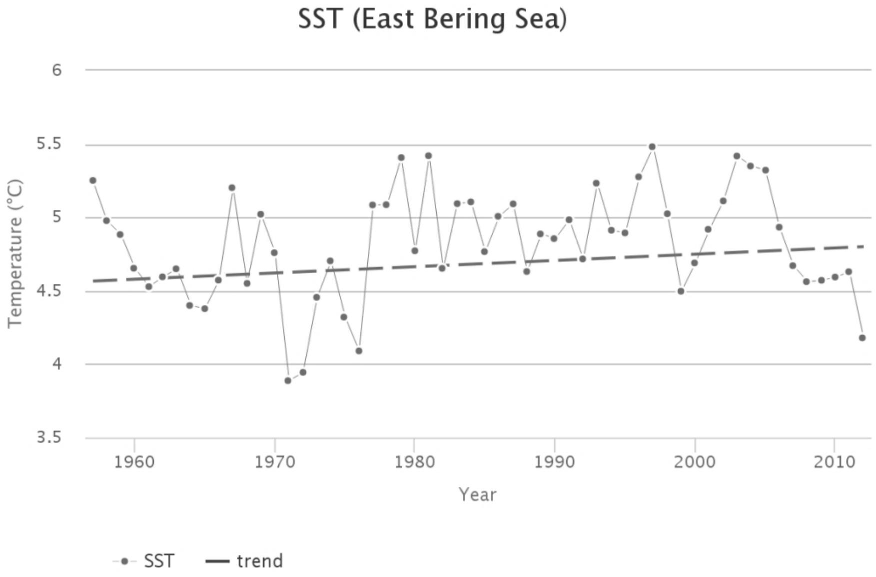
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the East Bering Sea LME #1 has warmed by 0.24°C. It thus belongs to Category 4 (slow-warming LME). The 1957-2012 time span included periods with opposite SST trends. From 1957 through 1971 SST decreased by >1°C. The SST drop was especially abrupt in the late 1960s-early 1970s. The cold spell lasted through 1976, after which SST jumped by ~1°C in one year and remained relatively high through 2003. The 1°C SST jump from 4°C to 5°C between 1976 and 1977 was a manifestation of a “regime shift” in the North Pacific that occurred during the winter of 1976-1977, caused by a large-scale shift of the North Pacific atmospheric pressure pattern (Hare and Mantua, 2000). After peaking at 5.5°C in 1998 and at 5.4°C in 2003, SST plunged below 4.2°C by 2012, a drop of 1.2°C in 9 years.

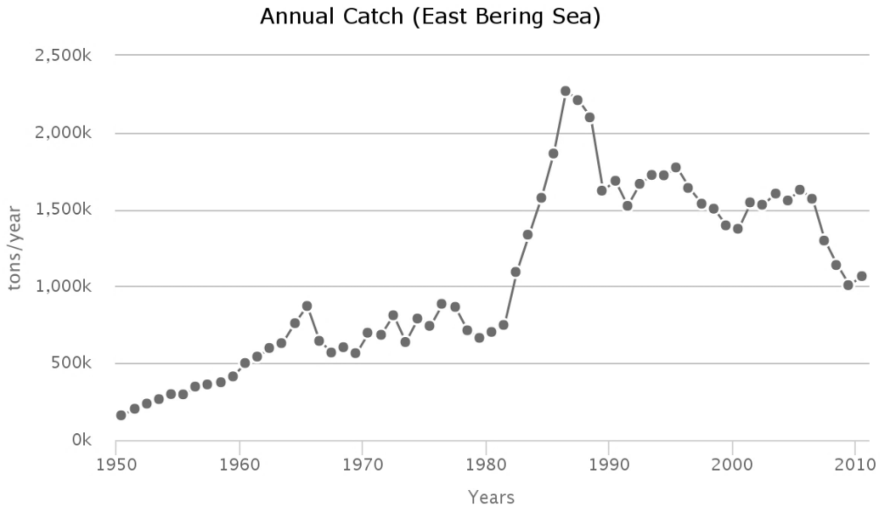


Fish and Fisheries

The East Bering Sea LME supports the world's largest single-species fishery, targeting Alaska pollock (*Theragra chalcogramma*).

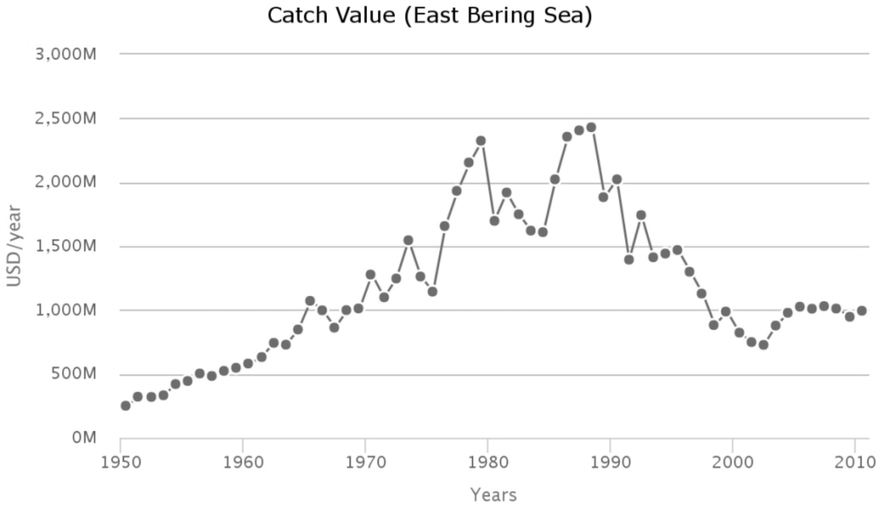
Annual Catch

Reported landings of this fishery now range between 0.4 and 0.7 million t, a level thought to be sustainable. Other commercially valuable species include halibut, herring, capelin, Pacific cod, skate, flounder, Greenland turbot, sole, dab, plaice and crab. Total reported landings rose steadily to a historic high of 1.8 million t in 1986, followed by a decline to 1.1million t in the mid-2000s and then followed by a further decline to 0.9 million t in the recent years.



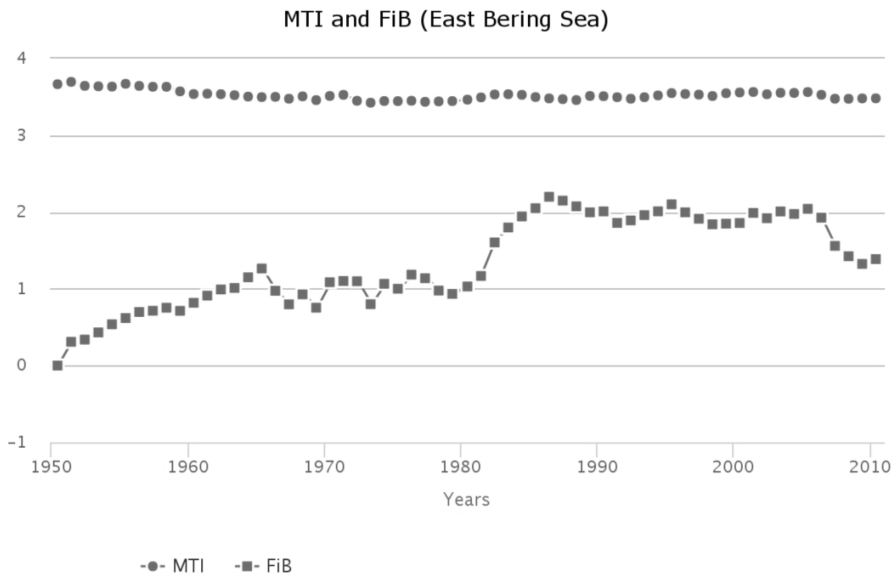
Catch value

The value of the fishery reached its peak at 1.9 billion US$ (in 2005 US$) in 1979.



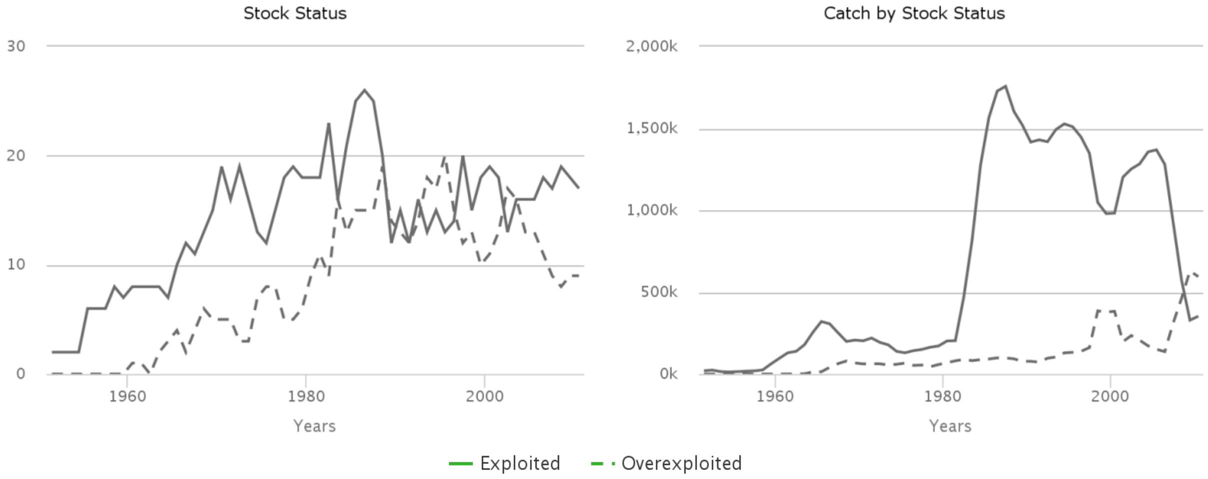
Marine Trophic Index and Fishing-in-Balance index

The MTI declined from the 1950s to the early 1970s, but has since leveled off at around 3.5 due to the enormous catch of Alaska pollock. The geographic expansion which led to this dominance of Alaska pollock is suggested by the increase of the FiB index from the mid-1970s to the mid-1980s. The system appears sustainable according to these two indices, although it must be stressed that such an interpretation is based on the overwhelming effect of a single, well-managed species.



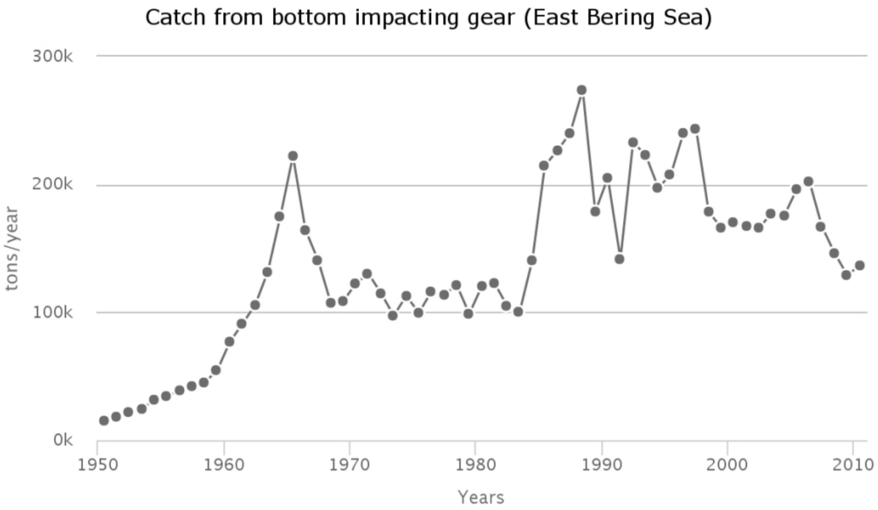
Stock status

The Stock-Catch Status Plots indicate that about 40% of the commercially exploited stocks have collapsed. The majority of the reported landings is still supplied by overexploited stocks, or more specifically, by Alaska pollock.



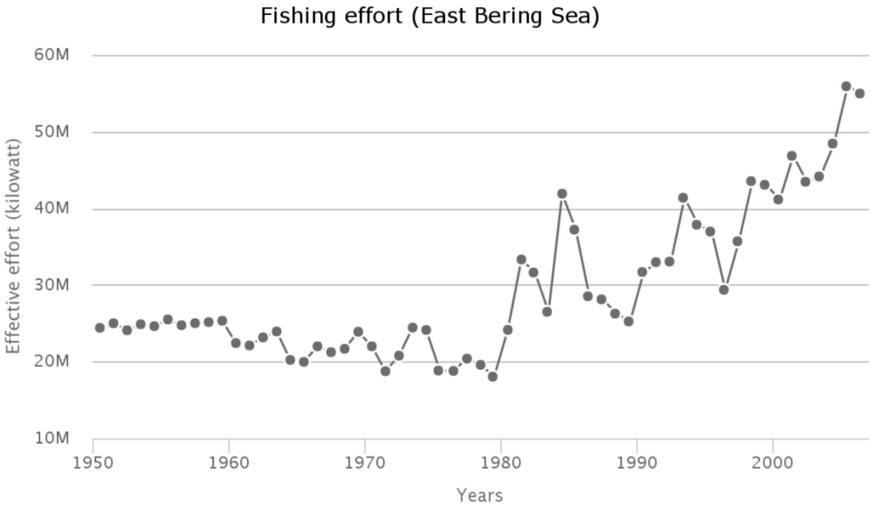
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 19% in 1965 and then this percentage ranges between 6 to 13% in the recent few decades.



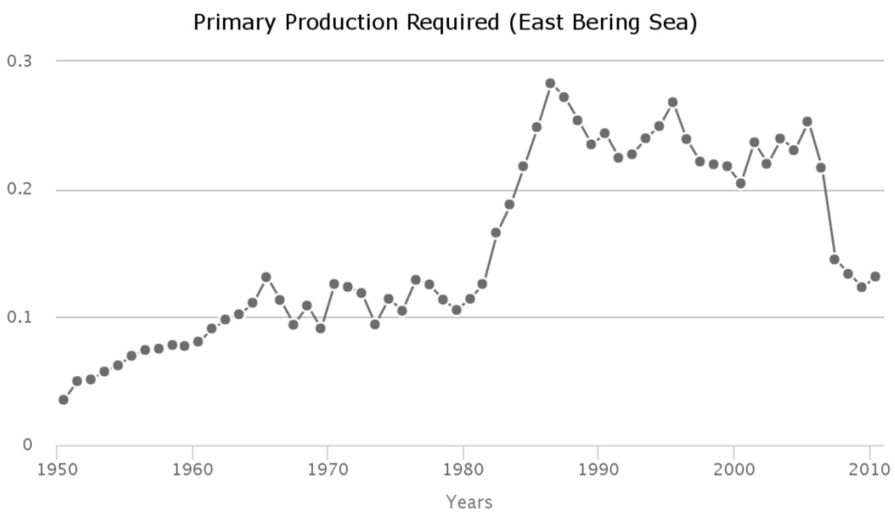
Fishing effort

The total effective effort fluctuated around 20 million kW from 1950 to 1980 and started to increase since the 1980s. It keeps increasing continuously in the last few decades and reaches its maximum in 2005 at 56 million kW.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in this LME reached 25% of the observed primary production in the mid of the 1980s, and has dropped to less than 15% in recent years.



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.

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	2	1	1	2	1	1	2	1

Legend:

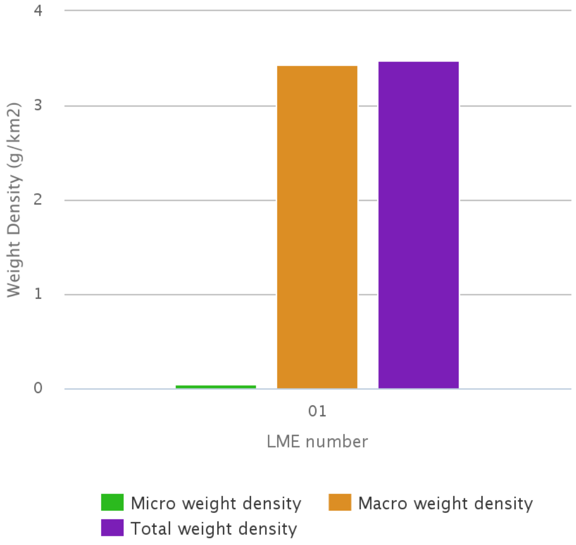
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

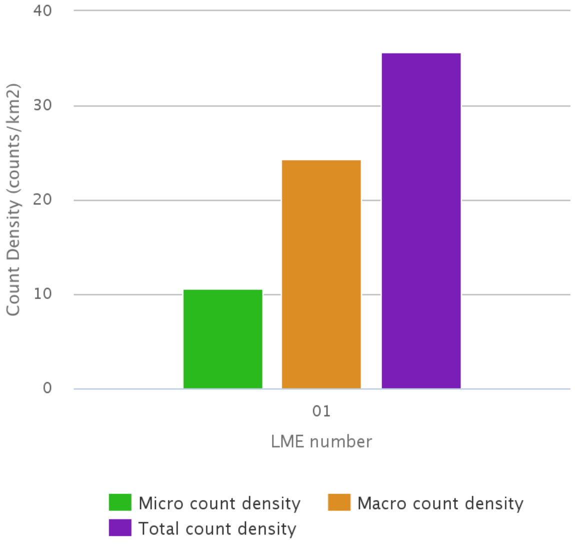
POPs

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 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

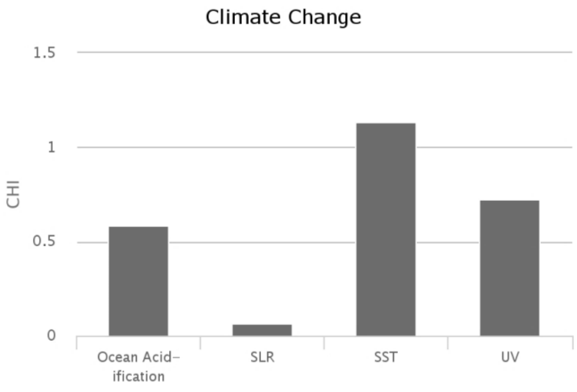
Not applicable

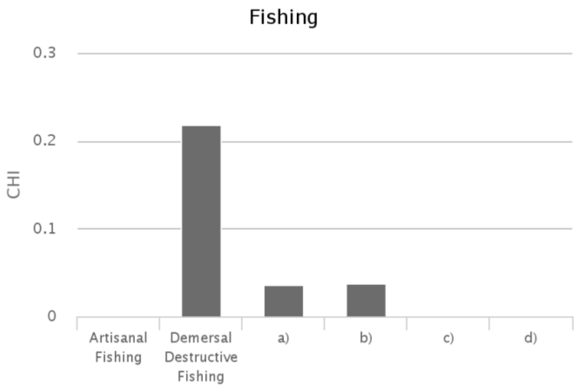
Marine Protected Area change

The East Bering Sea LME experienced an increase in MPA coverage from 13,228 km2 prior to 1983 to 122,905 km2 by 2014. This represents an increase of 829%, within the low category of MPA change.

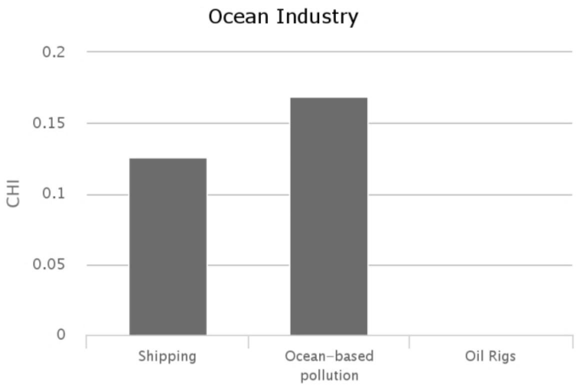
Cumulative Human Impact

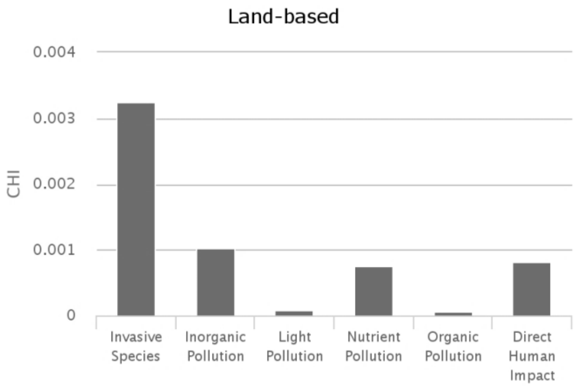
The East Bering Sea LME experiences an average overall cumulative human impact (score 3.1; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is particularly vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: sea surface temperature (1.13; maximum in other LMEs was 2.16), UV radiation (0.73; maximum in other LMEs was 0.76), and ocean acidification (0.58; maximum in other LMEs was 1.20). Other key stressors include commercial shipping, ocean based pollution, and demersal destructive commercial fishing.

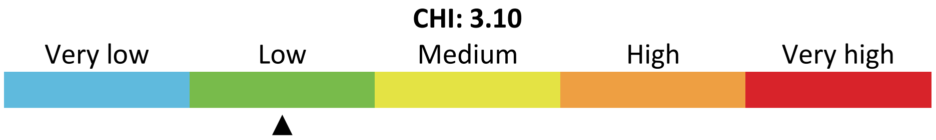




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

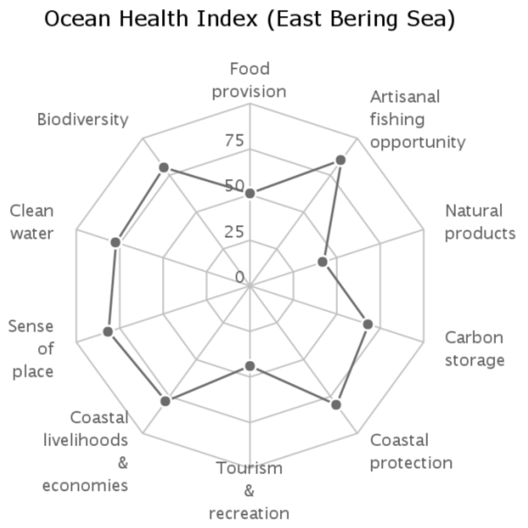






Ocean Health Index

The East Bering Sea LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82) but still relatively low. This score indicates that the LME is well below its optimal level of ocean health, although there are many aspects that are doing well. Its score in 2013 increased by 9 points compared to the previous year, due in large part to changes in the scores for clean waters and natural products goals. This LME scores lowest on mariculture, tourism & recreation and natural products goals, and highest on artisanal fishing opportunities, coastal protection, coastal economies, lasting special places, and species diversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



OHI: 68.84

Very low	Low	Medium	High	Very high
🟫	🟨	🟩	🟩	🟦
			▲	

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 the East Bering Sea 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 coast includes the southwest fringe of the Alaskan Peninsula and is among the most sparsely populated (lowest risk) and completely rural of LMEs. It covers 140,753 km^2, with a density of 1 person every 4 km^2 in 2010 and decreasing to 1 person every 5 km^2 in 2100.

Total population		**Rural population**	
2010	**2100**	**2010**	**2100**
33,447	26,429	33,447	26,429

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

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 of poor but among those with the lowest absolute number of poor at 5700 (present day estimate).

Coastal poor
5,732

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The East Bering Sea LME ranks in the high revenue category in fishing revenues based on yearly average total ex-vessel price of US

2013 $1.15 billion (thousand million) for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $4.2 billion 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 the East Bering Sea LME falls in the category with lowest risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
1,151,820,959	7.4	4,240,125,385	8.4	🟦 0.6022

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 East Bering Sea LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.909, this LME has an HDI Gap of 0.091, 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). The East Bering Sea LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the high risk category (low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
🟦 0.9094	🟦 0.9662	🟧 0.6971

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 to the East Bering Sea 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. Regardless of development pathway, this LME is projected to belong to the lowest risk category that is least threatened by sea level rise in 2100.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.4210	0.2348	0.2127	0.4336

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

The four fisheries arrangements in this LME - NPAFC, CCBSP, IPHC and WCPFC - are unique in addressing specific types of fisheries. The only area for commonality appears to be in the form of scientific advice being provided with input from PICES in arrangements relating to halibut, pollock and anadromous species. Additionally, the member countries are primarily responsible for implementation across all of the arrangements. The Arctic Council provides for some level of integration across pollution (LBS and MBS) and for biodiversity (general) in the part of the LME that is covered by the Arctic Council. However, overall, 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:

Engagement	Completeness	Integration
83	**70**	**0.1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 02 – Gulf of Alaska

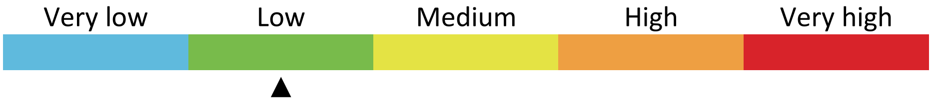
Bordering countries: United States of America, Canada
LME Total area: 1,491,252 km^2

List of indicators

LME overall risk

This LME falls in the cluster of LMEs that exhibit medium numbers of collapsed and overexploited fish stocks, as well as very high proportions of catch from bottom impacting gear.

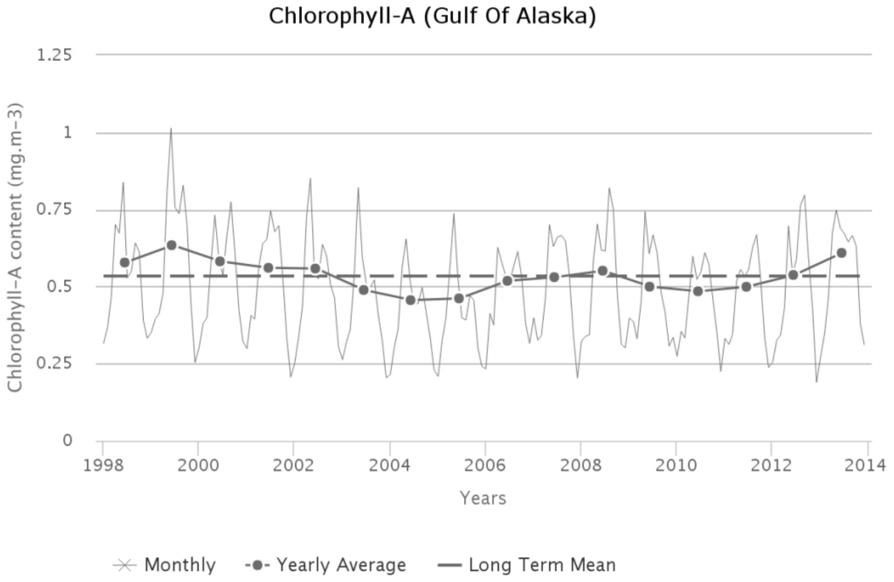
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

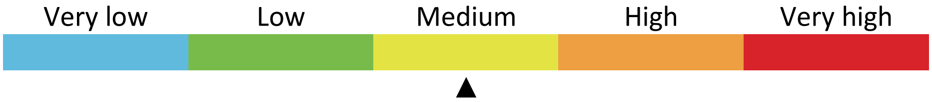


Productivity

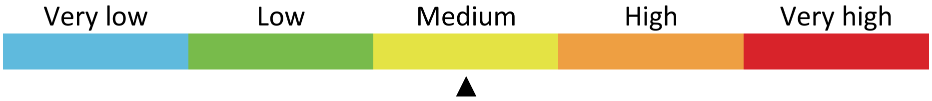
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.695 mg.m^{-3}) in May and a minimum (0.280 mg.m^{-3}) during December. The average CHL is 0.534 mg.m^{-3}. Maximum primary productivity (267 g.C.m^{-2}.y^{-1}) occurred during 1999 and minimum primary productivity (198 g.C.m^{-2}.y^{-1}) during 2011. There is a statistically insignificant increasing trend in Chlorophyll of 19.5 % from 2003 through 2013. The average primary productivity is 221 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).



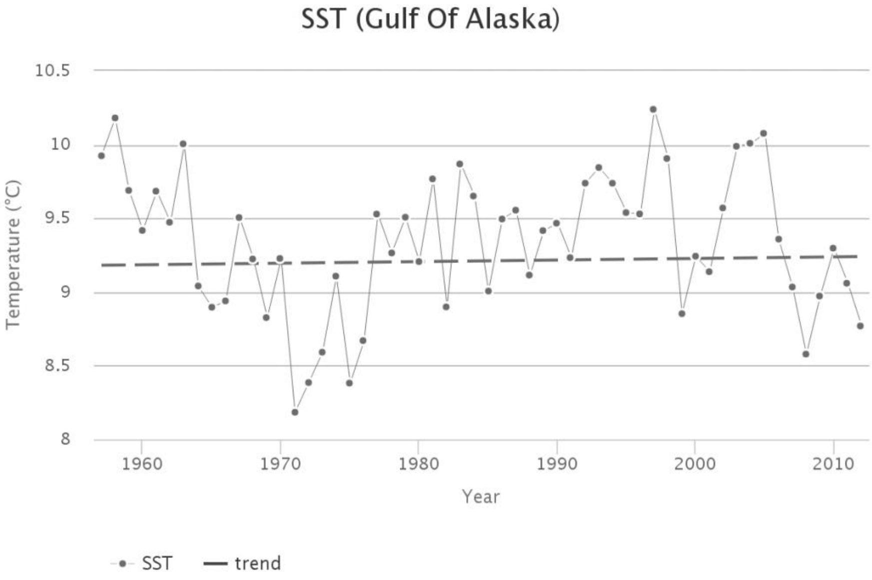


Primary productivity



Sea Surface Temperature

Between 1957 and 2012, the Gulf of Alaska (GOA) LME #2 has warmed by 0.06°C. It thus belongs to Category 4 (slow-warming LME). During 1957-2012 four epochs can be distinguished: (1) rapid cooling by nearly 2°C after the sharp peak of 1958; (2) cold spell, 1971-1976; (3) warming epoch, 1977-1997; (4) cooling epoch, 1998-2012. The transition from the cold spell to the warming epoch has occurred in one year, during the North Pacific regime shift of 1976-1977 (Hare and Mantua, 2000). In general, the SST history of the GOA is very similar to that of the East Bering Sea LME #01. In particular, the SST swings in 1996-2012 were synchronous: from the peaks in 1997-1998 (linked to El-Niño), followed by a 1°C drop by 1999, to another maximum in 2003-2005, followed by another drop in 2008.

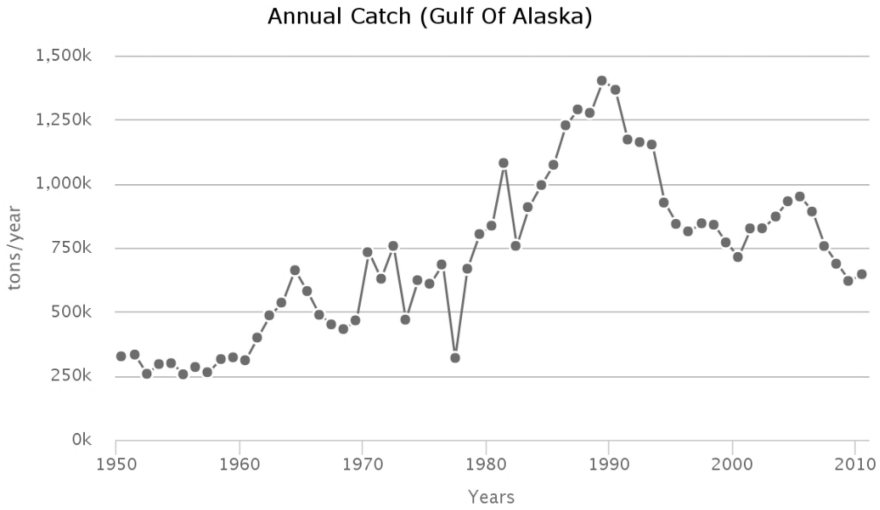


Fish and Fisheries

This LME supports a number of commercially important fisheries including crab, shrimp, pollock, Pacific cod, mackerel, sockeye salmon, pink salmon and halibut. Also caught are king crab, tanner crab, and shrimp.

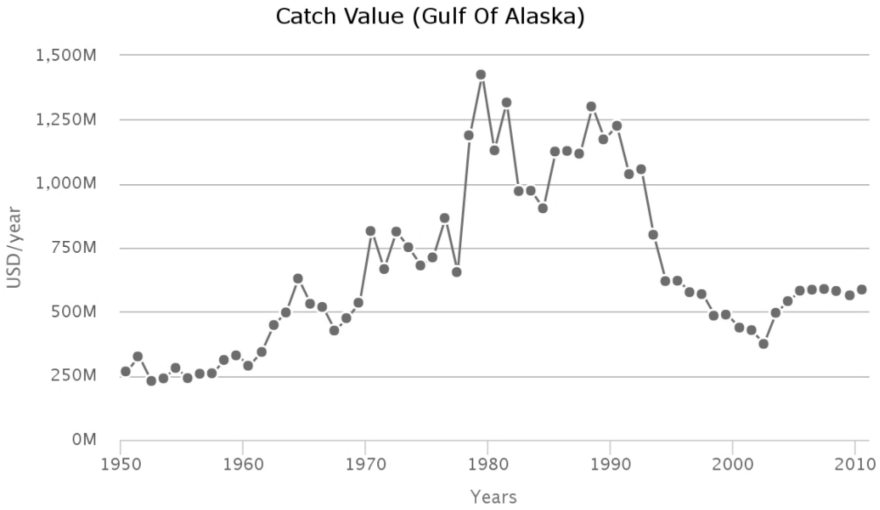
Annual Catch

Total reported landings in this LME showed increases in the early 1960s and in the mid-1980s, both linked to the increase in the Alaska pollock landings, and recorded a peak landing of 1.4 million t in 1989.



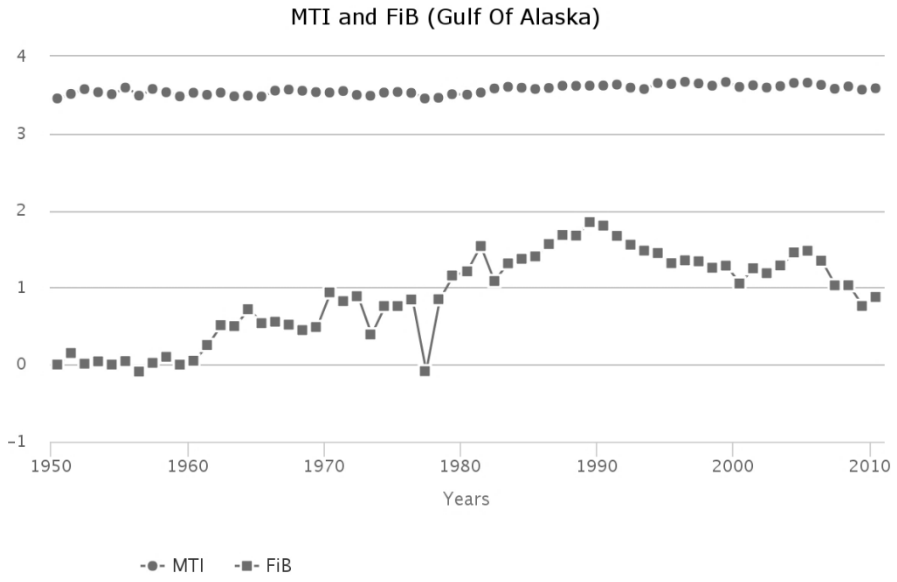
Catch value

The value of the reported landings recorded a peak of 1.4 billion US$ (in 2005 real US$) in 1979, and reached its second peak of 1.3 billion US$ (in 2005 real US$) in 1988 but has since declined to 580 million US$ (in 2005 real US$) in recent years.



Marine Trophic Index and Fishing-in-Balance index

The MTI has remained fairly stable over the reported period, due to the relative abundance of Alaska pollock in the landings. The increase in the FiB index in the early 1980s reflects the increased landings reported during that period.



Stock status

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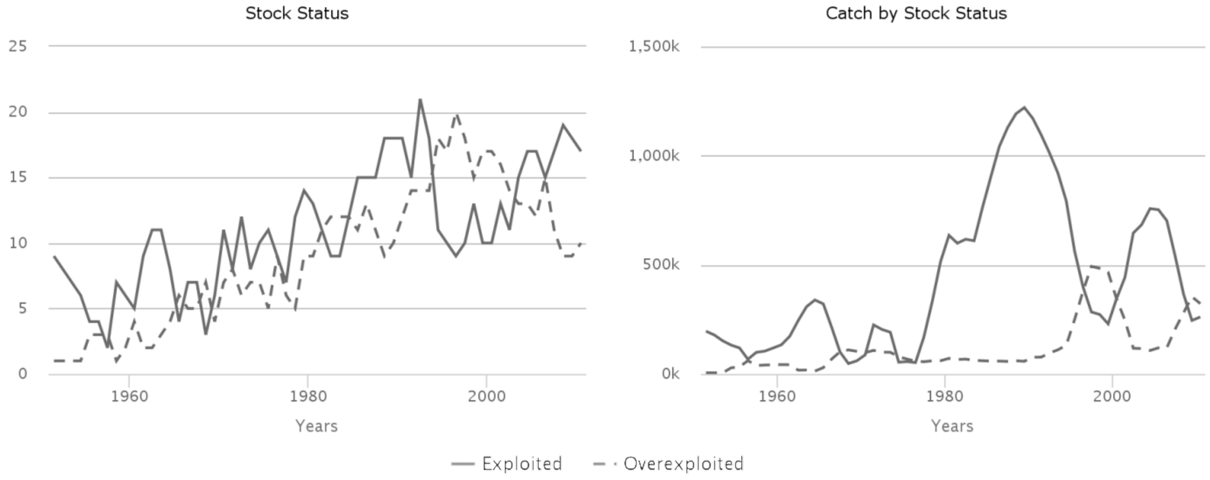
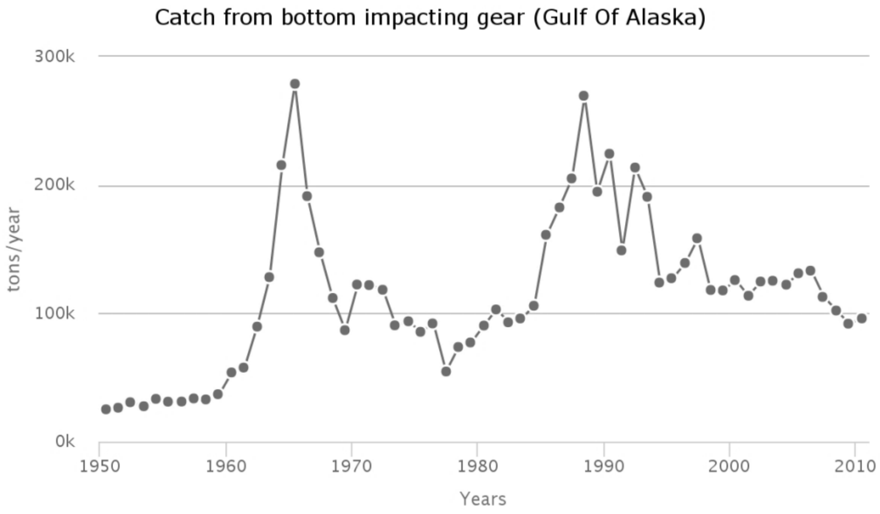


Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 48% in 1965 and then this percentage ranges between 12 to 18% in the recent few decades.

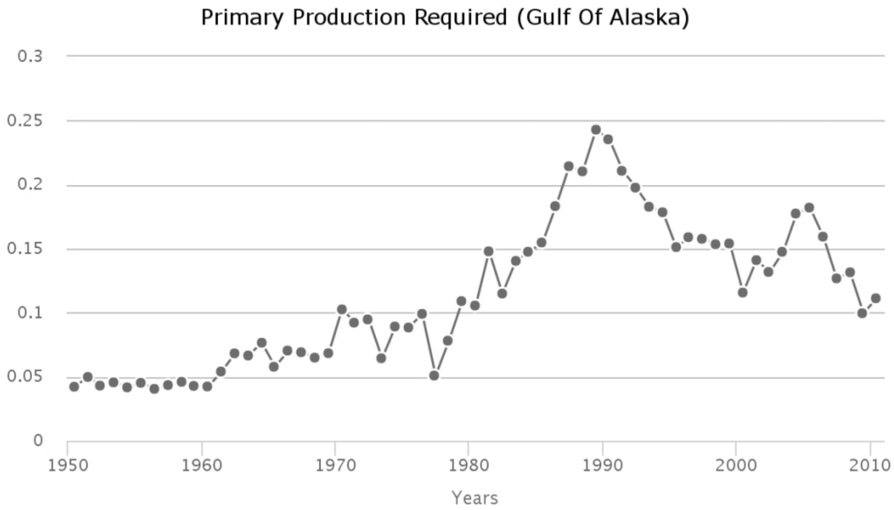


Fishing effort

The total effective effort increased from around 90 million kW in the 1970s to its peak at 300 million kW in 1993. It then fluctuated between 200 and 300 million kW in the recent decade.

Primary Production Required

The primary production required (PPR) to sustain the reported landings in this LME reached 30% of the observed primary production in the late 1980s and has leveled at around 25% in recent years.



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 low (level 2 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 very low (1). 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 low (2). 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
2	1	2	2	1	2	2	1	2

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

Data are available for only one sample at a rural location in Washington State (USA). The location shows a concentration (ng.g^{-1} of pellets) of 30 ng.g^{-1} for PCBs, 5 ng.g^{-1} for DDTs, and 0.3 ng.g^{-1} for HCHs. These correspond to risk category 2 for PCBs, 2 for DDTs, and 1 for HCHs, of the five risk categories (1 = lowest risk; 5 = highest risk). This is probably due to minimal anthropogenic activities involving the use of POPs (PCBs in industries and DDT and HCH pesticides in agriculture). More samples and locations are necessary to properly evaluate this LME.

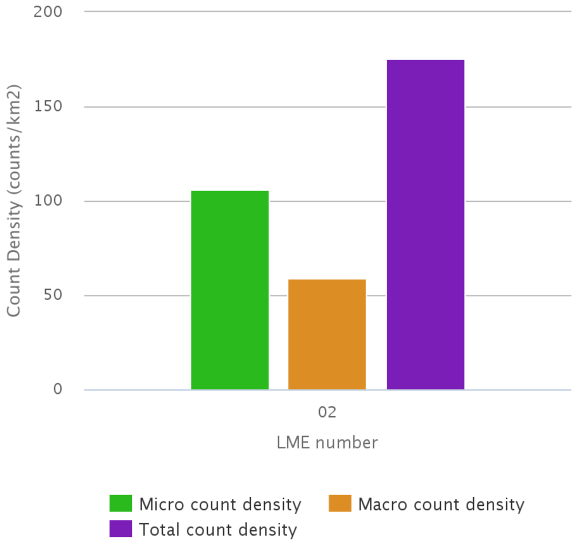
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
1	30	**2**	5	**2**	0.3	**1**

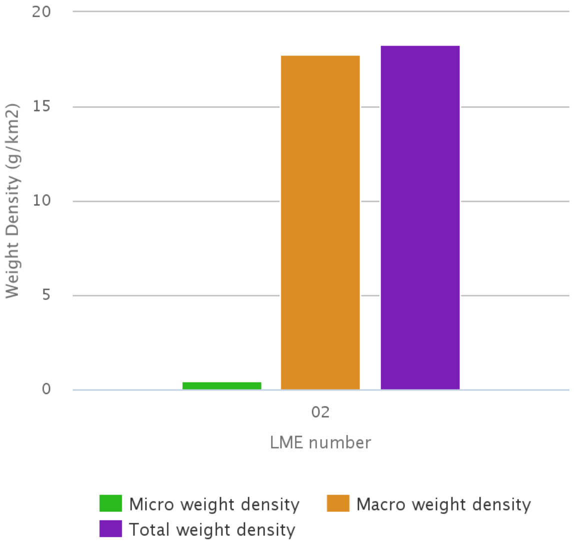
Legend:

🟦 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 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

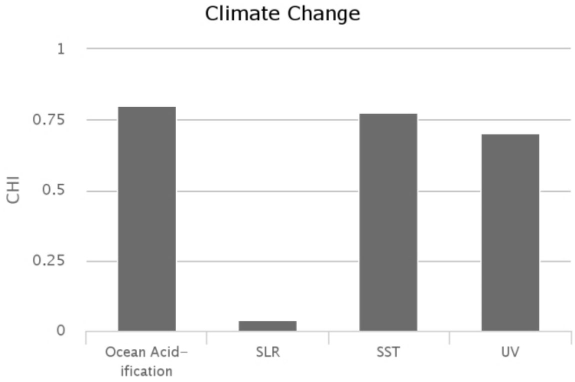
Not applicable

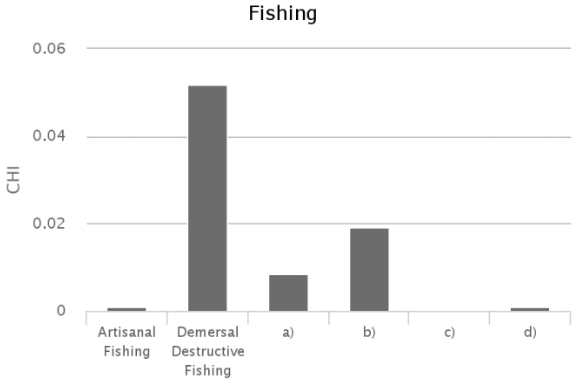
Marine Protected Area change

The Gulf of Alaska LME experienced an increase in MPA coverage from 8,082 km^2 prior to 1983 to 85,277 km by 2014. This represents an increase of 955%, within the low category of MPA change.

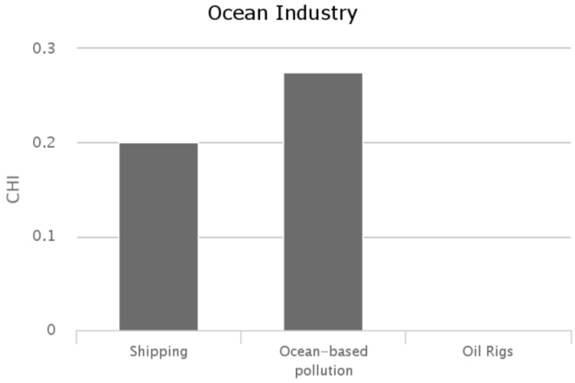
Cumulative Human Impact

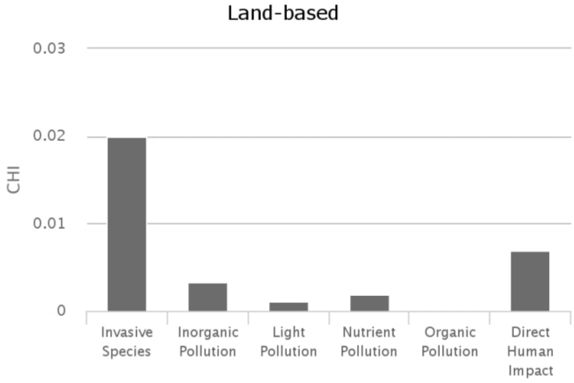
The Gulf of Alaska LME experiences an average overall cumulative human impact (score 2.91; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.80; maximum in other LMEs was 1.20), UV radiation (0.7; maximum in other LMEs was 0.76), and sea surface temperature (0.78; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, ocean based pollution, and demersal destructive commercial fishing.

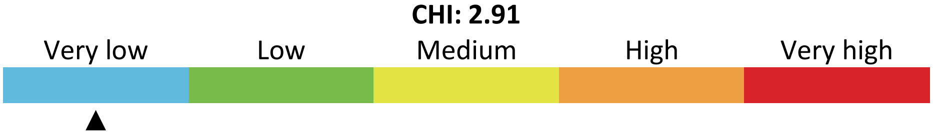

Climate Change


Fishing

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

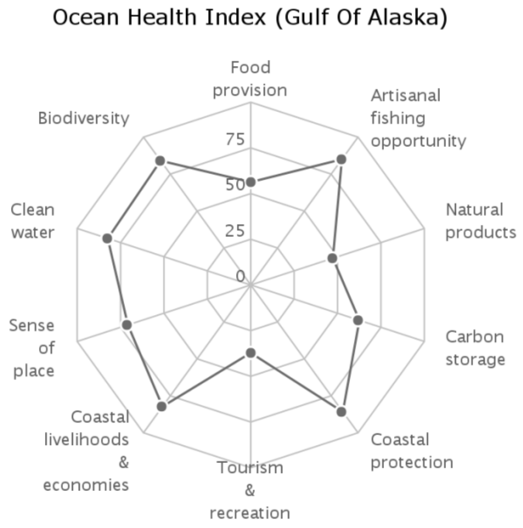

Ocean Industry


Land-based



Ocean Health Index

The Gulf of Alaska LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82) but still relatively low. 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 7 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on food provision, natural products, and tourism & recreation goals and highest on artisanal fishing opportunities, coastal protection, coastal economies, and species diversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



OHI: 69.36

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 the Gulf of Alaska 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

This LME's coastal area includes the southern shoreline of the Alaskan Peninsula and Canada's west coast. It is moderately large in population size and is among the most urbanized LMEs with 7% and 11% living in rural areas in 2010 and 2100, respectively. It covers 634,046 km^2, with a density of 13 people per km^2 in 2010 and increasing to 15 per km^2 in 2100.

Total population		Rural population	
2010	**2100**	**2010**	**2100**
8,473,872	9,205,202	592,079	1,048,598

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 15% of the LME's coastal dwellers. This LME places in the moderate risk category based on percentage and absolute number of poor at nearly 1.3 million (present day estimate).

Coastal poor
1,273,903

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Gulf of Alaska LME ranks in the moderately high revenue category in fishing revenues based on yearly average total ex-vessel price of almost US 2013 $634 million for the period 2001-2010. Fish protein accounts for 8% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of close to US 2013 $15 billion (thousand million) places it in the moderately high revenue category as well. 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 the Gulf of Alaska LME falls in the category with lowest risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
633,863,884	8.3	14,778,546,015	6.1	🟦 0.5929

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 Gulf of Alaska LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.905, this LME has an HDI Gap of 0.095, 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). The Gulf of Alaska LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the moderate risk category (moderately high HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
🟦 0.9055	🟦 0.9694	🟨 0.7256

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 to the Gulf of Alaska 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 low. Under a sustainable development scenario, this LME is projected to belong to the lowest risk category that is least threatened by sea level rise in 2100. In a fragmented world development pathway, this LME goes up to the low risk category because of a wider HDI Gap generated by a bigger population and reduced income, with the same hazard level.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟩 0.5116	🟩 0.2655	🟦 0.2554	🟩 0.5177

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 03 – California Current

Bordering countries: United States of America, Mexico
LME Total area: 2,224,665 km^2

List of indicators

LME overall risk

This LME falls in the cluster of LMEs that exhibit medium numbers of collapsed and overexploited fish stocks, as well as very high proportions of catch from bottom impacting gear.

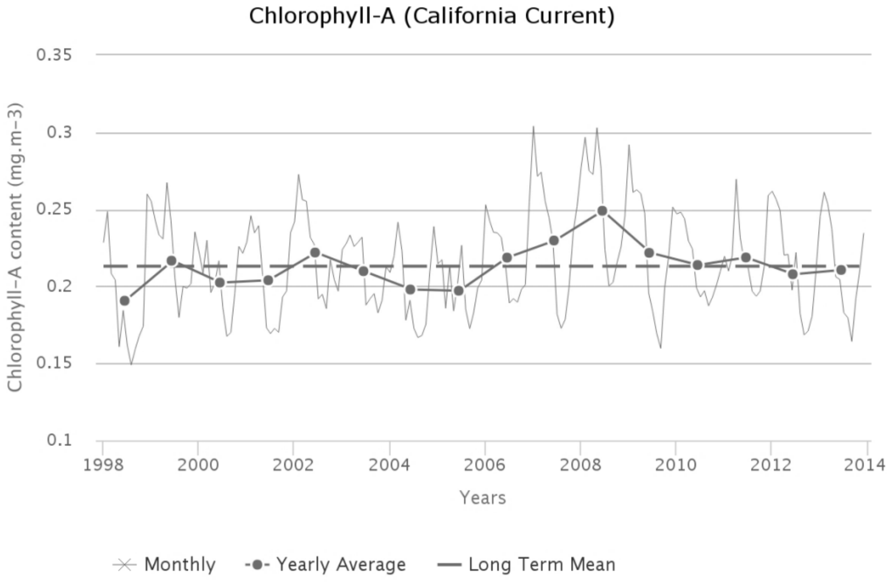
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥
▲				

Productivity

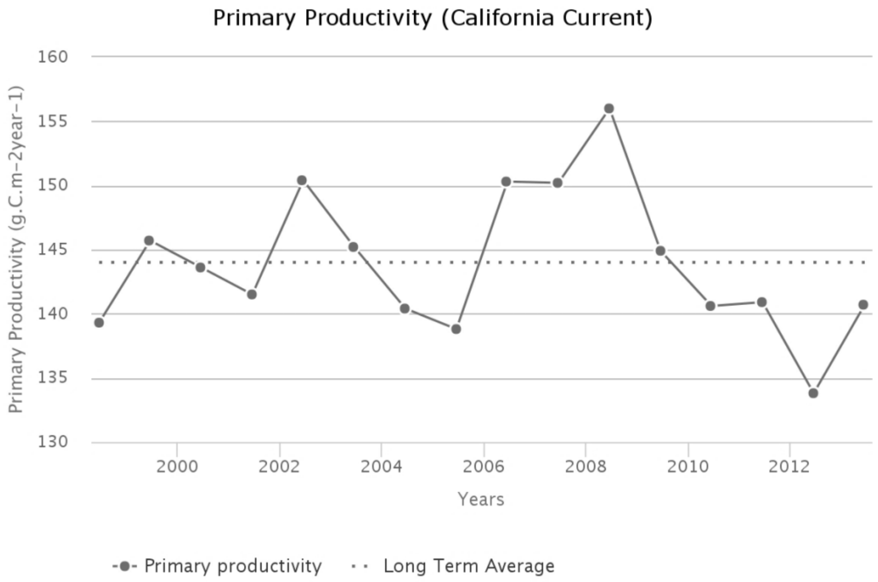
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.245 mg.m^{-3}) in February and a minimum (0.176 mg.m^{-3}) during September. The average CHL is 0.213 mg.m^{-3}. Maximum primary productivity (156 g.C.m^{-2}.y^{-1}) occurred during 2008 and minimum primary productivity (134 g.C.m^{-2}.y^{-1}) during 2012. There is a statistically insignificant increasing trend in Chlorophyll of 2.92 % from 2003 through 2013. The average primary productivity is 144 g.C.m^{-2}.y^{-1}, which places this LME in Group 2 of 5 categories (with 1 = lowest and 5= highest).



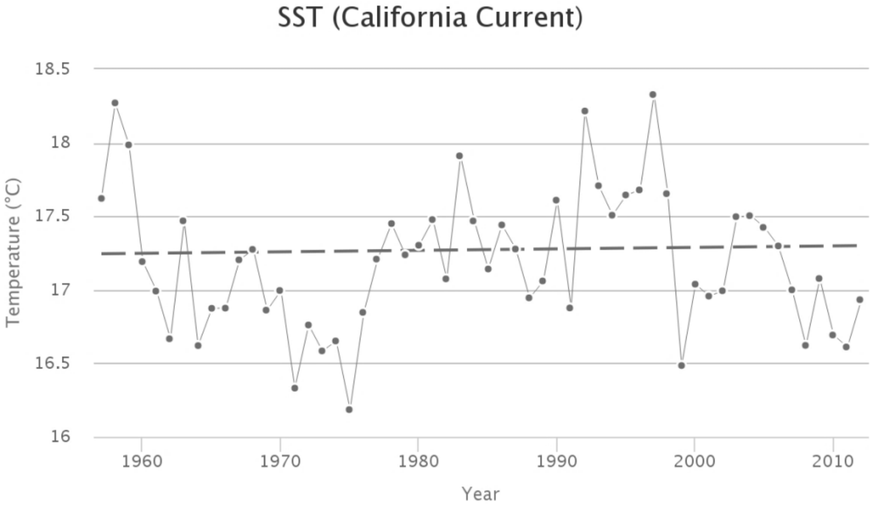
Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥
	▲			

Primary productivity



Sea Surface Temperature

Between 1957 and 2012, the California Current LME #3 has warmed by 0.02°C. It thus belongs to Category 4 (slow-warming LME). Very much like the East Bering Sea LME #01 and the Gulf of Alaska LME #02, the California Current cooled dramatically from 1958 to 1975, by ~2°C. After bottoming at 16.2°C in 1975, SST abruptly warmed by 1977 following the North Pacific regime shift in 1976-1977 (Hare and Mantua, 2000). The absolute minimum of 1975 was synchronous with the absolute minima in two other East Pacific LMEs: Gulf of California LME #04 and Central American Pacific LME #11. The absolute maximum of 18.3°C in 1997 is attributed to El Niño, whereas the dramatic 1.7°C cooling of 1998-1999 was likely associated with La Niña. The California Current is one of several LMEs that cooled since 1997. The thermal history of the California Current LME resembles that of the Humboldt Current LME#13, apparently due to both LMEs being located in similar oceanographic regimes of East Pacific coastal upwelling systems.

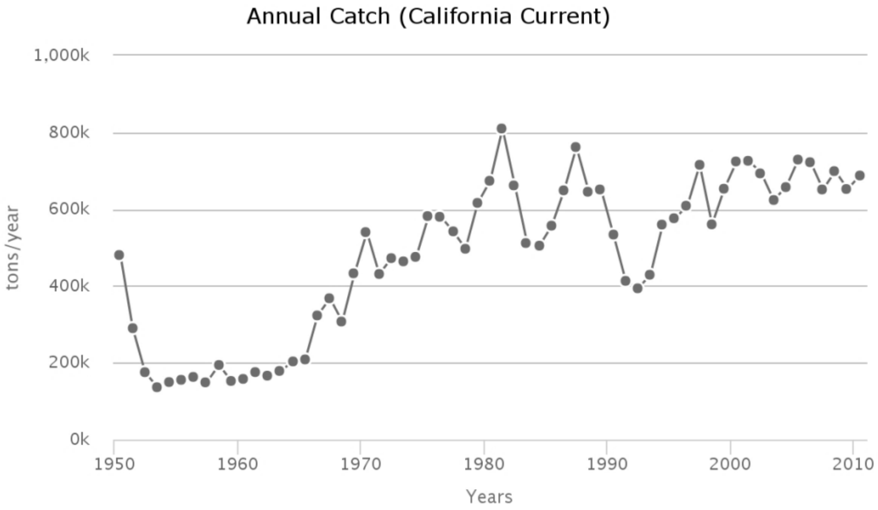


Fish and Fisheries

The major commercial fish species are Pacific salmon, pelagic fishes (Pacific sardine, northern anchovy, jack mackerel, chub Pacific mackerel, Pacific herring, Pacific halibut and other groundfish. Shrimp, crab, clam and abalone have high commercial value.

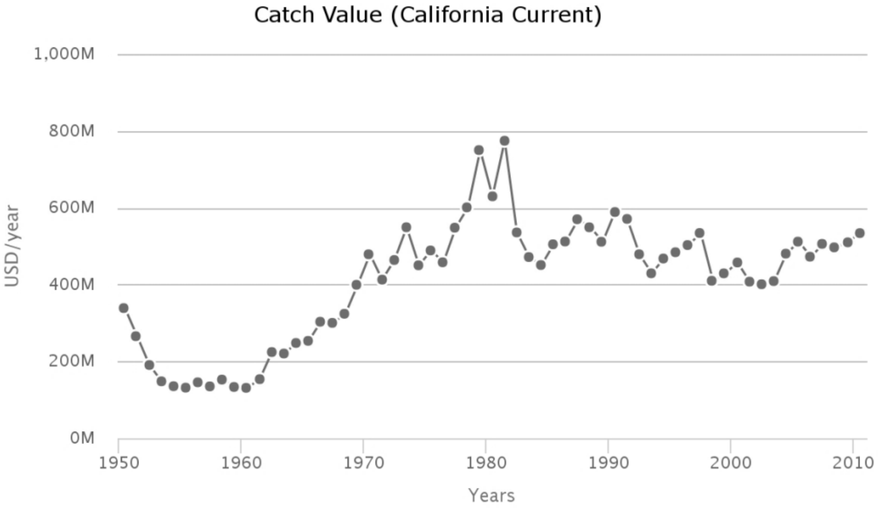
Annual Catch

Natural environmental change and intensive fishing are causing long-term shifts in abundance of both sardine and anchovy in this LME. Total reported landings show several peaks and troughs over the reported period, with a record landing of 810,000 t in 1981 with notable, substantial decline in 1984 and 1992.



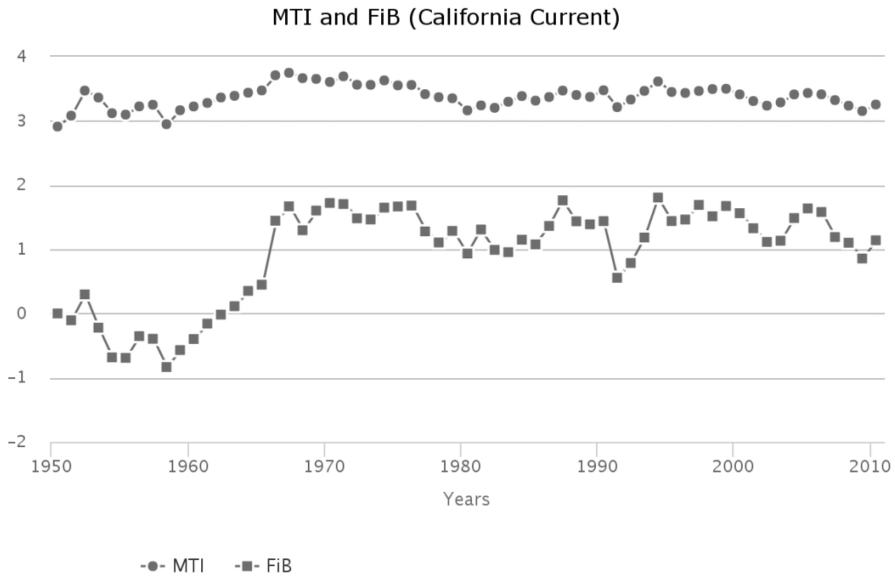
Catch value

The value of the reported landings peaked in 1981 at 770 million US$ (in 2005 real US$).



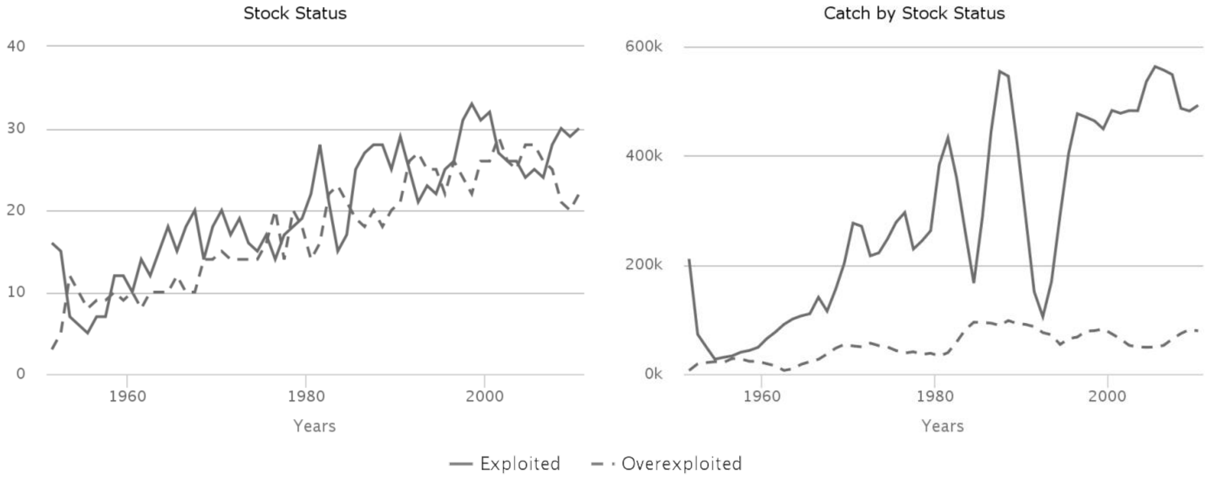
Marine Trophic Index and Fishing-in-Balance index

Both the MTI and the FiB index showed considerable fluctuations over the reported period with no clear trend, except for the initial increase in the FiB index corresponding to the growth in the fisheries in the LME during the 1960s.



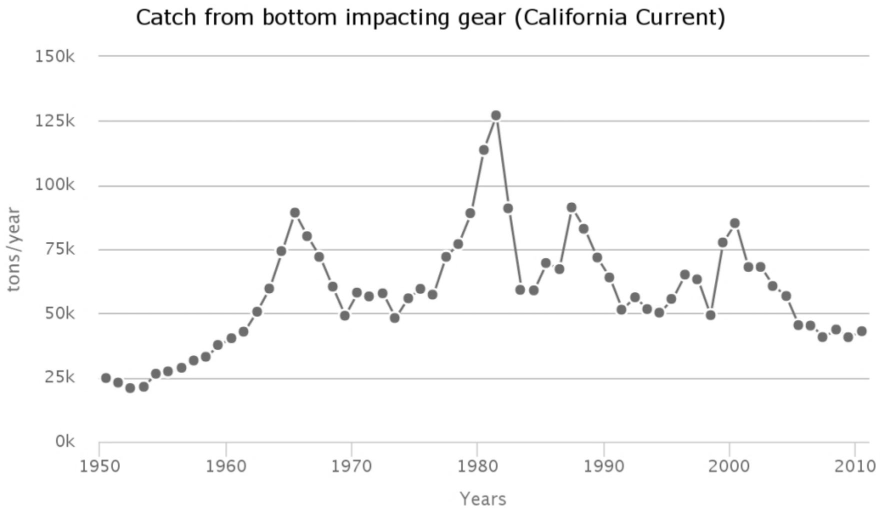
Stock status

The Stock-Catch Status Plots indicate that about 45% of the stocks in the LME have collapsed, or are currently over-exploited, but with more than half of the reported landings biomass still supplied by fully exploited stocks.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 43% in 1965 and then this percentage ranges between 6 to 14% in the recent few decades.

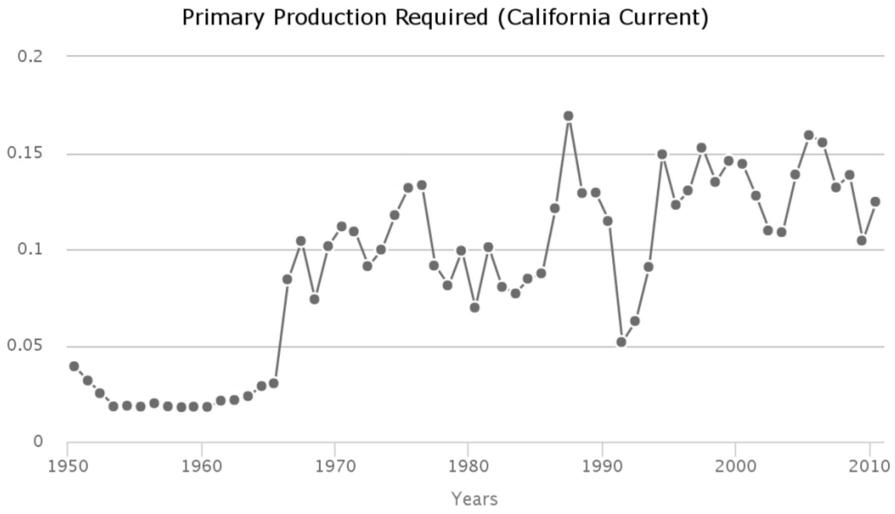


Fishing effort

The total effective effort increased steadily from around 60 million kW in the 1960s to its peak at 200 million kW in the mid-2000s.

Primary Production Required

The primary production required (PPR) to sustain reported landings in this LME reached 16% of the observed primary production in the late 1980s, and fluctuated between 7 to 15% in recent years.



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 low (level 2 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 decreased to low in 2050.

Merged nutrient indicator

The risk level for the Merged Nutrient Indicator for contemporary (2000) conditions was low (2). 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
2	3	2	2	3	2	2	2	2

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

The California Current LME has 18 samples at 15 locations. The average concentration (ng.g^{-1} of pellets) was 156 (range 11-602 ng.g^{-1}) for PCBs, 67 (range 3-312 ng.g^{-1}) for DDTs, and 1.0 (range 0.1 - 5.7 ng.g^{-1}) for HCHs. The PCBs and DDT averages correspond to risk category 3 and HCH to category 1, of the 5 risk categories (1 = lowest risk; 5 = highest risk). The highest concentrations of PCBs (risk categories 4 and 5) were observed for samples collected around Los Angeles (409 ng.g^{-1}) and San Francisco (602 ng.g^{-1}), and ascribed to legacy pollution. The decreasing trend (by about 50 % in 5 years) in the legacy PCB pollution was suggested through time-series collection and analysis of pellets. High concentrations of DDTs were also ascribed to legacy pollution from agricultural application of DDT pesticide. In addition, legacy pollution caused by past discharge of wastewater from an industrial plant (the world's largest producer of DDT pesticide) was suggested at one location (Hermosa Beach, California). The level of legacy DDTs pollution appeared to decrease over time. Although PCBs and DDT concentrations show a decreasing trend, both are still moderate. Continuous monitoring is recommended.

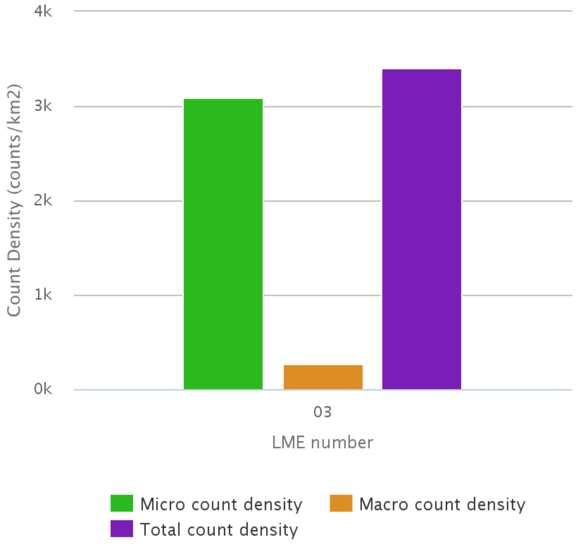
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
18	156	**3**	67	**3**	1.0	**1**

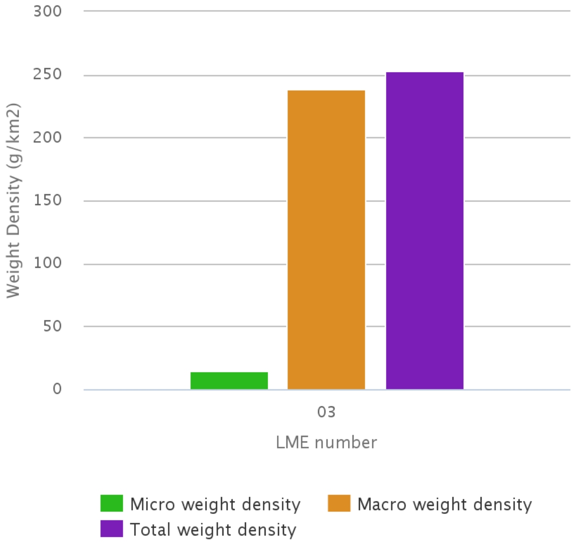
Legend:

🟦 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 relatively moderate levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 12 times lower that those LMEs with lowest values. There is good evidence from sea-based direct observations and towed nets to support this conclusion.





Ecosystem Health

Mangrove and coral cover

Not applicable.

Reefs at risk

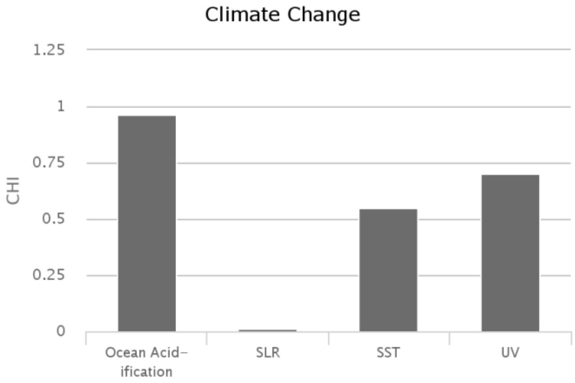
Not applicable.

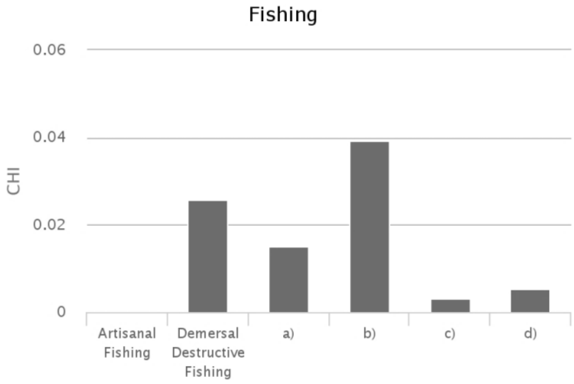
Marine Protected Area change

The California Current LME experienced an increase in MPA coverage from 3,178 km^2 prior to 1983 to 44,090 km^2 by 2014. This represents an increase of 1,287%, within the low category of MPA change.

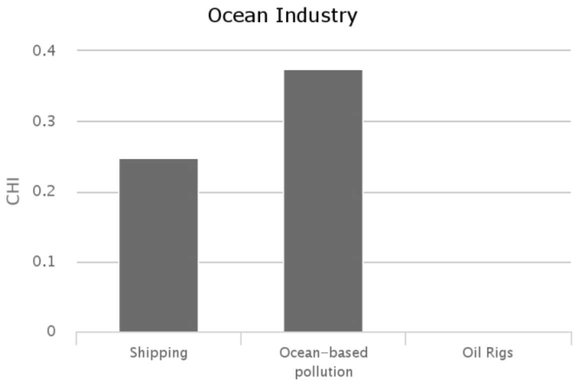
Cumulative Human Impact

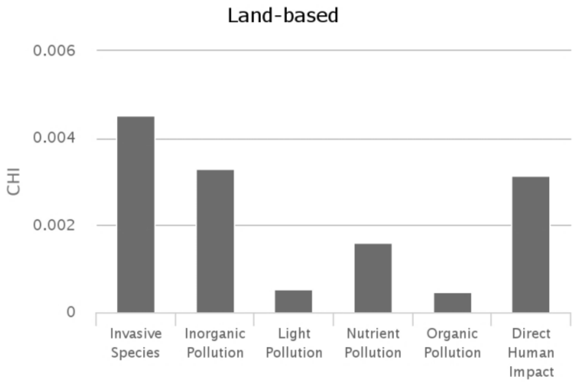
The California Current LME experiences an average overall cumulative human impact (score 2.95; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.97; maximum in other LMEs was 1.20), UV radiation (0.7; maximum in other LMEs was 0.76), and sea surface temperature (0.55; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, ocean based pollution, and demersal non-destructive low-bycatch commercial fishing.

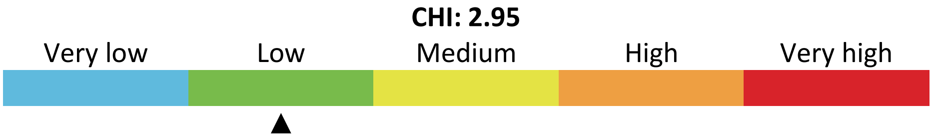




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

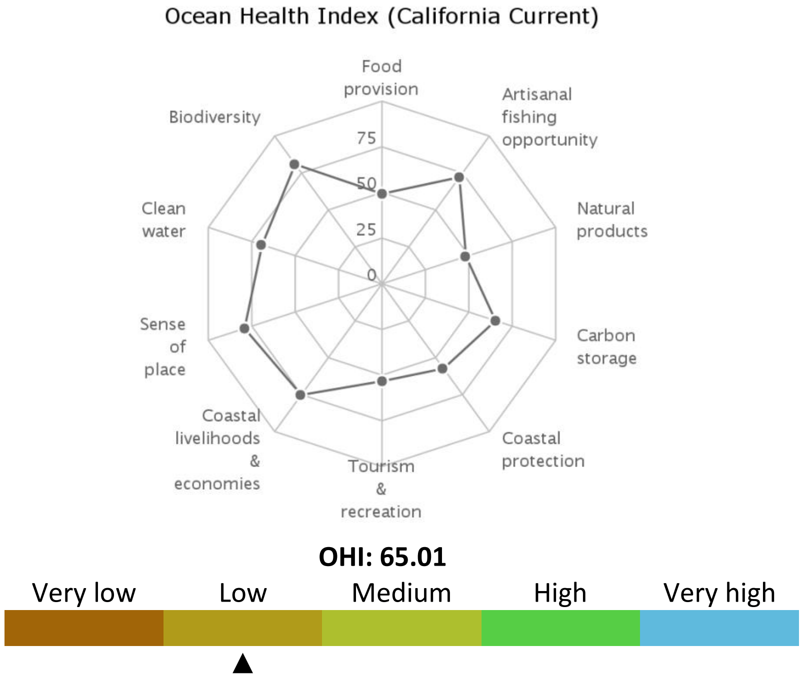






Ocean Health Index

The California Current LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82) but still relatively low. 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 5 points compared to the previous year, due in large part to changes in the scores for coastal economies and clean waters. This LME scores lowest on mariculture, coastal protection, coastal livelihoods, and iconic species goals and highest on artisanal fishing opportunities, coastal economies, lasting special places, and species diversity 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).



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 the California Current 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 includes the western coasts of the United States of America and Baja California, Mexico. Its population size is in the large (high risk) category with the rural portion increasing from 3% in 2010 to 4% in 2100. Covering 286,072 km^2, a population density of 138 people per km^2 in 2010 increases to 190 people per km^2 in 2100.

Total population		Rural population	
2010	2100	2010	2100
39,398,712	54,244,644	1,358,644	2,348,489

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 18% of the LME's coastal dwellers. This LME places in the high-risk category based on percentage of poor and in absolute number of poor at slightly over 7.3 million (present day estimate).

Coastal poor
7,348,786

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The California Current LME ranks in the moderately high revenue category in fishing revenues based on yearly average total ex-vessel price of nearly US 2013 $563 million for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $227 billion places it in the highest 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 the California Current LME falls in the category with lowest risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
562,754,489	7.4	227,106,000,000	8.5	0.5766

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 California Current LME HDI belongs to the highest HDI and lowest 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). The California Current LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the high risk category (low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
0.9027	0.9638	0.6918

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 to the California Current LME is within the moderate risk (moderate 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 pathway, this LME is projected to belong to the lowest risk category that is least threatened by sea level rise in 2100. In a fragmented world development scenario, the sea level rise threat index increases to moderate risk level.

2010		2100	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟨 0.5423	🟩 0.2923	🟦 0.2805	🟨 0.5592

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

In this LME, the two transboundary arrangements for fisheries relating to halibut and the anadromous species (IPHC and NPAFC) are assisted by PICES in the provision of policy and planning level advice. However, these arrangements are not linked in any formal way with IATTC and it is unclear to what extent PICES participates in the IATTC. In terms of pollution and biodiversity arrangements, there appears to be no formal arrangement in force although the US and Mexico has an action plan (MEXUS-PAC) to assist each other in the event of a significant spill in each other's waters that could affect the neighboring country. Since the Antigua Convention is not yet in force, there appears to be no formal arrangements for addressing land-based or marine-based sources of pollution (other than the MEXUS-PAC action plan) in the LME. Likewise, biodiversity arrangements are limited to the Inter-American Convention for the protection of turtles.

Further, no integrating mechanisms, such as an overall policy coordinating organisation for the LME, could be found. There may be interaction among the arrangements through participation in each other's meetings, but this appears to be informal.

The overall scores for ranking of risk were:

Engagement	Completeness	Integration
🟨 **50**	🟨 **50**	🟥 **0**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Channel Islands National Marine Sanctuary, California Current LME

Claire Fackler, NOAA National Marine Sanctuaries

LME 04 – Gulf of California

Bordering country: Mexico
LME Total area: 216,344 km^2

List of indicators

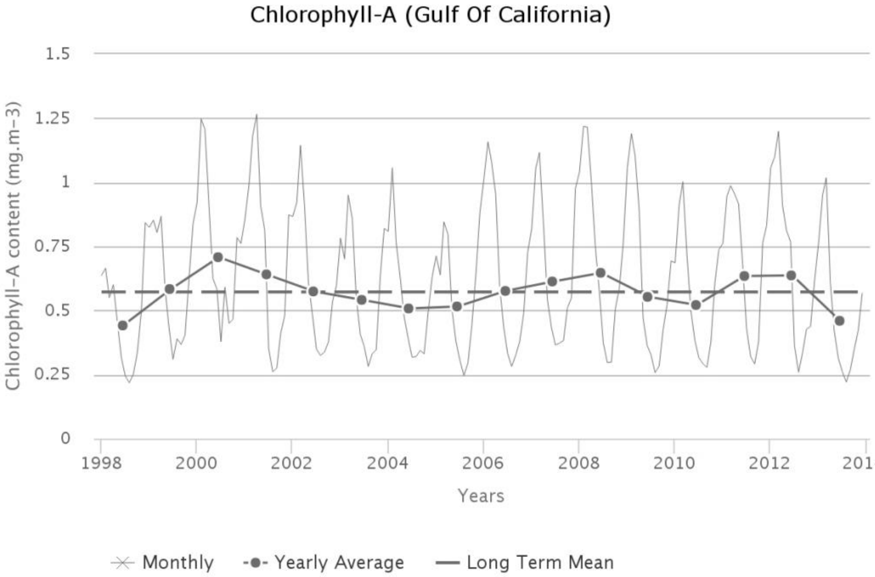
LME overall risk

This LME falls in the cluster of LMEs that exhibit high rates of increase in MPA coverage.
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.

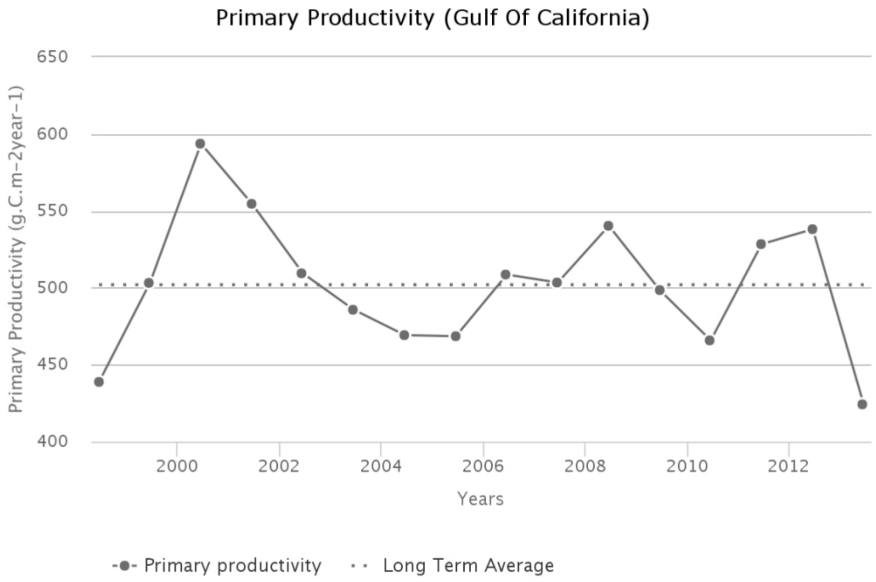
Productivity

Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.996 mg.m^{-3}) in March and a minimum (0.308 mg.m^{-3}) during August. The average CHL is 0.572 mg.m^{-3}. Maximum primary productivity (594 g.C.m^{-2}.y^{-1}) occurred during 2000 and minimum primary productivity (424 g.C.m^{-2}.y^{-1}) during 2013. There is a statistically insignificant increasing trend in Chlorophyll of 24.6 % from 2003 through 2013. The average primary productivity is 502 g.C.m^{-2}.y^{-1}, which places this LME in Group 5 of 5 categories (with 1 = lowest and 5= highest).

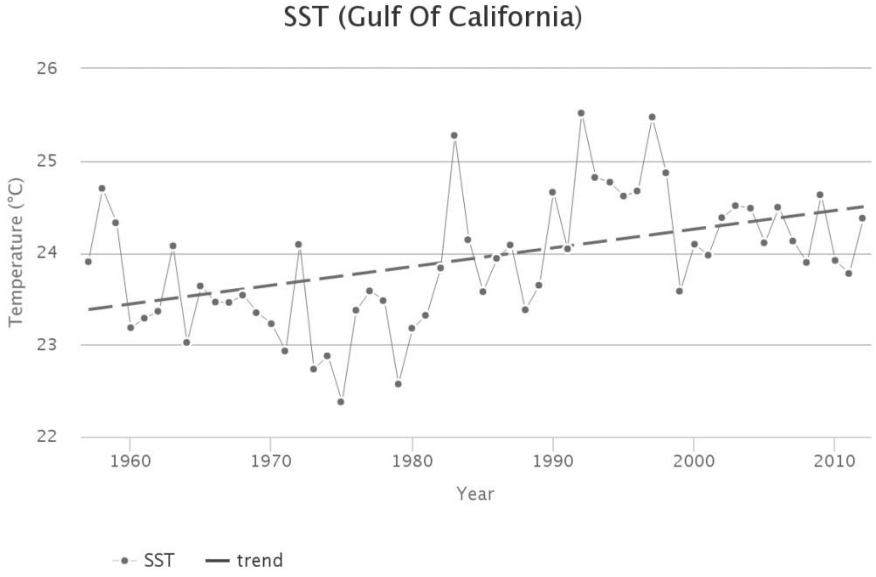


Primary productivity



Sea Surface Temperature

Between 1957 and 2012, the Gulf of California LME #4 has warmed by 1.13°C, thus belonging to Category 1 (super-fast warming LME). The semi-landlocked Gulf of California shares some similarities with the California Current. The global cooling of the 1960s-1970s manifested here as a 2°C drop from 1958 to 1975. After a 2°C rebound in 1979-1983, the Gulf of California remained warm until present. The sharp SST peak of 1983 was synchronous with similar peaks in the Central American Pacific LME #11, where SST reached the all-time maximum of 28.2°C, and in the Humboldt Current LME #13, where SST reached 17.3°C, second only to the 1997 all-time record high of 17.6°C. The California Current SST also peaked in 1983. The 1983 SST peak in four East Pacific LMEs (#3, 4, 11, and 13) is attributed to the El Niño 1982-1983. Since 1983, the Gulf of California's thermal history is strongly correlated with that of the California Current LME #03, including major events (peaks) of 1992 and 1997, likely associated with major El Niños.

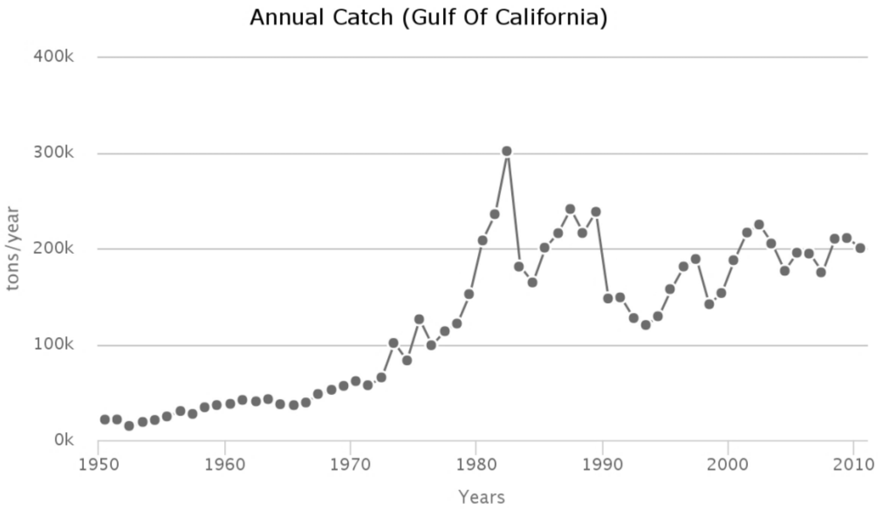


Fish and Fisheries

Historically, this LME has supported numerous fisheries of commercially valuable species. Fisheries resources in the Gulf are targeted by the commercial, artisanal, and recreational fishing sectors.

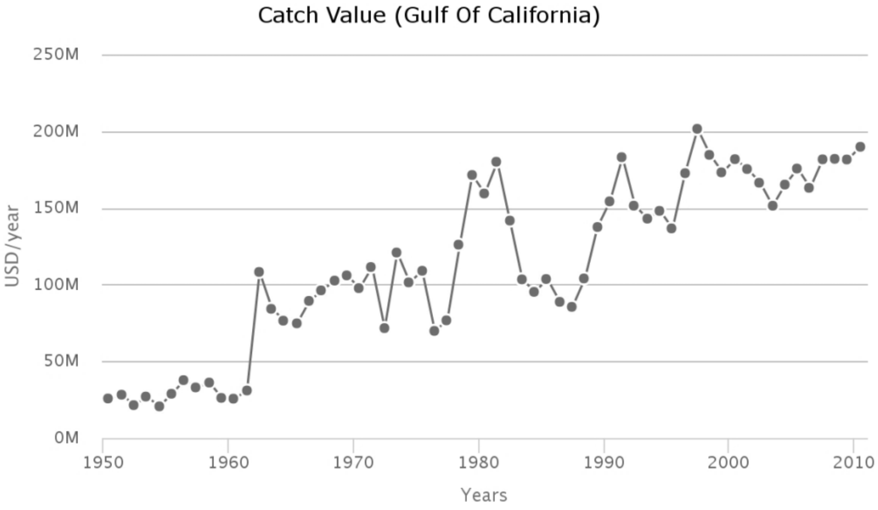
Annual Catch

In terms of weight caught, the major fisheries are dominated by small pelagic fish, namely Californian anchovy and Pacific sardine, as well as penaeid shrimps (blue, white and brown shrimp, *Litopenaeus stylirostris*, *Litopenaeus vannamei*, *Farfantepenaeus californiensis*, respectively, together with other less important species). The total annual catch of tuna-like resources increased rapidly from the late 1970s to peak in the mid-1980s. Total reported landings in this LME recorded a peak of 300,000 t in 1982 driven by record catches of anchovy.



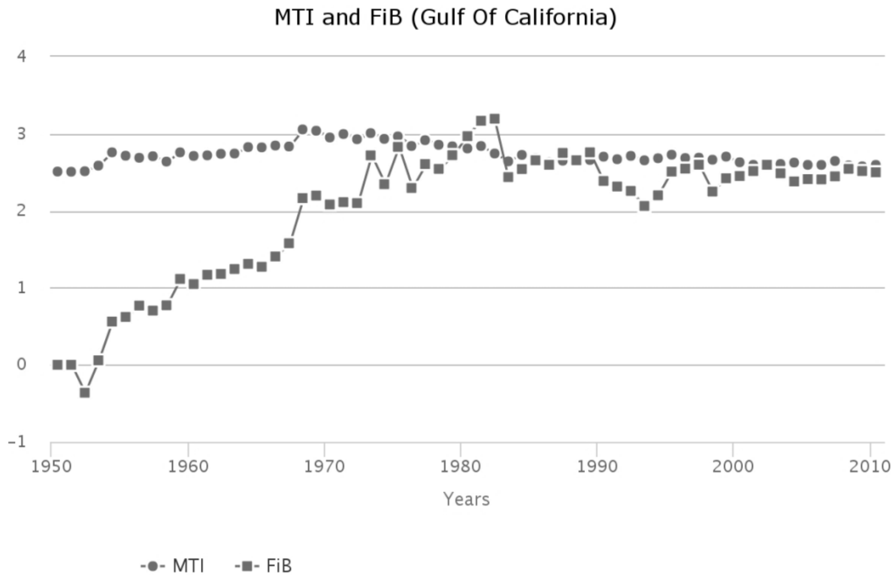
Catch value

Crustaceans, mainly in the form of penaeid shrimps account for a large portion of the value of the reported landings, which peaked at 200 million US$ (in 2005 real US$) in 1997.



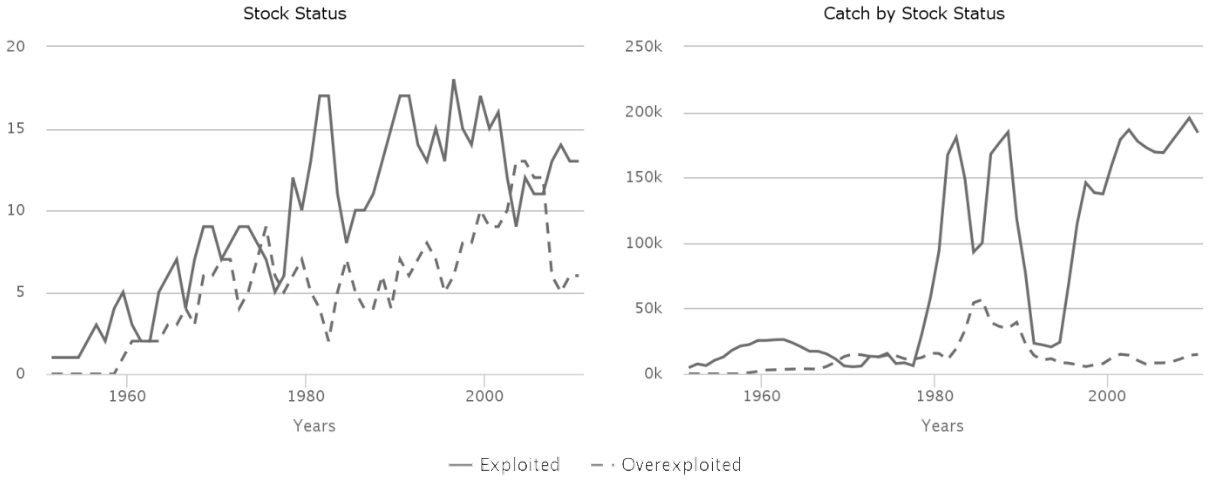
Marine Trophic Index and Fishing-in-Balance index

The MTI has increased from 1950 to the early 1970s, and then declined slightly and remained relatively steady thereafter, except for a more recent increase. The FiB index suggests a spatial expansion of the fisheries until the early 1980s, and has remained relatively level since, suggesting that natural limits may have been reached.



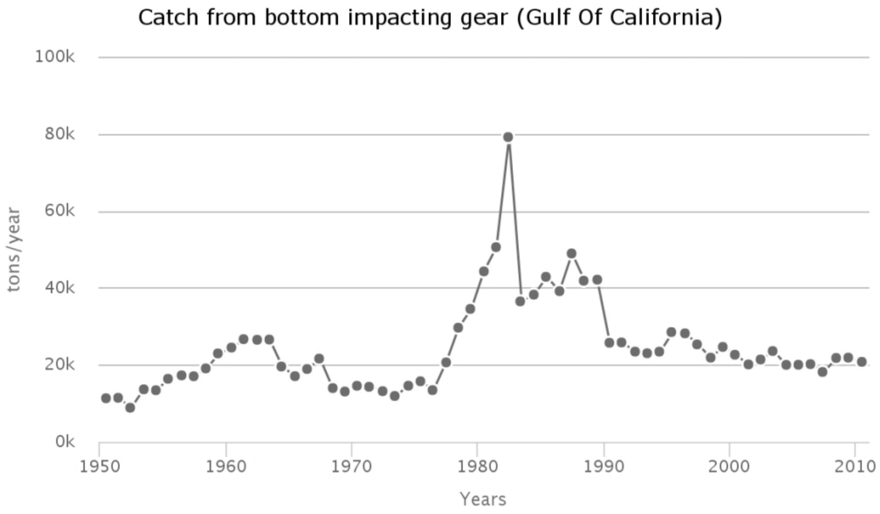
Stock status

The Stock-Catch Status Plots indicate that the number of collapsed and overexploited stocks have been increasing in the LME, to about 40% of the commercially exploited stocks. The majority of the reported landings is supplied by fully exploited stocks.



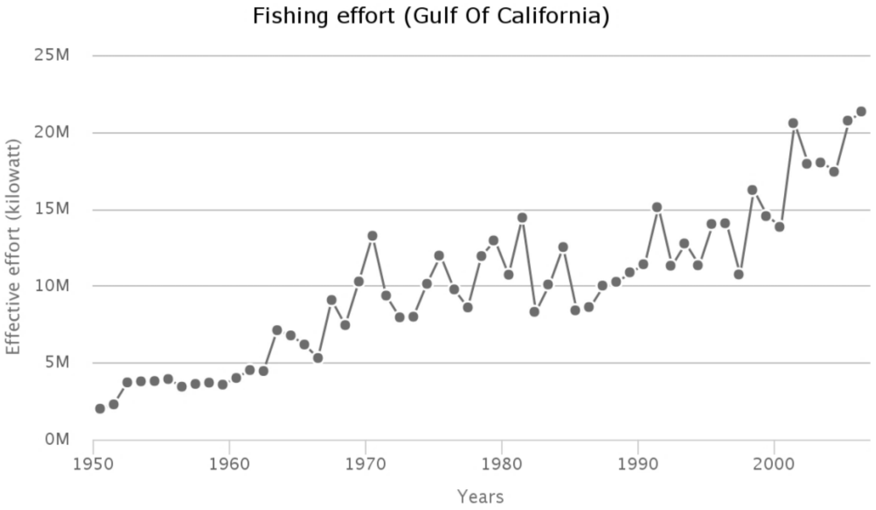
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch ranges between 13.5 and 30%.



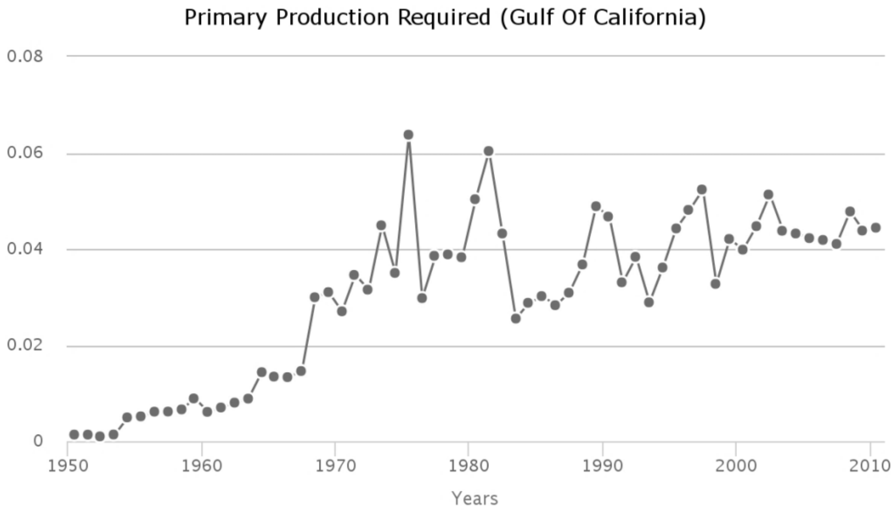
Fishing effort

The total effective effort increased steadily from around 60 million kW in the 1960s to its peak at 200 million kW in the mid-2000s.



Primary Production Required

The primary production required (PPR) to sustain the reported landings reached 10% of the observed primary production in 1996 and fluctuated between 5 to 9% in recent years.



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 increased to moderate in 2030 and remained moderate in 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	2	1	1	3	1	1	3	1

Legend:

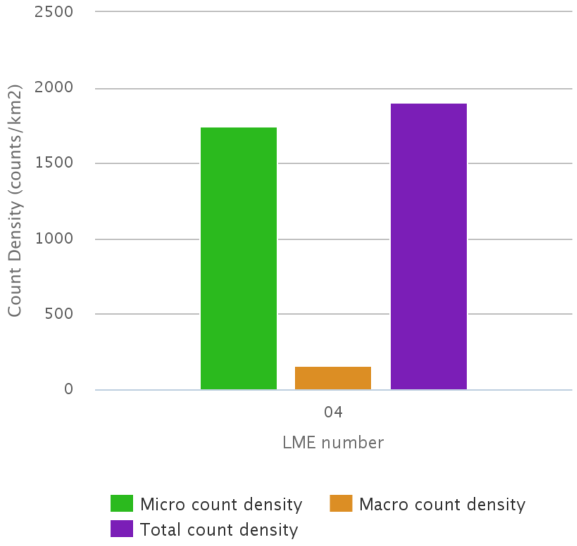
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

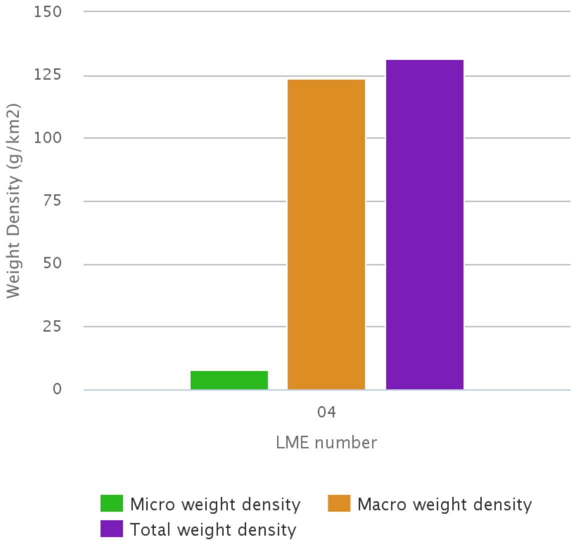
POPs

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 relatively low levels of 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 relative remoteness of this LME from significant sources of plastic. The abundance of floating plastic in this category is estimated to be on average over 40 times lower that those LMEs with the highest values. There is evidence from sea-based direct observations and towed nets to support this conclusion.





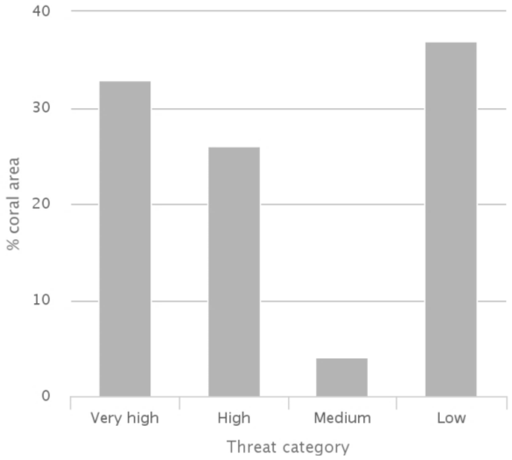
Ecosystem Health

Mangrove and coral cover

0.52% of this LME is covered by mangroves (US Geological Survey, 2011) and 0.01% by coral reefs(Global Distribution of Coral Reefs, 2010), the lowest coral cover of any LME.

Reefs at risk

This LME has a present (2011) integrated threat index (combining threat from overfishing and destructive fishing, watershed-based and marine-based pollution and damage) of 255. 32% of coral reefs cover is under very high threat, and 26% under high threat (of the 5 possible threat categories, from low to critical). When combined with past thermal stress (between 1998 and 2007), these remain constant. By year 2030, 59% of coral cover in this LME is predicted to be under very high to critical level of threat from warming and acidification; this proportion increases to 63% by 2050.

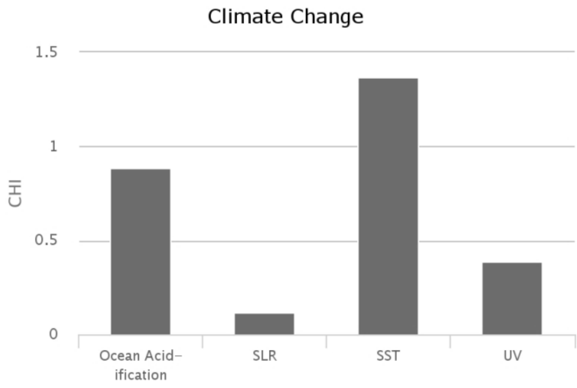


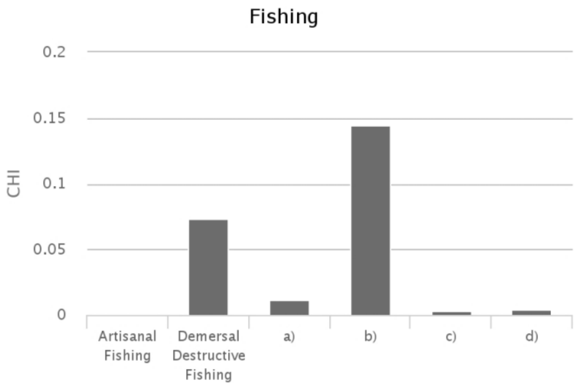
Marine Protected Area change

The Gulf of California LME experienced an increase in MPA coverage from 0 km^2 prior to 1983 to 14,369 km^2 by 2014. This represents an increase of 50,000%, within the highest category of MPA change.

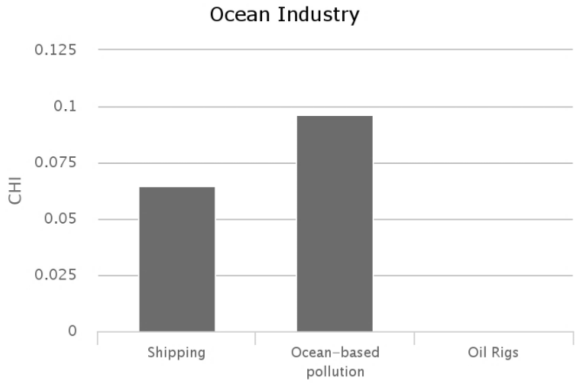
Cumulative Human Impact

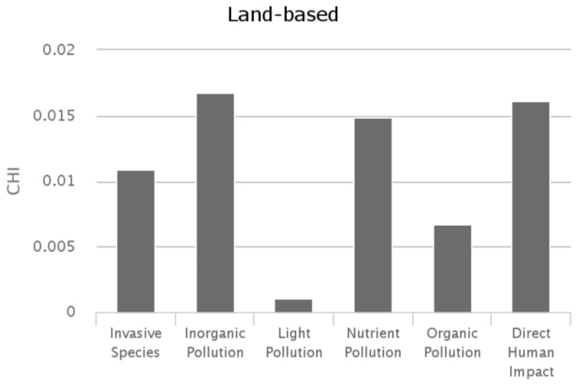
The Gulf of California LME experiences an average overall cumulative human impact (score 3.23; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, all four connected to climate change have the highest average impact on the LME: sea surface temperature (1.37; maximum in other LMEs was 2.16), ocean acidification (0.88; maximum in other LMEs was 1.20), UV radiation (0.39; maximum in other LMEs was 0.76), and sea level rise (0.12; maximum in other LMEs was 0.71). Other key stressors include ocean based pollution, demersal destructive commercial fishing, and demersal non-destructive low-bycatch commercial fishing.





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

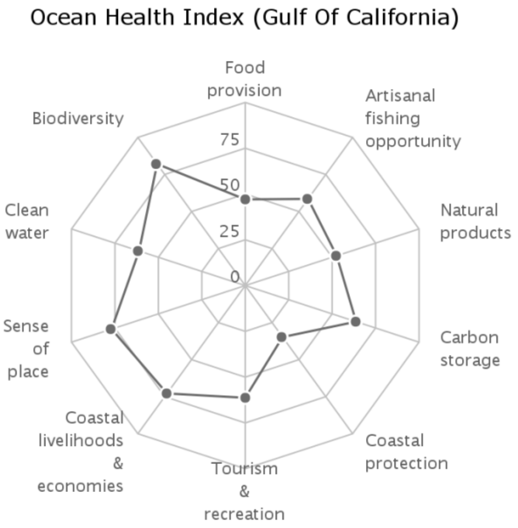




CHI: 3.23

Ocean Health Index

The Gulf of California LME scores 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 well below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 1 point compared to the previous year, due in large part to changes in the scores for food provision, coastal livelihoods and economies, and clean waters. This LME scores lowest on food provision, coastal protection, carbon storage, coastal livelihoods, and iconic species goals and highest on artisanal fishing opportunities, natural products, 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).



OHI: 61.09

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 the Gulf of California 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, 225,547 km^2 wide, includes the eastern coast of Baja California and the northwest shoreline of Mexico. Its population is moderately large (medium risk) 30% of which lives in rural areas. Population size is projected to decrease by a million in 2100, a density of 27 persons per km^2 in 2010 decreasing to 22 persons per km^2 in 2100.

Total population		Rural population	
2010	2100	2010	2100
6,044,600	4,945,965	1,839,165	1,542,890

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 49% of the LME's coastal dwellers. This LME places in the highest-risk category based on percentage of poor and among those with medium risk category using absolute number of poor at nearly 3 million (present day estimate).

Coastal poor
2,965,269

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Gulf of California LME ranks in the low revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $206 million for the period 2001-2010. Fish protein accounts for 8% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $12.9 billion places it in the low revenue category. On average, LME-based tourism income contributes 14% 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 the Gulf of California LME falls in the category with medium risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
206,088,671	7.8	12,873,651,360	13.8	0.7582

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 Gulf of California LME HDI belongs to the average HDI and medium risk category. Based on present-day HDI of 0.750, this LME has an HDI Gap of 0.250, the difference between contemporary 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). The Gulf of California LME is projected to increase its HDI to the very high category with the lowest risk in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the highest risk category (very low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway

	HDI 2100	
HDI	**SSP1**	**SSP3**
0.7498	0.9253	0.5925

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 to the Gulf of California LME is in the high risk category. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, is high. In a sustainable development scenario, the threat index for sea level rise in 2100 is in the lowest risk category, and which increases to medium risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.6504	0.3837	0.3198	0.5718

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 05 – Gulf of Mexico

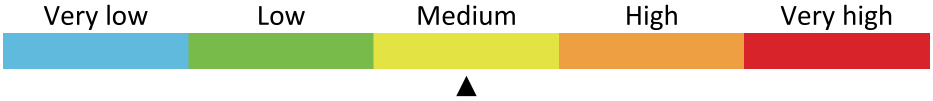
Bordering countries: Mexico, United States of America
LME Total area: 1,530,387 km^2

List of indicators

LME overall risk

This LME falls in the cluster of LMEs that exhibit medium numbers of collapsed and overexploited fish stocks, as well as very high proportions of catch from bottom impacting gear.

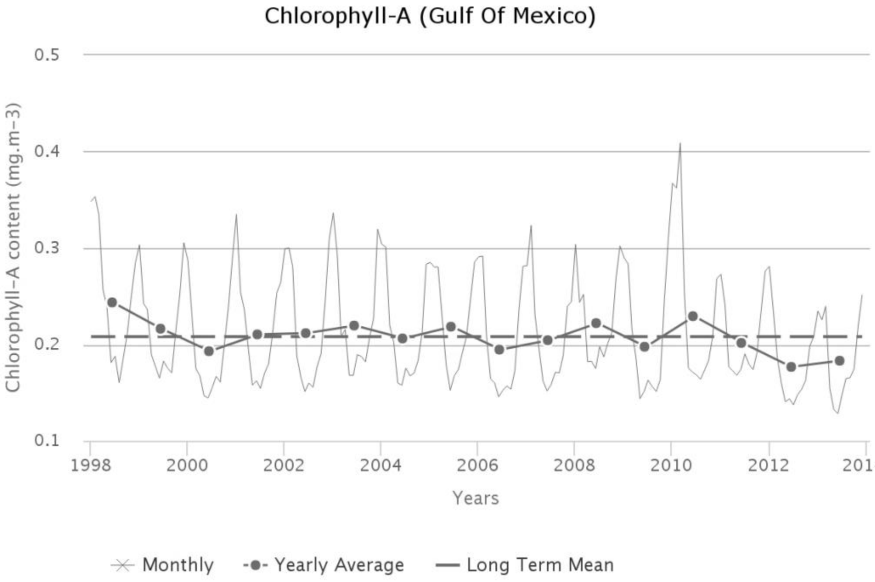
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is medium.

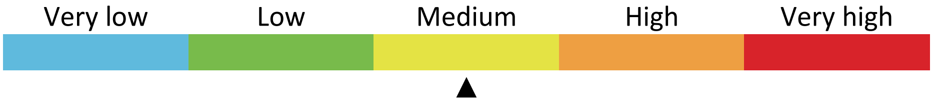


Productivity

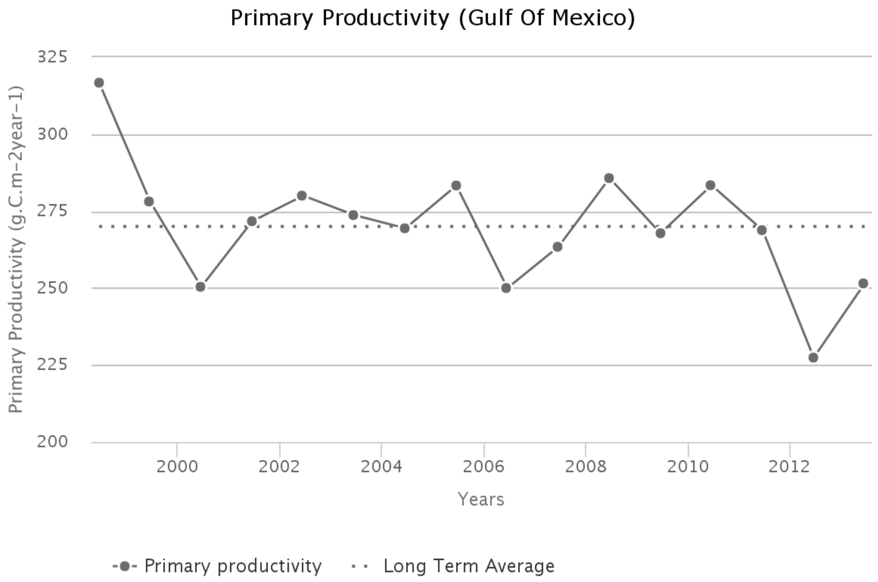
Chlorophyll-A

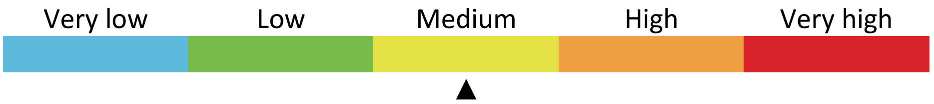
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.297 mg.m^{-3}) in January and a minimum (0.159 mg.m^{-3}) during June. The average CHL is 0.208 mg.m^{-3}. Maximum primary productivity (317 g.C.m^{-2}.y^{-1}) occurred during 1998 and minimum primary productivity (227 g.C.m^{-2}.y^{-1}) during 2012. There is a statistically insignificant decreasing trend in Chlorophyll of -0.221 % from 2003 through 2013. The average primary productivity is 270 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest)





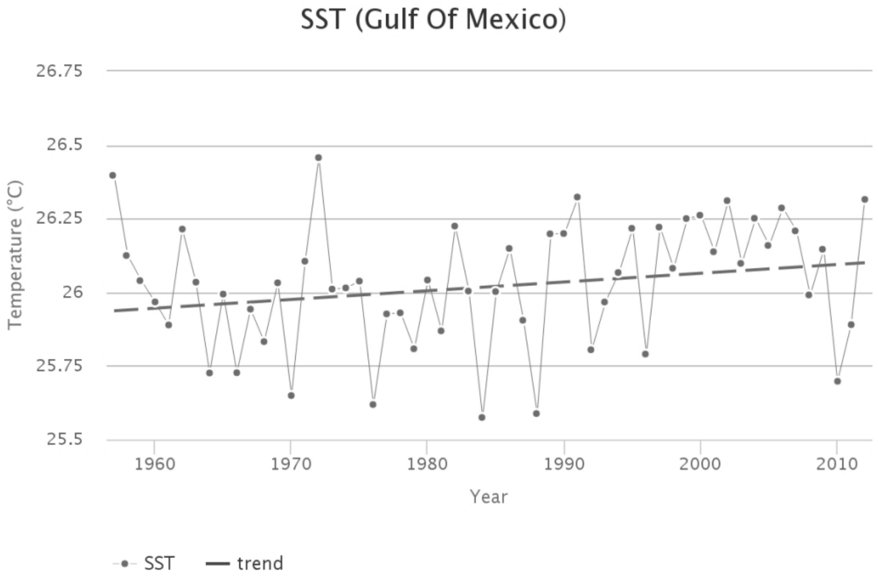
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Gulf of Mexico LME #5 has warmed by 0.16, thus belonging to Category 4 (slow warming LME). The Gulf of Mexico's thermal history is quite peculiar. The global cooling of the 1960s transpired as an SST drop of <1°C, followed by a slow warming until present. The relatively slow warming of the last 50 years was modulated by strong interannual variability with a typical magnitude of 0.5°C. The all-time high of >26.4°C in 1972 was a major event as SST increased by 0.8°C in just two years. This event was localized within the Gulf of Mexico LME. The relative stability of the Gulf of Mexico's thermal regime can be explained by the Gulf Stream (Loop Current) flowing through the Gulf of Mexico.

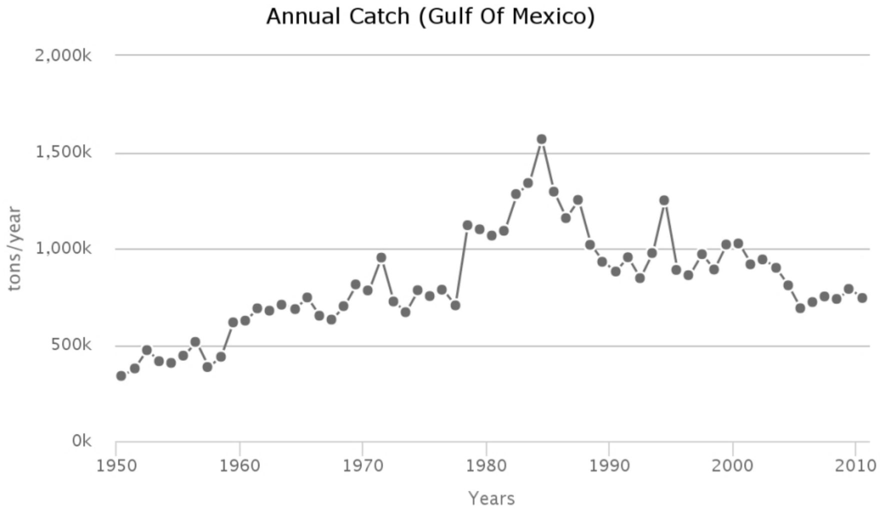


Fish and Fisheries

The Gulf of Mexico LME fisheries are multispecies, multigear and multifleet in character and include artisanal, commercial and recreational fishing. Species of economic importance include brown shrimp (*Penaeus aztecus*), white shrimp (*Penaeus setiferus*), pink shrimp (*Penaeus duorarum*), Gulf menhaden (*Brevoortia patronus*), king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculatus*), red grouper (*Epinephelus morio*), red snapper (*Lutjanus campechanus*), seatrout, tuna and billfish

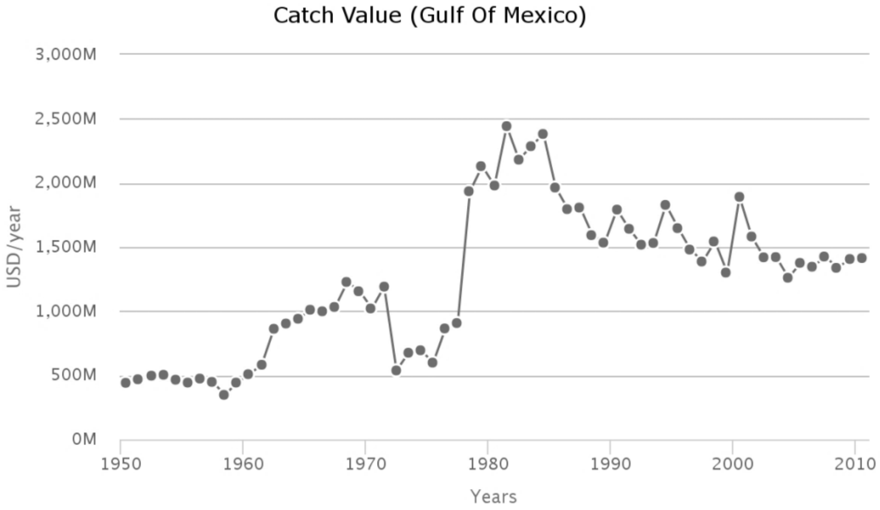
Annual Catch

Total reported landings showed an increase to over 1.6 million t in 1984, followed by a decline to 750,000 t in recent years.



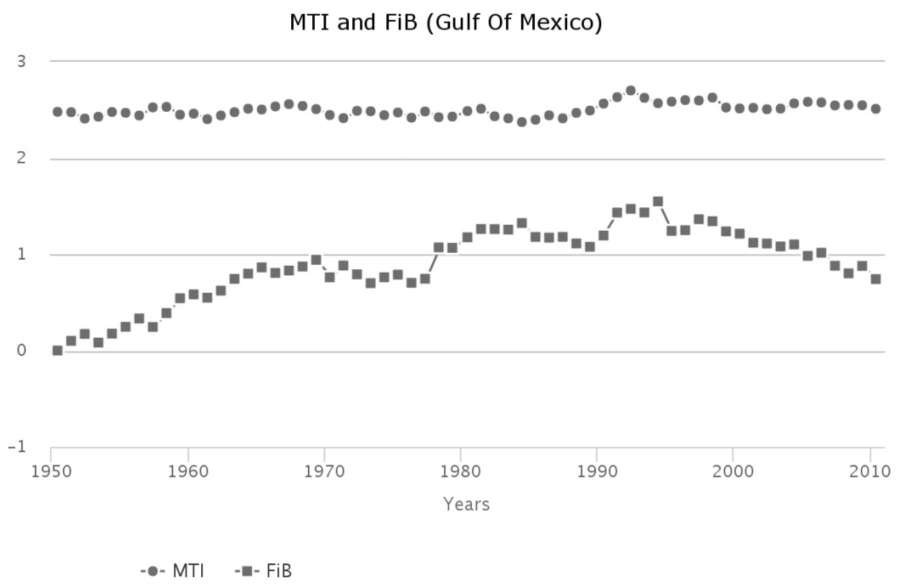
Catch value

In 1981, the annual value of the reported landings was over 2.4 billion US$ (in 2005 value).



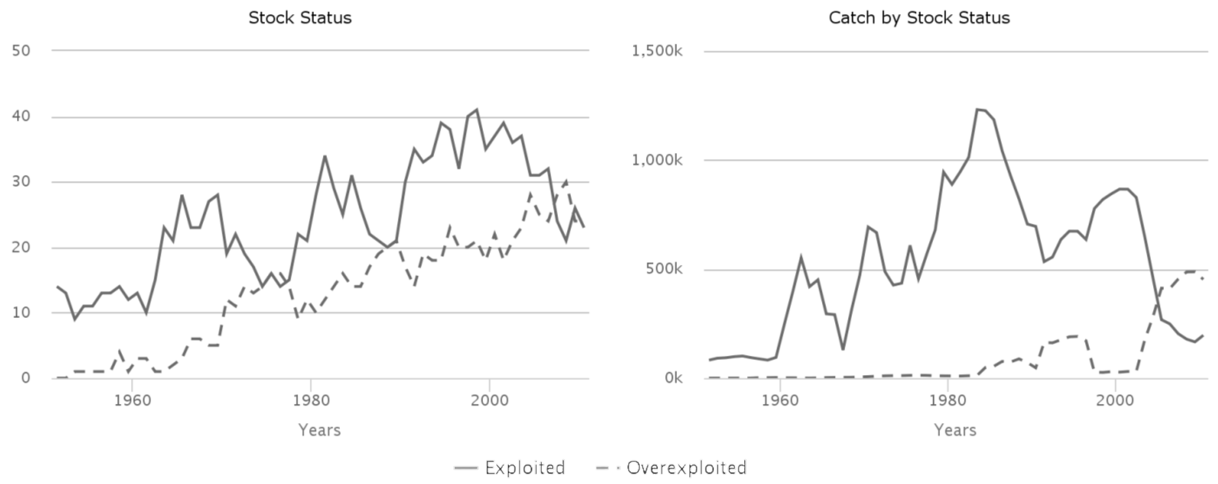
Marine Trophic Index and Fishing-in-Balance index

The MTI has increased slightly from the early 1950s to 2010. The very low value of the MTI (2.4-2.5) is due to the high proportion of small, low trophic-level fishes, especially Gulf menhaden and shrimps in the landings, and the exclusion of the shrimp trawler bycatch in estimating mean trophic levels. The decline of the FiB index from the mid-1980s is likely a result of the declining reported landings.



Stock status

The Stock-Catch Status Plots indicate that collapsed and overexploited stocks now account for about 60% of all commercially exploited stocks in the LME, with overexploited stocks contributing almost 70% of the reported landings.

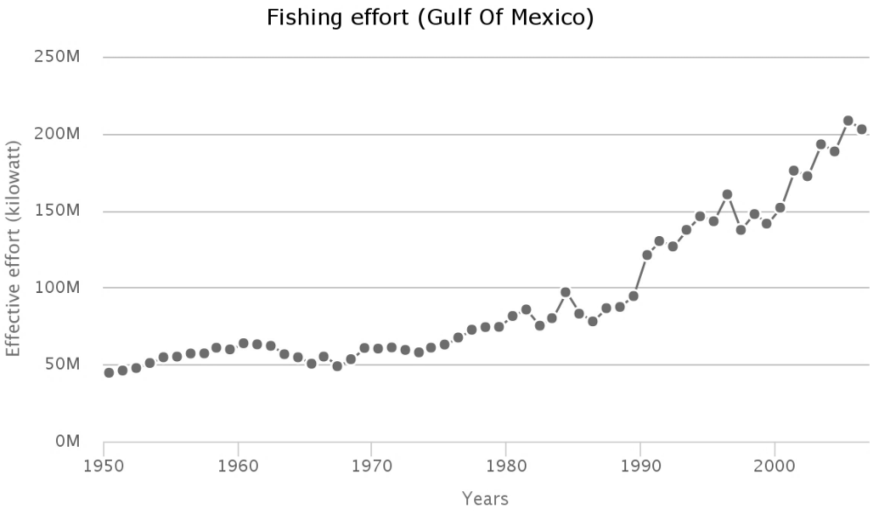


Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its first maximum at 72% in 1953 and then this percentage declined steadily to around 19% in the 1970s. This percentage then further declined to around 10% in the recent decade.

Fishing effort

The total effective effort increased from around 2 million kW in the 1950s to its peak at 200 million kW in the mid- 2000s.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME reached 8% of the observed primary production in 1994, but this is probably an underestimate due to the high level of shrimp bycatch absent from the underlying statistics.

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 high. (level 5 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 very high (5). 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
🟥 5	🟧 4	🟥 5	🟥 5	🟧 4	🟥 5	🟥 5	🟧 4	🟥 5

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

Data are available for only one sample at a rural location in Mississippi State (USA). The location shows a concentration (ng.g^{-1} of pellets) of 28 for PCBs, 13 for DDTs, and 0.1 for HCHs. These correspond to risk category 2 for PCBs, 2 for DDTs, and 1 for HCHs, of the five risk categories (1 = lowest risk; 5 = highest risk). This is probably due to minimal anthropogenic activities involving the use of POPs (PCBs in industries and DDT and HCH pesticides in agriculture). More samples and locations are necessary to properly evaluate this LME.

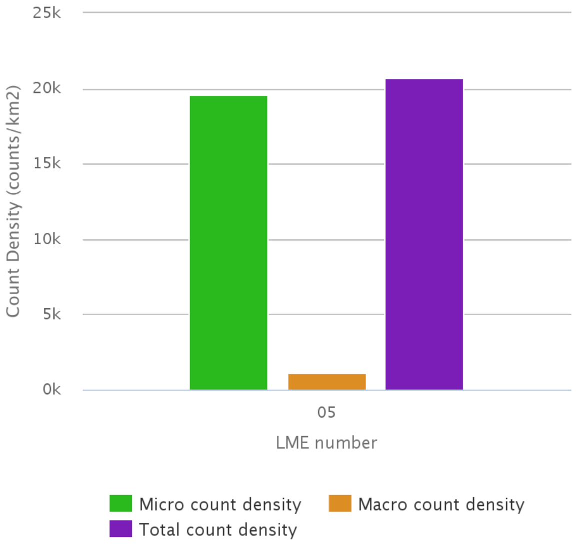
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
1	28	🟩 **2**	13	🟩 **2**	0.1	🟦 **1**

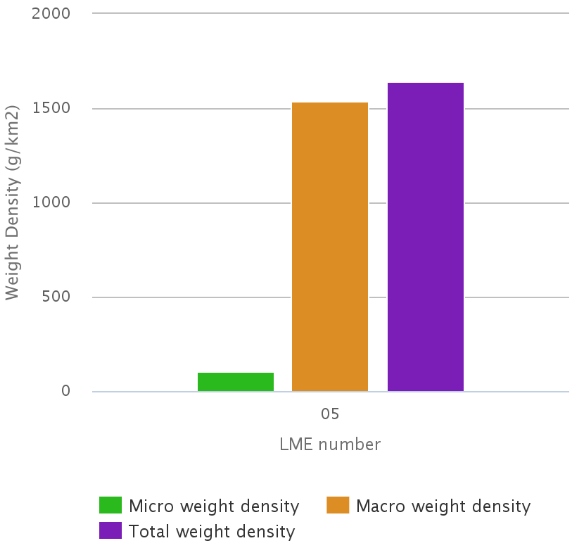
Legend:

🟦 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 relatively high levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 100 times higher that those LMEs with lowest values. There is limited evidence from sea-based direct observations and towed nets to support this conclusion.





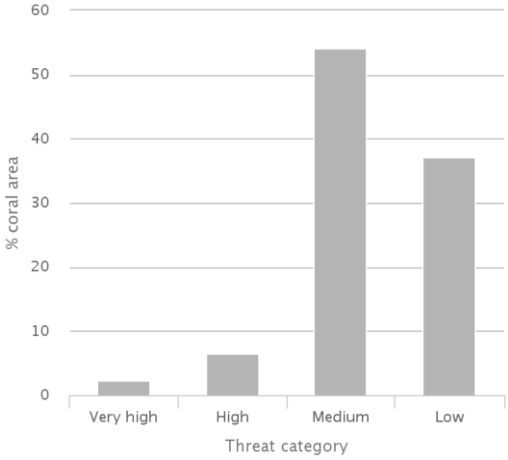
Ecosystem Health

Mangrove and coral cover

0.36% of this LME is covered by mangroves (US Geological Survey, 2011) and 0.09% by coral reefs (Global Distribution of Coral Reefs, 2010).

Reefs at risk

This LME has a present (2011) integrated threat index (combining threat from overfishing and destructive fishing, watershed-based and marine-based pollution and damage) of 174. 2% of coral reefs cover is under very high threat, and 6% under high threat (of the 5 possible threat categories, from low to critical). When combined with past thermal stress (between 1998 and 2007), these values increase to 8% and 19% for very high and high threat categories respectively. By year 2030, 7% of coral cover in this LME is predicted to be under very high to critical level of threat from warming and acidification; this proportion increases to 9% by 2050.

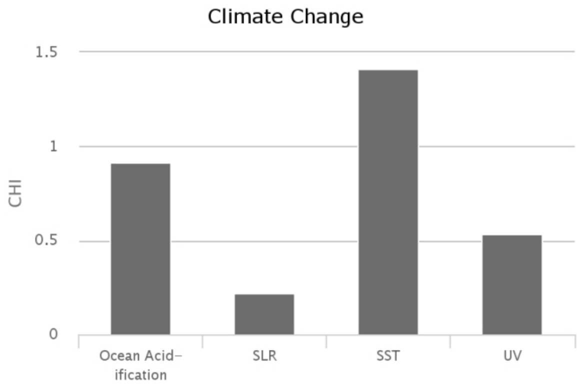


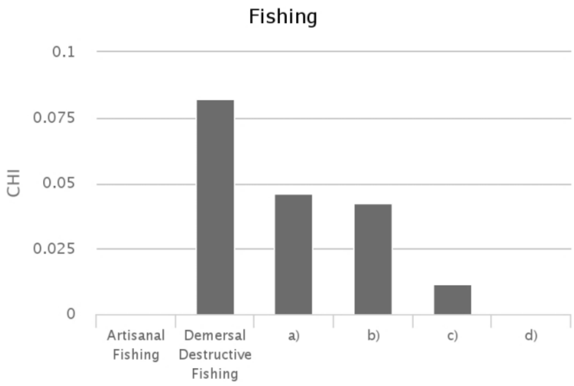
Marine Protected Area change

The Gulf of Mexico LME experienced an increase in MPA coverage from 6,671 km^2 prior to 1983 to 290,795 km^2 by 2014. This represents an increase of 4,259%, within the medium category of MPA change.

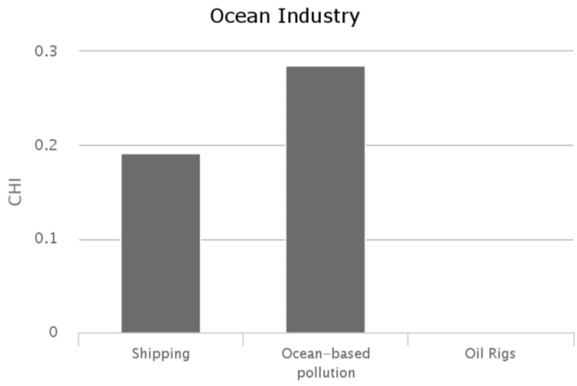
Cumulative Human Impact

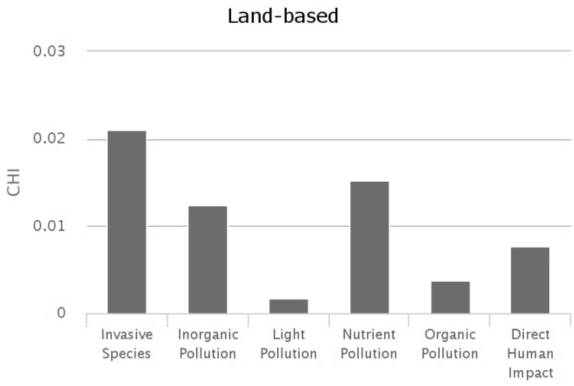
The Gulf of Mexico LME experiences an above average overall cumulative human impact (score 3.81; maximum LME score 5.22), which is well above the LME with the least cumulative impact. It falls in risk category 3 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.92; maximum in other LMEs was 1.20), UV radiation (0.53; maximum in other LMEs was 0.76), and sea surface temperature (1.41; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, sea level rise, ocean based pollution, and demersal destructive commercial fishing.

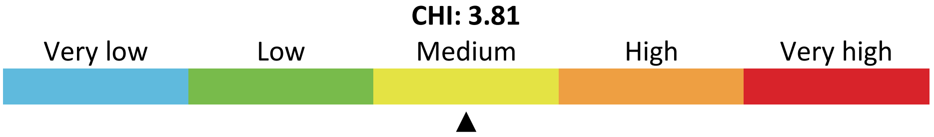




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

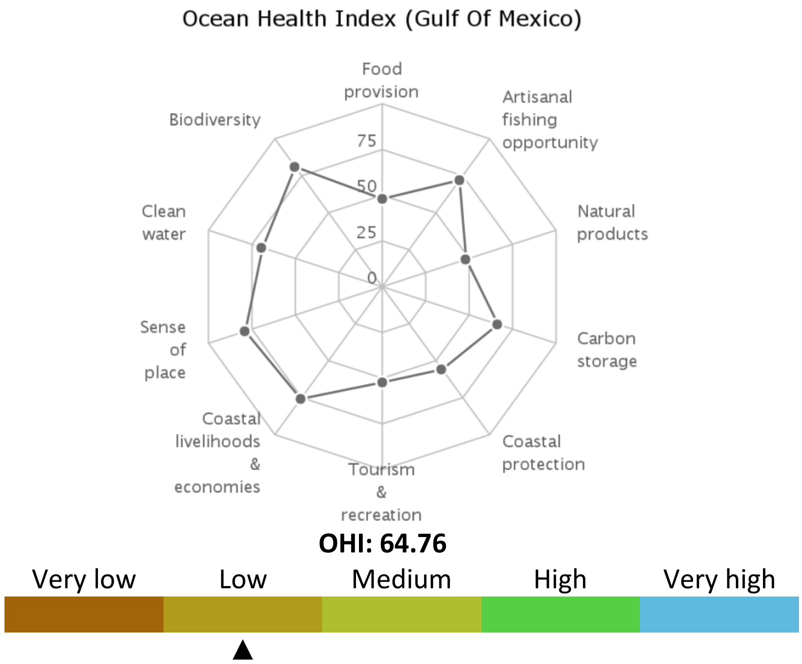






Ocean Health Index

The Gulf of Mexico 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 well below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 5 points compared to the previous year, due in large part to changes in the scores for clean waters and natural products. This LME scores lowest on food provision, coastal protection, coastal livelihoods, and iconic species goals and highest on artisanal fishing opportunities, coastal economies, lasting special places and species diversity 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).



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 the Gulf of Mexico 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 includes the southern coast of the United States of America and the eastern shoreline of Mexico. Covering about 140,753 km^2, current and projected population in 2100 are both in the large population size category (high risk) with a density of 81 persons per km^2 in 2010 and increasing to 129 per km^2 in 2100. About 24% of coastal population lives in rural areas, and is projected to decrease slightly to 23% in 2100.

Total population		Rural population	
2010	**2100**	**2010**	**2100**
40,522,728	64,430,109	9,748,728	14,849,820

Legend:

🟦	Very low	🟩	Low	🟨	Medium	🟧	High	🟥	Very high

Coastal poor

The indigent population makes up 31% of the LME's coastal dwellers. The Gulf of Mexico places in the highest-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
12,438,783

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Gulf of Mexico LME ranks in the high revenue category in fishing revenues based on yearly average total ex-vessel price of US

2013 $1.7 billion (thousand million) for the period 2001-2010. Fish protein accounts for 8% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $252 billion places it in the highest revenue category. On average, LME-based tourism income contributes 9% 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 the Gulf of Mexico LME falls in the category with lowest risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
1,664,680,557	7.6	252,343,000,000	9.0	🟦 0.6416

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 Gulf of Mexico LME HDI belongs to the highest HDI and lowest 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). The Gulf of Mexico LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the high risk category (low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.8563	🟦 0.9528	🟧 0.6671

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 to the Gulf of Mexico 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. In a sustainable development scenario, the risk index for sea level rise in 2100 is in the lowest risk category, and which increases to high-risk category under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.6438	0.3387	0.3103	0.5847

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

In this LME, none of the transboundary arrangements for fisheries (OLDESPECA, WECAFC and ICCAT) appear to be closely connected. However, the arrangements for pollution and biodiversity within the LME are closely integrated within the Cartagena Convention. The specific biodiversity arrangement for turtles does not appear to be linked to any of the arrangements within the LME. Overall, no integrating mechanisms, such as an overall policy coordinating organisation for the LME, could be found. However, this is not to suggest that there is not an abundance of collaboration and interactions amongst the fisheries arrangements through participation in each other's meetings, complementing the integration found within the arrangements for pollution and biodiversity.

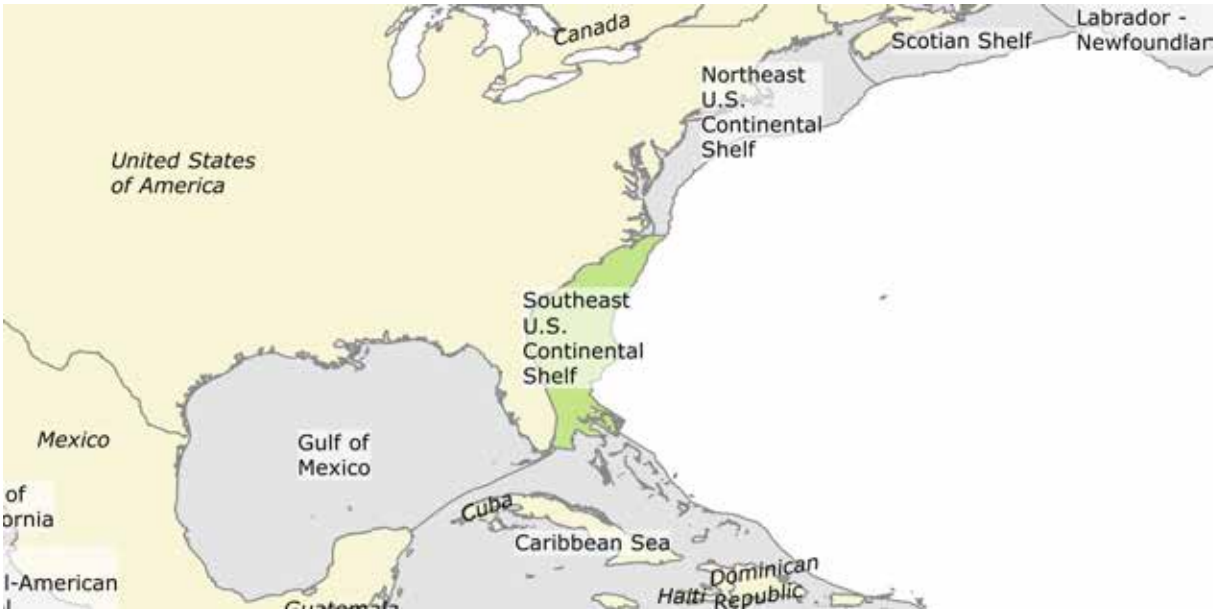
The overall scores for ranking of risk were:

Engagement	Completeness	Integration
71	**58**	**0.2**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 06 – Southeast U.S. Continental Shelf



Bordering countries: United States of America, Bahamas
LME Total area: 303,029 km^2

List of indicators

LME overall risk

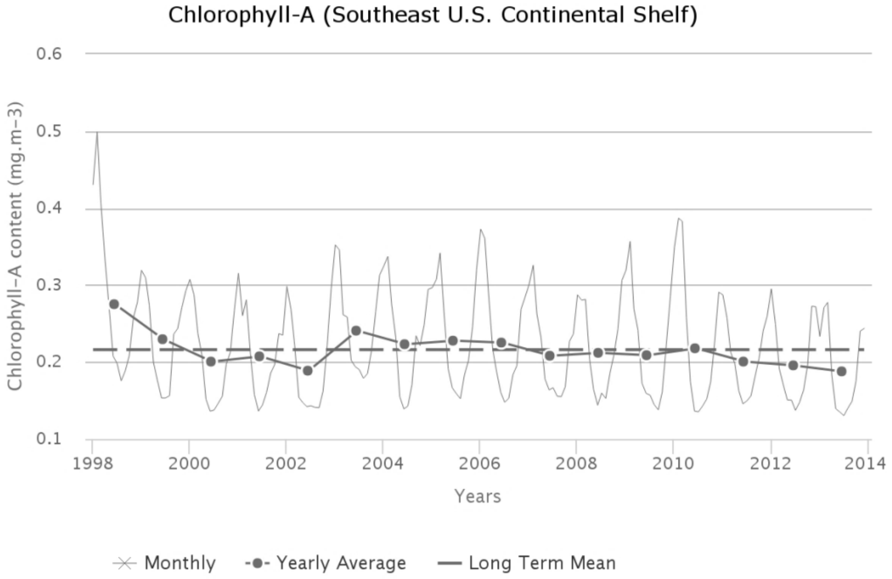
This LME falls in the cluster of LMEs that exhibit medium to high numbers of collapsed and overexploited fish stocks, high levels of demersal non-destructive low bycatch fishing, as well as very high shipping pressure.

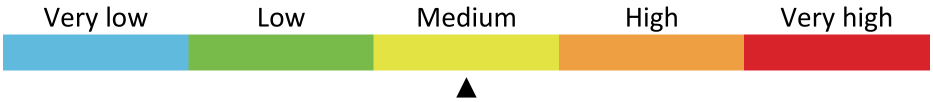
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Productivity

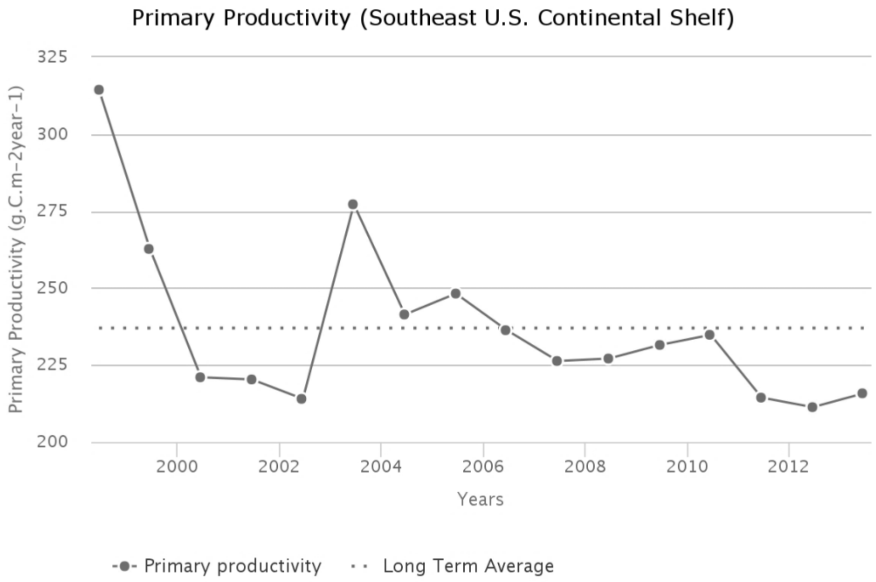
Chlorophyll-A

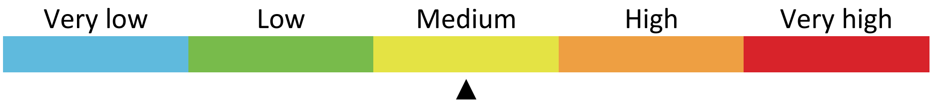
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.315 mg.m^{-3}) in February and a minimum (0.154 mg.m^{-3}) during July. The average CHL is 0.216 mg.m^{-3}. Maximum primary productivity (314 g.C.m^{-2}.y^{-1}) occurred during 1998 and minimum primary productivity (211 g.C.m^{-2}.y^{-1}) during 2012. There is a statistically insignificant decreasing trend in Chlorophyll of -20.6 % from 2003 through 2013. The average primary productivity is 237 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





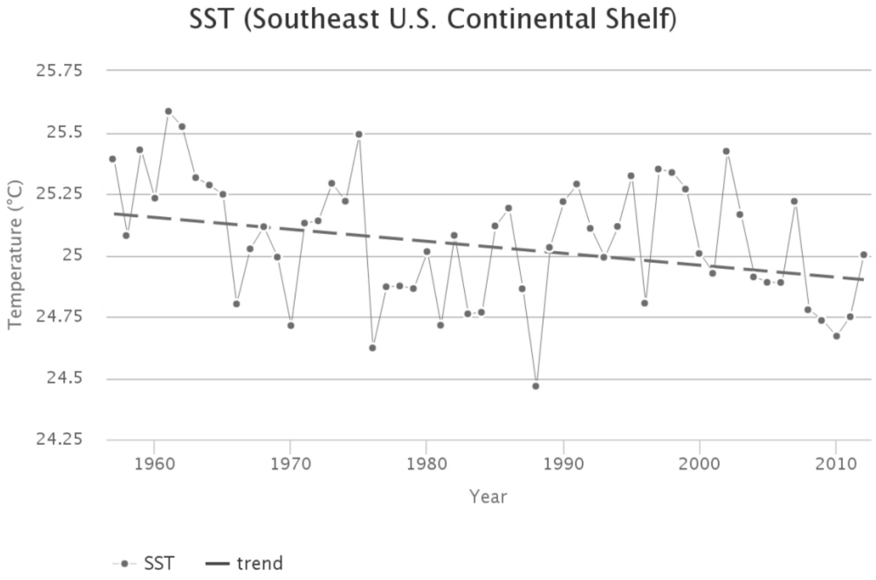
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Southeast US Continental Shelf LME #6 has cooled by 0.28°C, thus belonging to Category 5 (cooling LMEs). This is one of just two LMEs that experienced long-term cooling between 1957 and 2012, another cooling LME being the Barents Sea LME #20. The all-time peak of SST at 25.6°C in 1961 was followed by a cooling phase in 1962-1976, which culminated in the 1976 SST minimum of 24.6°C, before a long-term warming epoch began in 1977. The 1976 breakpoint could be associated with a similar breakpoint of 1976 in the Gulf of Mexico LME #05 as these LMEs are connected by the Gulf Stream flowing from the Gulf of Mexico past the Southeast US Shelf. Therefore, propagation of SST anomalies from the Gulf of Mexico to the Southeast US Shelf plays an important role in shaping thermal regime of the Southeast US Shelf.

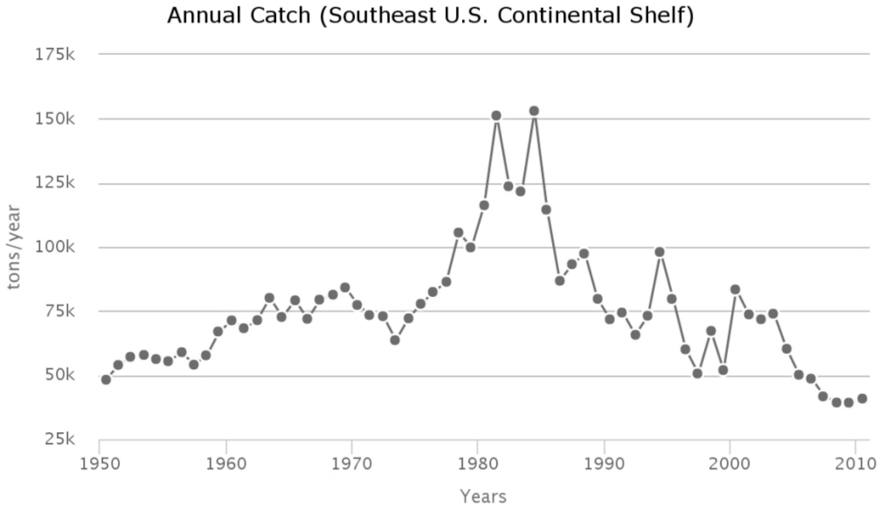


Fish and Fisheries

The LME has important commercial and recreational fishery resources. Major species landed are Atlantic menhaden, American cupped oysters and northern brown shrimps

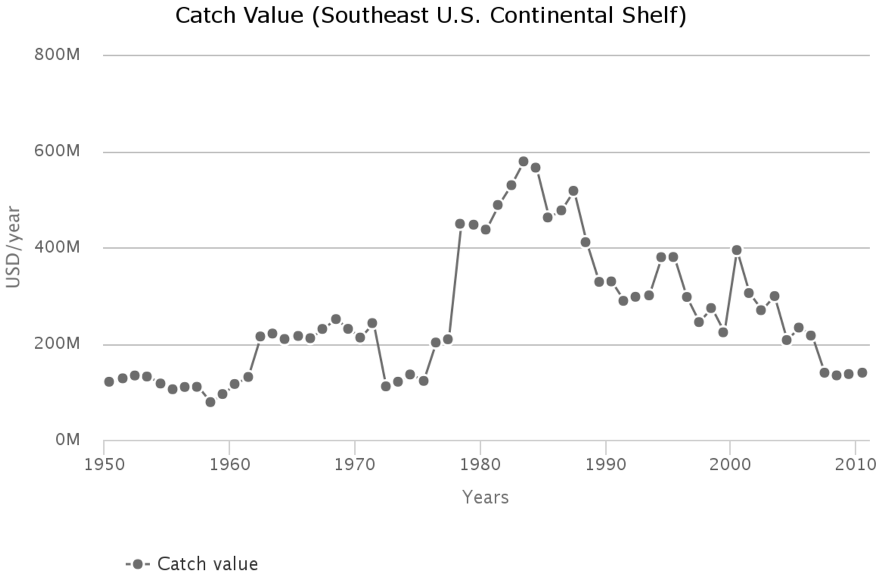
Annual Catch

In the 1980s, there were significant landings of the calico scallop. Total reported landings increased from 1950, recording over 150,000 t in 1981 and 1984, but have since declined to 40,000 t in recent years. There are major fluctuations in the landings of Atlantic menhaden, with less than 2,000 t landed in 1984 and 1997



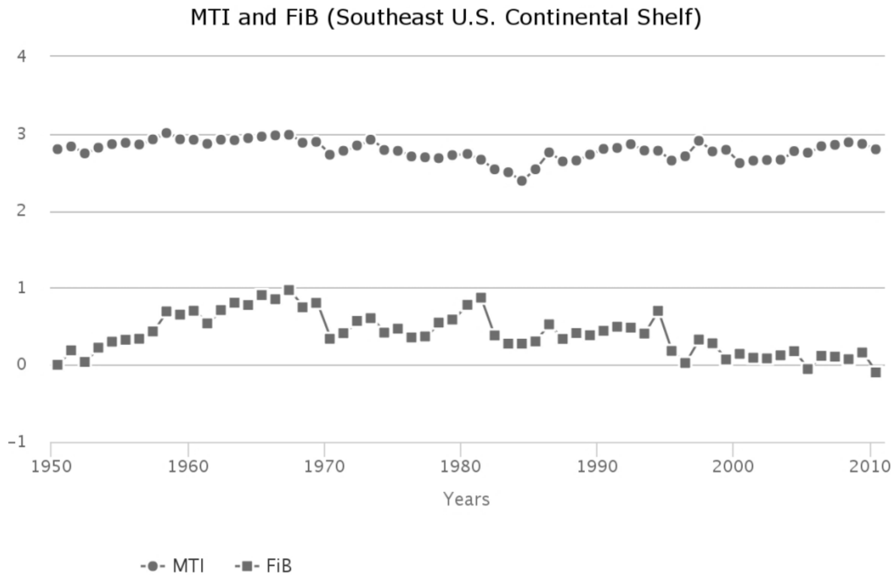
Catch value

The value of the reported landings reached almost 580 million US$ (in 2005 real US$) in 1983, two-thirds of which was from the landings of crustaceans.



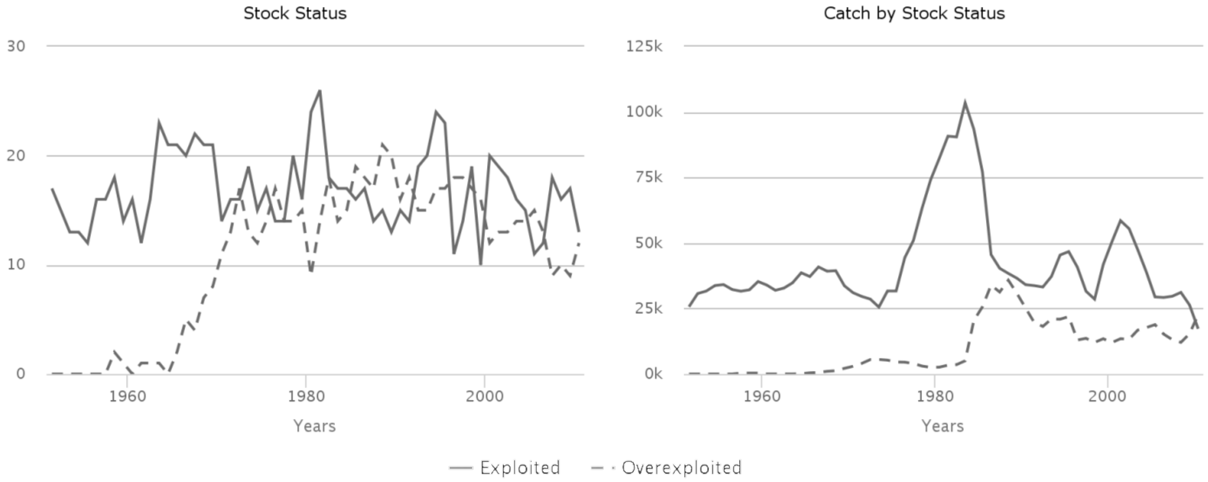
Marine Trophic Index and Fishing-in-Balance index

The MTI is decreasing, though with some fluctuations, and this trend becomes more pronounced when tuna landings are excluded. With the FiB index also declining sharply since the mid-1970s, the state of the LME can be diagnosed as undergoing a ‘fishing down’ of the food web with no increase in the landings to compensate for the decline in the mean trophic level of the catch



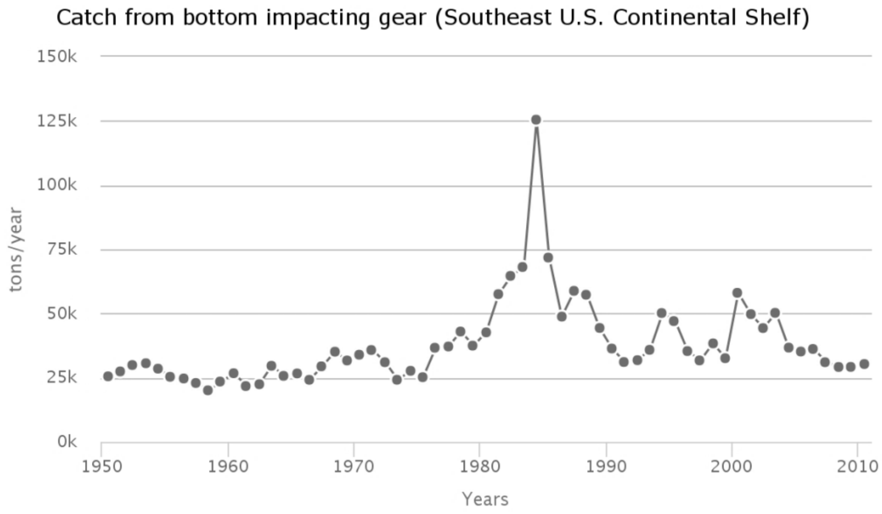
Stock status

The Stock-Catch Status Plots indicate that collapsed and overexploited stocks now account for about 60% of all commercially exploited stocks in the LME, with overexploited stocks contributing more than half of the catch.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 82% in 1984 and then this percentage ranges between 60 to 75% in the recent decade.

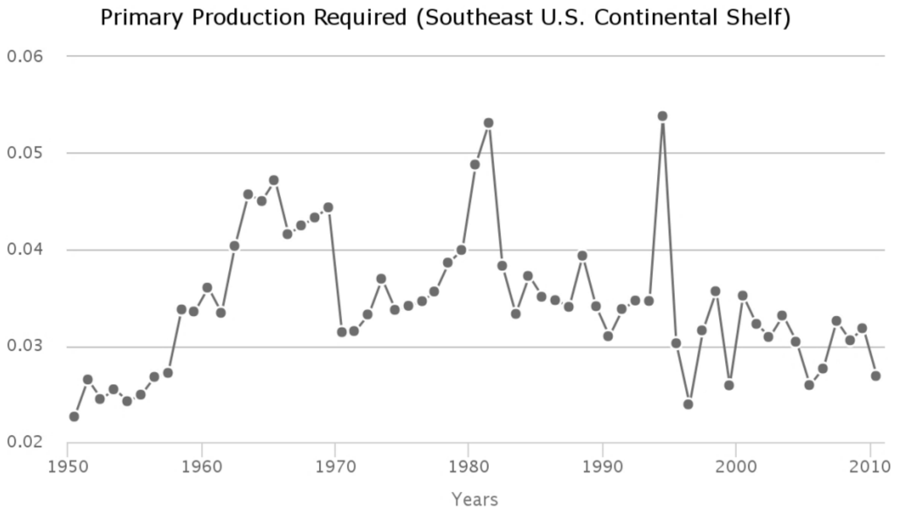


Fishing effort

The total effective effort increased steadily from around 10 million kW in the 1950s to its peak at 270 million kW in the mid-1990s and then ranged between 200 and 280 million kW in the recent decade.

Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME reached 6.5% of the observed primary production in 1980 but has not reached this level since.



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 low (level 2 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 low (2). 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
2	2	2	2	2	2	2	2	2

Legend:

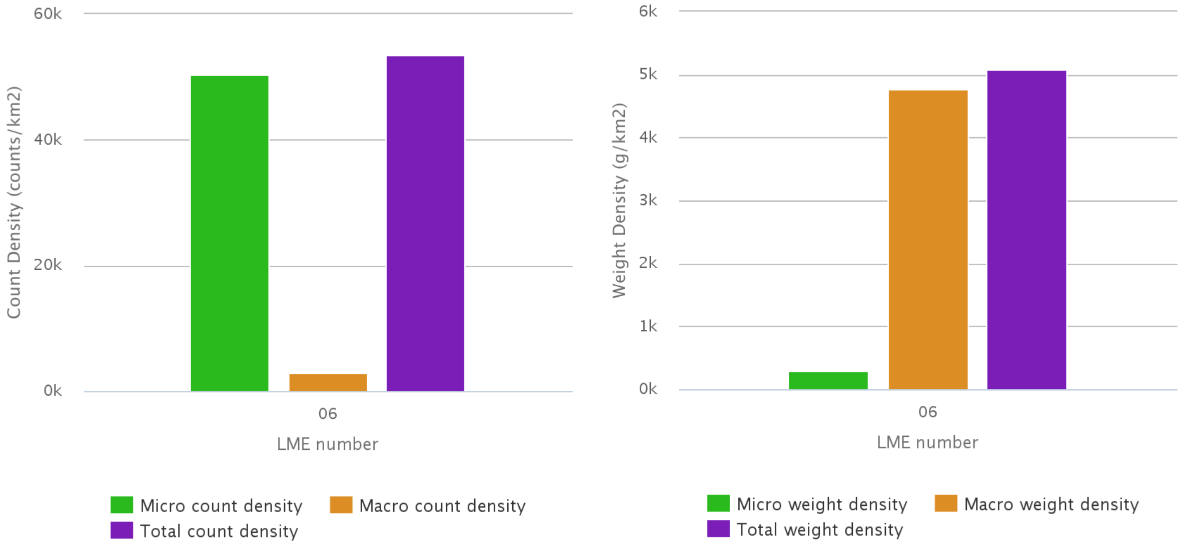
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

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 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 that those LMEs with lowest values. There is good evidence from sea-based direct observations and towed nets to support this conclusion.



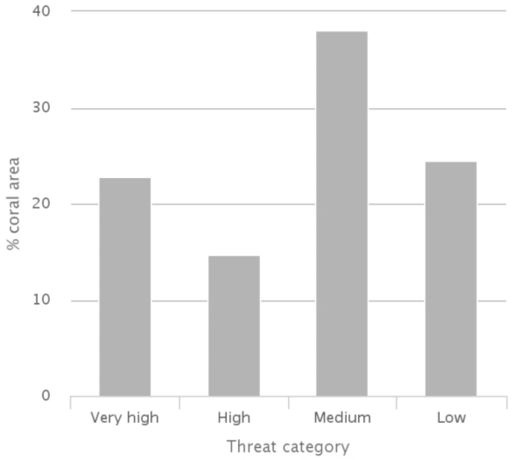
Ecosystem Health

Mangrove and coral cover

0.14% of this LME is covered by mangroves (US Geological Survey, 2011) and 0.39% by coral reefs (Global Distribution of Coral Reefs, 2010).

Reefs at risk

This LME has a present (2011) integrated threat index (combining threat from overfishing and destructive fishing, watershed-based and marine-based pollution and damage) of 236. 22% of coral reefs cover is under very high threat, and 15% under high threat (of the 5 possible threat categories, from low to critical). When combined with past thermal stress (between 1998 and 2007), these values increase to 24% and 25% for very high and high threat categories respectively. By year 2030, 23% of coral cover in this LME is predicted to be under very high to critical level of threat from warming and acidification; this proportion increases to 37% by 2050.

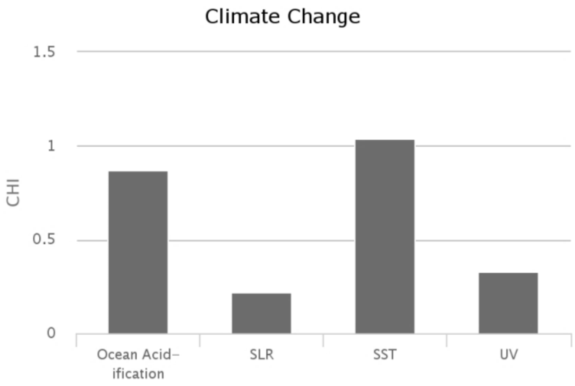


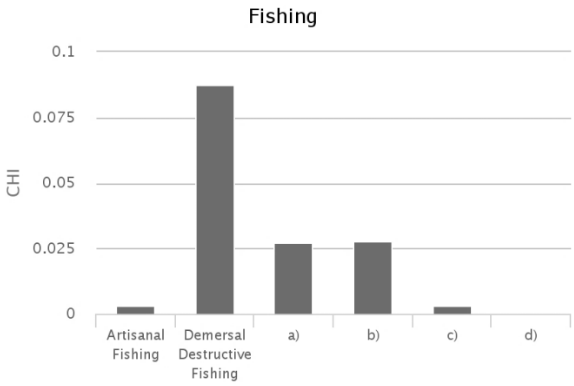
Marine Protected Area change

The Southeast U.S. Continental Shelf LME experienced an increase in MPA coverage from 2,252 km^2 prior to 1983 to 122,065 km2 by 2014. This represents an increase of 5,320%, within the medium category of MPA change.

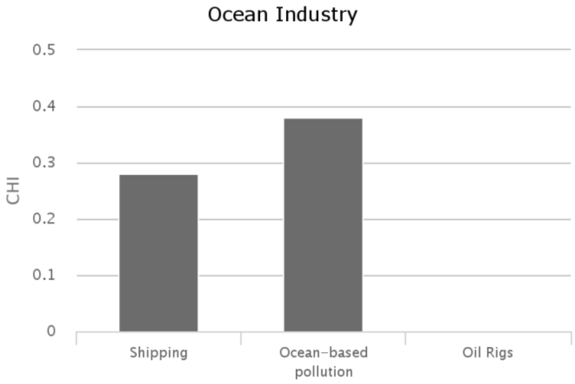
Cumulative Human Impact

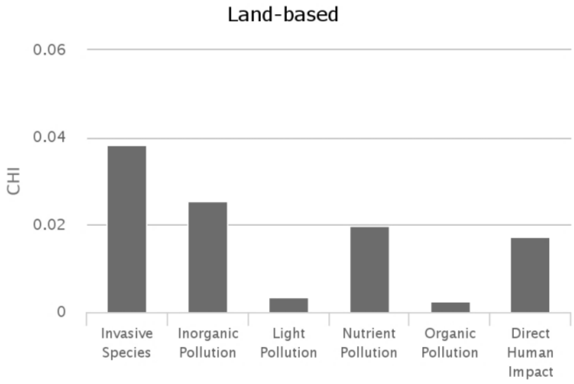
The Southeast US Continental Shelf LME experiences an average overall cumulative human impact (score 3.38; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This 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 (0.87; maximum in other LMEs was 1.20), UV radiation (0.33; maximum in other LMEs was 0.76), and sea surface temperature (1.04; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, sea level rise, ocean based pollution, and demersal destructive commercial fishing.

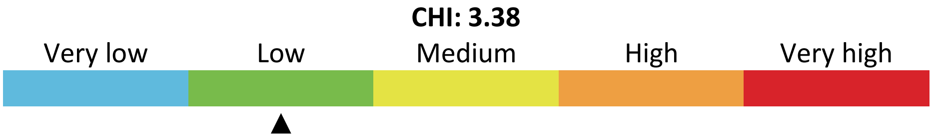




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

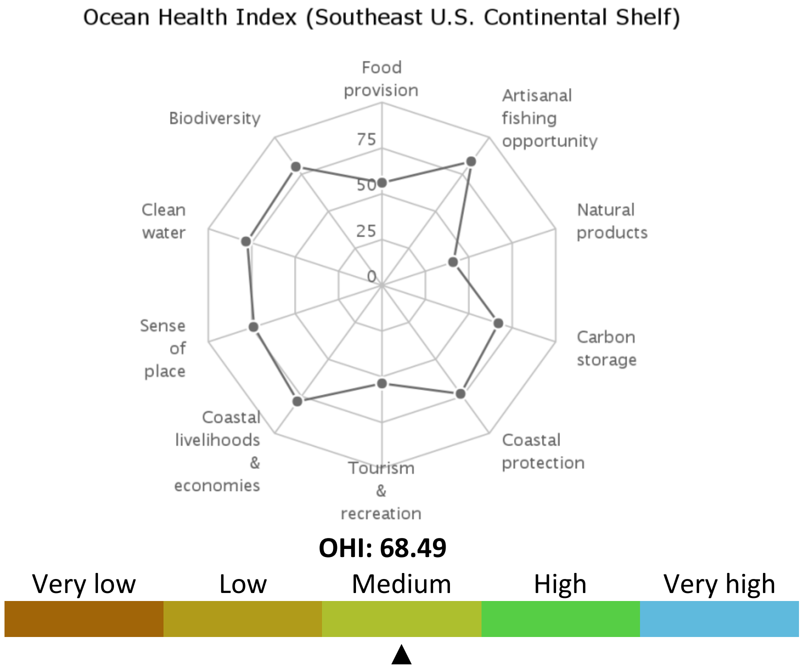






Ocean Health Index

The Southeast US Continental Shelf LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82) but still relatively low. 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 7 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on food provision, natural products, coastal livelihoods, tourism & recreation, and iconic species goals and highest on artisanal fishing opportunities, coastal economies, lasting special places, and species diversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



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 the Southeast U.S. Continental Shelf 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 includes the eastern seaboard of the United States of America and the northern islands of the Bahamas (Abacos and Grand Bahama), and covers about 139,074 km^2. Its current population of 14 million is projected to double in 2100, and a density of 102 persons per km^2 in 2010 increasing to 211 per km^2 in 2100. About 8% of coastal population lives in rural areas, and is projected to decrease in share to 5% in 2100.

Total population		**Rural population**	
2010	**2100**	**2010**	**2100**
14,144,033	29,368,453	1,198,868	1,607,710

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 17% of the LME's coastal dwellers. The Southeast U.S. Continental Shelf places in the high-risk category based on percentage and medium risk using absolute number of coastal poor (present day estimate).

Coastal poor
2,418,529

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Southeast U.S. Continental Shelf LME ranks in the low revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $247 million for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $164 billion (thousand million) places it in the highest revenue category. On average, LME-based tourism income contributes 9% 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 the Southeast U.S. Continental Shelf LME falls in the category with lowest risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
247,412,741	7.4	164,160,000,000	8.6	🟦 0.5420

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 Southeast U.S. Continental Shelf LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.909, this LME has an HDI Gap of 0.091, 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). The Southeast U.S. Continental Shelf LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the high risk category (low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.9088	🟦 0.9662	🟧 0.6970

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 to the Southeast U.S. Continental Shelf 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 low. In a sustainable development scenario, the risk index from sea level rise in 2100 is lowest, and which increases to medium risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟩 0.5051	🟩 0.2912	🟦 0.2777	🟨 0.5627

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

Only the two arrangements for pollution in the areas within national jurisdiction are closely connected under the Cartagena Convention. No integrating mechanisms, such as an overall policy coordinating organization 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:

Engagement	Completeness	Integration
🟨 **58**	🟩 **65**	🟥 **0.2**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 07 – Northeast U.S. Continental Shelf

Bordering countries: United States of America, Canada

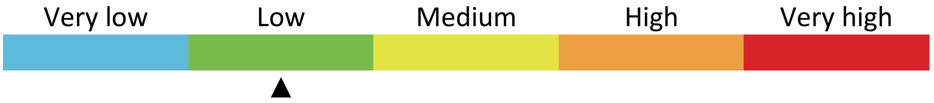
LME Total area: 308,554 km^2

List of indicators

LME overall risk

This LME falls in the cluster of LMEs that exhibit medium to high numbers of collapsed and overexploited fish stocks, high levels of demersal non-destructive low bycatch fishing, as well as very high shipping pressure.

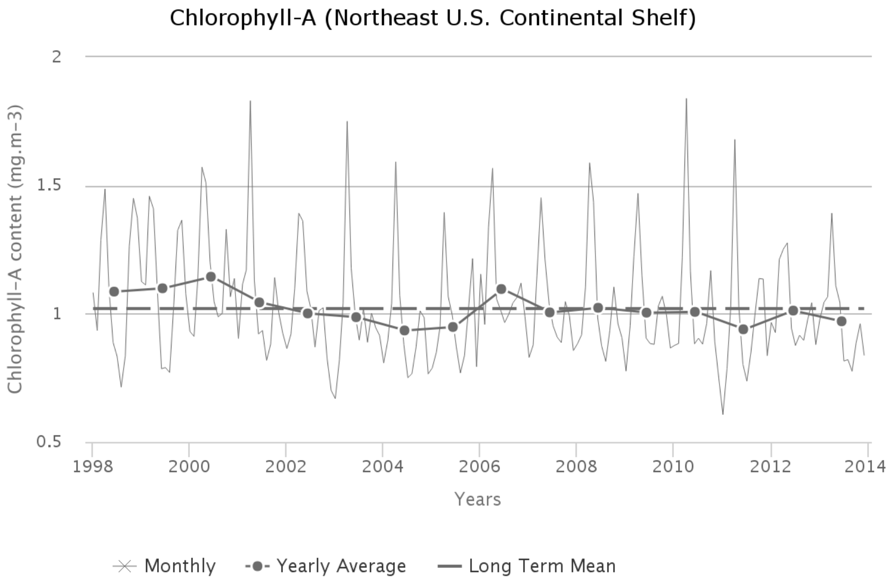
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.



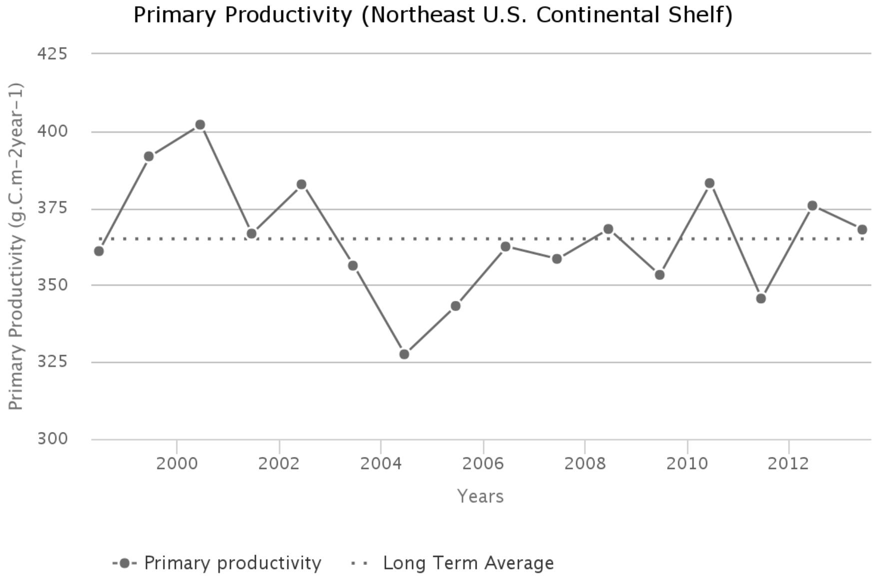
Productivity

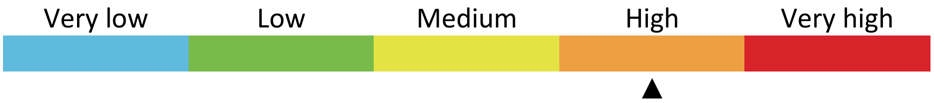
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (1.51 mg.m^{-3}) in April and a minimum (0.866 mg.m^{-3}) during August. The average CHL is 1.02 mg.m^{-3}. Maximum primary productivity (402 g.C.m^{-2}.y^{-1}) occurred during 2000 and minimum primary productivity (327 g.C.m^{-2}.y^{-1}) during 2004. There is a statistically insignificant increasing trend in Chlorophyll of 7.75 % from 2003 through 2013. The average primary productivity is 365 g.C.m^{-2}.y^{-1}, which places this LME in Group 4 of 5 categories (with 1 = lowest and 5= highest).



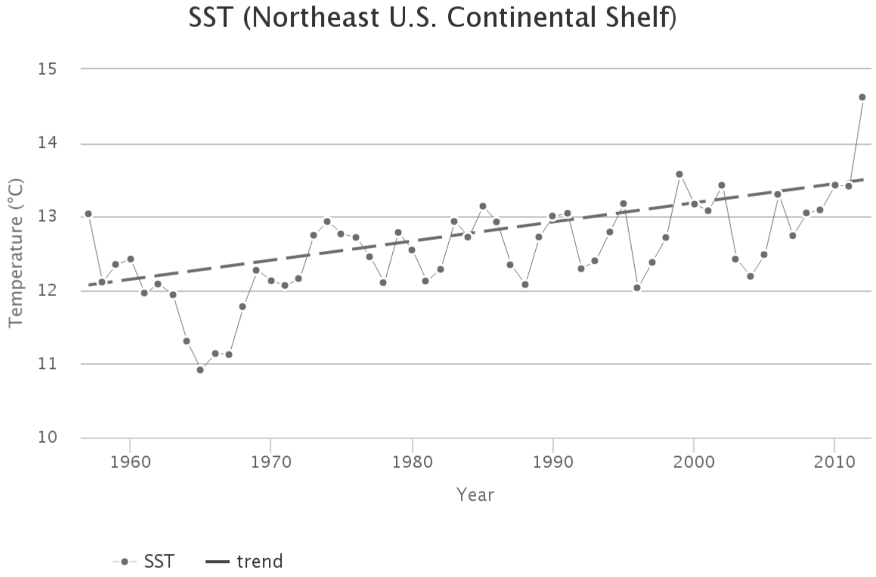
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Northeast U.S. Continental Shelf LME #07 has warmed by 1.40°C, thus belonging to Category 1 (super-fast warming LME). The cold spell in the 1960s resulted in a 2°C SST drop down to 10.9°C by 1965; a recovery took four years. This cold event profoundly affected the Northeast U.S. Shelf ecosystem. For example, winter flounder thrived during the cold spell, whereas stocks of other species less tolerant to the cold, dwindled. After 1965, the Northeast U.S. Continental Shelf experienced a steady long-term warming, from 10.9°C in 1965 up to 14.6°C in 2012, hence a 3.7°C warming in 47 years, making the Northeast U.S. Continental Shelf one of the fastest warming LMEs. The most recent rapid warming (since 2007) is especially notable. The thermal history of the Northeast U.S. Continental Shelf LME #07 is dramatically different from that of the adjacent Southeast U.S. Continental Shelf LME #06. This can be explained by cardinal differences in oceanographic settings of these ecosystems.

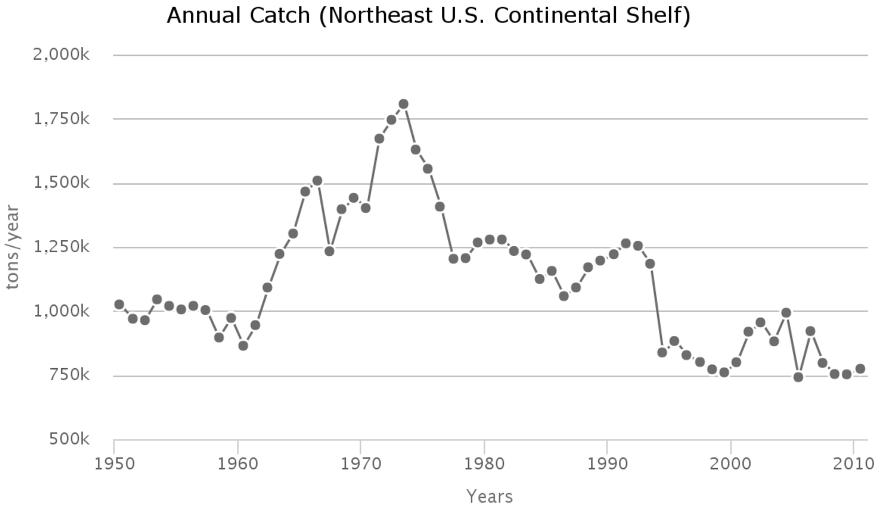


Fish and Fisheries

The catch composition of this LME is diverse. In the late 1960s and early 1970s, there was intense foreign fishing within the LME. The precipitous decline in biomass of fish stocks during this period was the result of excessive fishing mortality.

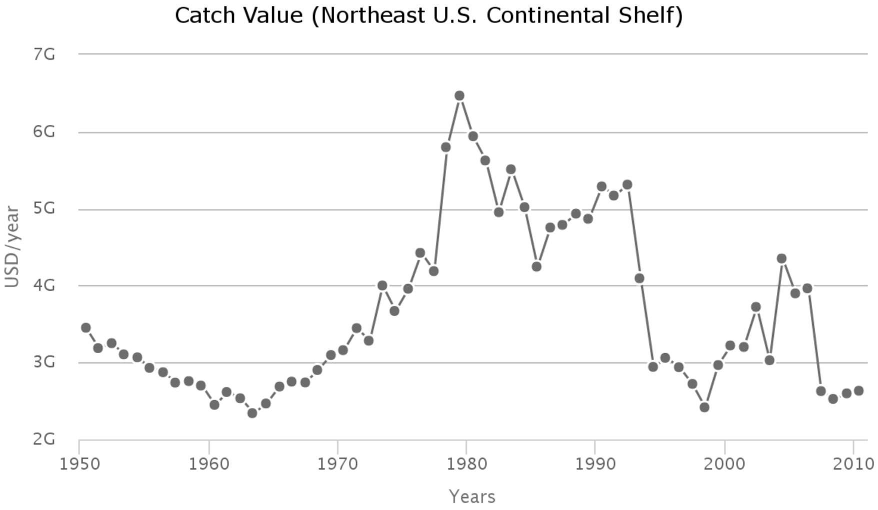
Annual Catch

Total reported landings declined from more than 1.8 million t in 1973 to less than 800,000 t from 1998 to 2000, and then fluctuated between 740,000 and 1 million t in the past 10 years.



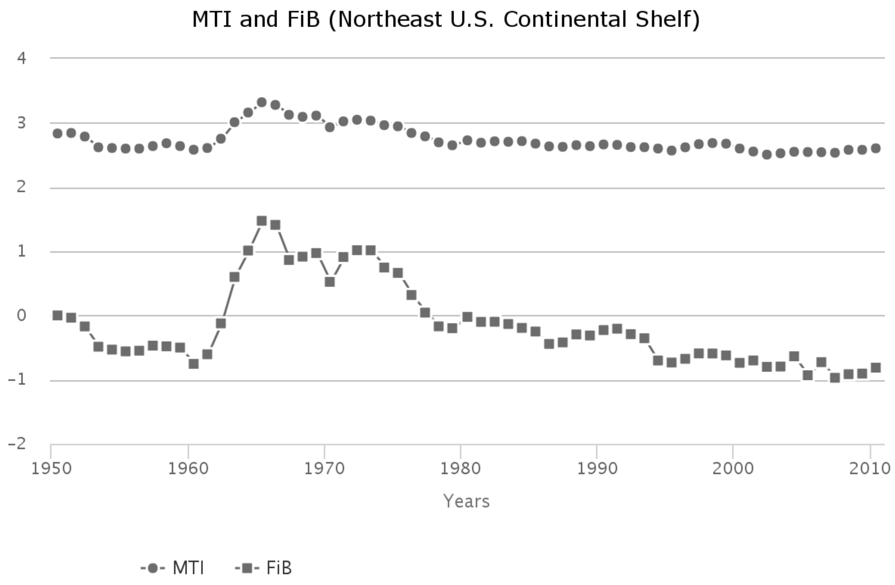
Catch value

The value of the reported landings reached 6.5 billion US$ (in 2005 real US$) in 1979, and fluctuated between 2.5 and 4.4 billion US$ in the recent decade (2001 – 2010).



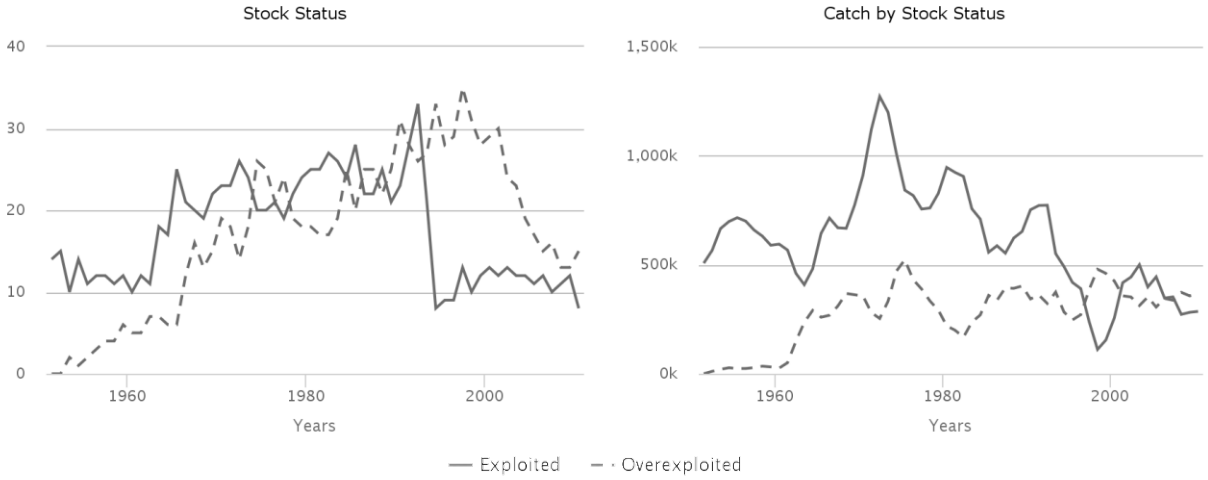
Marine Trophic Index and Fishing-in-Balance index

The MTI declined since the early 1960s, when demersal fish in the LME came under strong exploitation, which is a clear case of 'fishing down' of the food web. The FiB index showed a similar decline, implying that the increase in the reported landings recorded in the 1970s did not compensate for the decline in the MTI over that period.



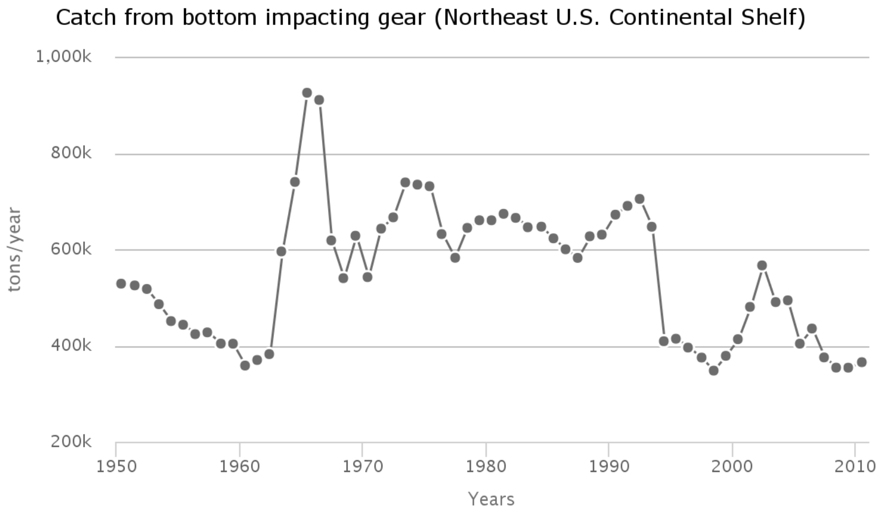
Stock status

The Stock-Catch Status Plots shows that about 50% of commercially exploited stocks in the LME have collapsed, with another 20% being overexploited. Slightly over 50% of the reported landings biomass is supplied by these two stock categories.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 63% in 1965 and then this percentage ranges between 45 to 60% in the recent few decades.

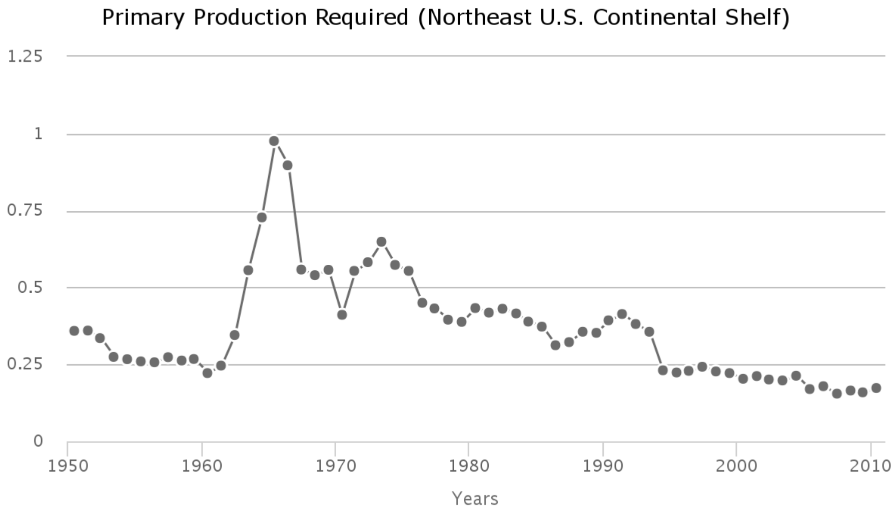


Fishing effort

The total effective effort increased steadily from around 9 million kW in the 1950s to its peak at 380 million kW in 2006.

Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME reached 90 % of the observed primary production in the mid-1960s, but has declined to less than 20 % in recent years. The extremely high PPR recorded in the 1960s and 1970s was likely due to the exploitation of the accumulated biomass of cod and other stocks rather than from exploitation of annual surplus production in the LME.



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 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 moderate (3). According to the Global Orchestration scenario, this increased to high in 2030 and decreased back to moderate in 2050.

Merged nutrient indicator

The risk level for the Merged Nutrient Indicator for contemporary (2000) conditions was moderate (3). According to the Global Orchestration scenario, this increased to high in 2030 and then decreased to moderate in 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
3	3	3	3	4	4	3	3	3

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

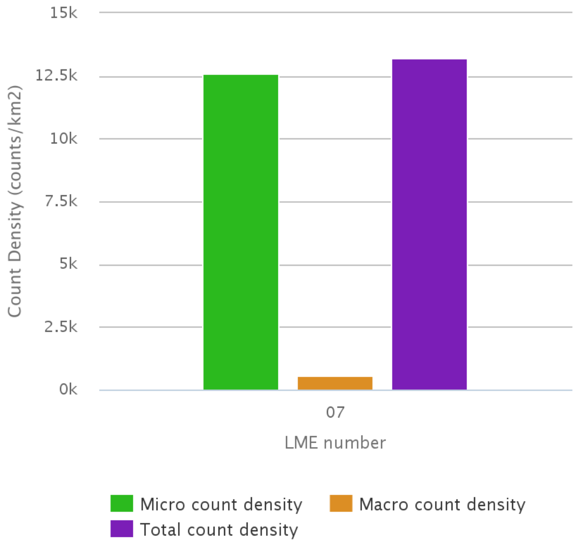
The Northeast U.S. Continental Shelf LME has 3 samples at 3 locations. The average concentration (ng.g^{-1} of pellets) was 275 (range 92-405 ng.g^{-1}) for PCBs, 20 (range 7-47 ng.g^{-1}) for DDTs, and 1.6 (range 0.04 -4.3 ng.g^{-1}) for HCHs. The PCBs, DDTs and HCHs averages correspond to risk category 4, category 3, and category 1, respectively, of the 5 risk categories (1 = lowest risk; 5 = highest risk). Higher concentrations of PCBs (405 ng.g^{-1} in Boston Harbor; 328 ng.g^{-1} in New Jersey) were probably due to proximity to the urban centers such as Boston and New York, and are ascribed to legacy pollution. For comprehensive evaluation of this LME, collection and analysis of pellets from suburban and rural areas in addition to more locations in urban areas are necessary.

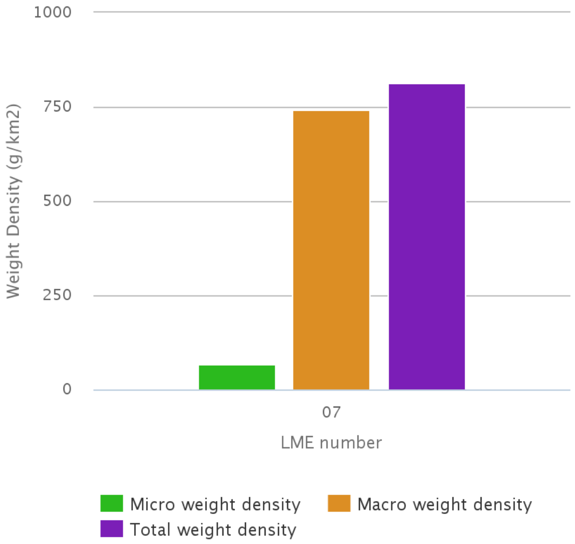
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
3	275	**4**	20	**3**	1.6	**1**

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 relatively high levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 100 times higher that those LMEs with lowest values. There is good evidence from sea-based direct observations and towed nets to support this conclusion.





Ecosystem Health

Mangrove and coral cover

Not applicable.

Reefs at risk

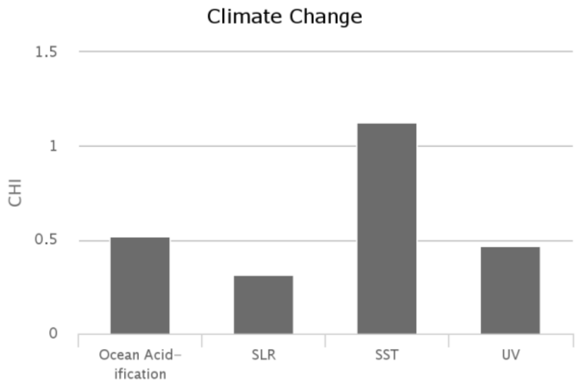
Not applicable.

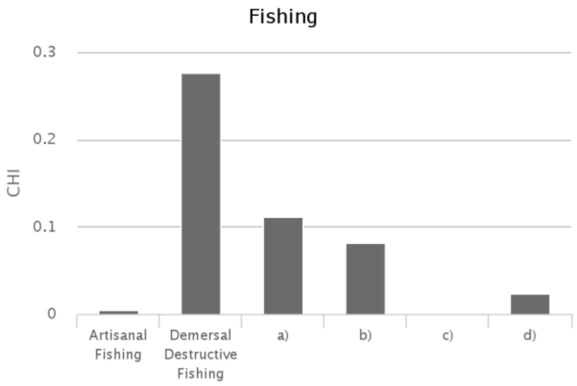
Marine Protected Area change

The Northeast U.S. Continental Shelf LME experienced an increase in MPA coverage from 1,366 km^2 prior to 1983 to 38,729 km^2 by 2014. This represents an increase of 2,734%, within the medium category of MPA change.

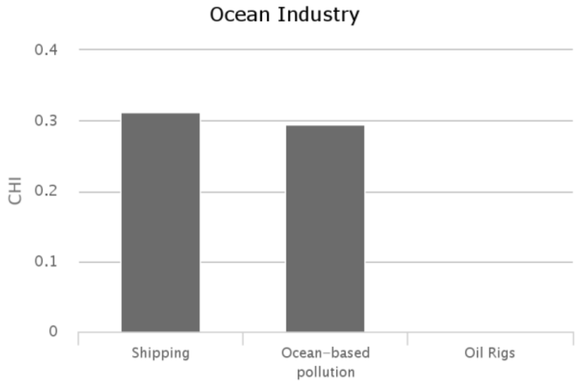
Cumulative Human Impact

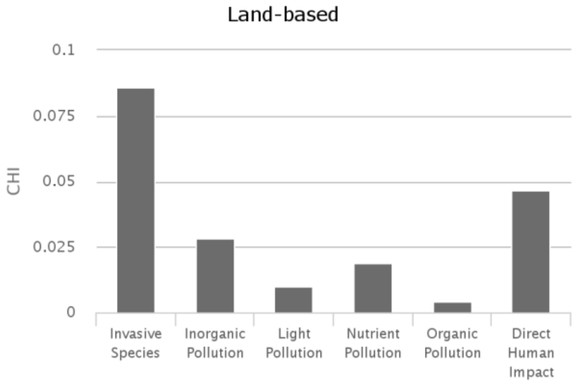
The Northeast US Continental Shelf LME experiences an above average overall cumulative human impact (score 3.73; maximum LME score 5.22), which is well above the LME with the least cumulative impact. It falls in risk category 3 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME 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: sea surface temperature (1.13; maximum in other LMEs was 2.16), ocean acidification (0.52; maximum in other LMEs was 1.20), UV radiation (0.47; maximum in other LMEs was 0.76), and sea level rise (0.31; maximum in other LMEs was 0.71). Other key stressors include commercial shipping, ocean based pollution, and all three types of demersal commercial fishing (destructive, non-destructive low-bycatch, and non-destructive high-bycatch).



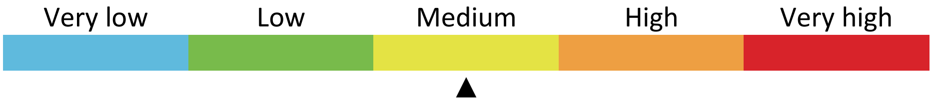


a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing



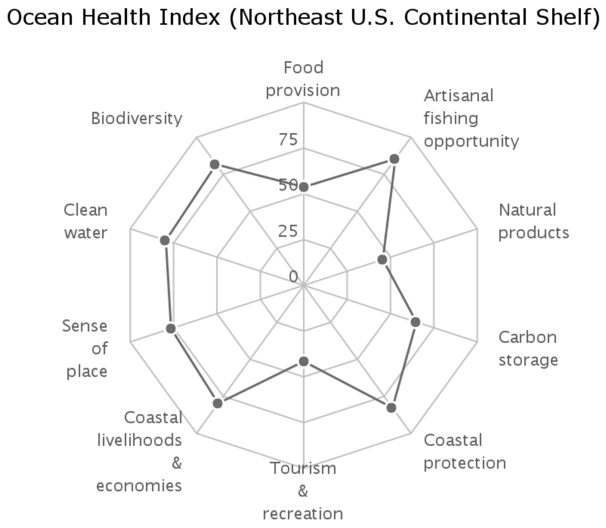


CHI: 3.73



Ocean Health Index

The Northeast US Continental Shelf LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82) but still relatively low. 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 8 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on food provision, natural products, carbon storage, coastal livelihoods, tourism & recreation, and iconic species goals and highest on artisanal fishing opportunities, coastal economies, lasting special places, and species diversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



OHI: 69.13

Very low	Low	Medium	High	Very high
🟫	🟨	🟩	🟩	🟦
			▲	

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 the Northeast U.S. Continental Shelf 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 includes the northeastern seaboard of the United States of America and the western shore of the Bay of Fundy in Canada, and stretches over 264,996 km^2. Its current population of 60 million is projected to increase by 13.6 million in 2100, and a density increasing from 227 persons per km^2 in 2010 to 278 per km^2 by 2100. About 9% of coastal population lives in rural areas, and is projected to decrease to 12% in 2100.

Total population		**Rural population**	
2010	**2100**	**2010**	**2100**
60,069,714	73,602,865	5,365,459	9,137,827

Legend:

🟦	Very low	🟩	Low	🟨	Medium	🟧	High	🟥	Very high

Coastal poor

The indigent population makes up 17% of the LME's coastal dwellers. The Northeast U.S. Continental Shelf places in the high-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
10,267,164

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Northeast U.S. Continental Shelf LME ranks in the highest revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $3,873 million for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $201,155 million places it in the highest revenue category as well. 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 the Northeast U.S. Continental Shelf LME falls in the category with lowest risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
3,872,613,421	7.4	203,155,000,000	8.4	🟦 0.5679

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 Northeast U.S. Continental Shelf LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.909, this LME has an HDI Gap of 0.091, 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). The Northeast U.S. Continental Shelf LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to place in the high risk category (low HDI) because of reduced income level and bigger population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.9093	🟦 0.9663	🟧 0.6973

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 to the Northeast U.S. Continental Shelf 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 low. In a sustainable development scenario, the risk index from sea level rise in 2100 is lowest, and which increases to high risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟩 0.5207	🟩 0.2967	🟦 0.2901	🟧 0.5878

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

None of the four transboundary fisheries agreements (NAFO, ICCAT, NASCO and NAMMCO) in this LME have formal linkages identified across the different stages of the policy cycle.

The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
🟩 **75**	🟨 **49**	🟥 **0**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 08 – Scotian Shelf

Bordering country: Canada
LME Total area: 412,676 km^2

List of indicators

LME overall risk

This LME falls in the cluster of LMEs that exhibit medium to high numbers of collapsed and overexploited fish stocks, high levels of demersal non-destructive low bycatch fishing, as well as very high shipping pressure.

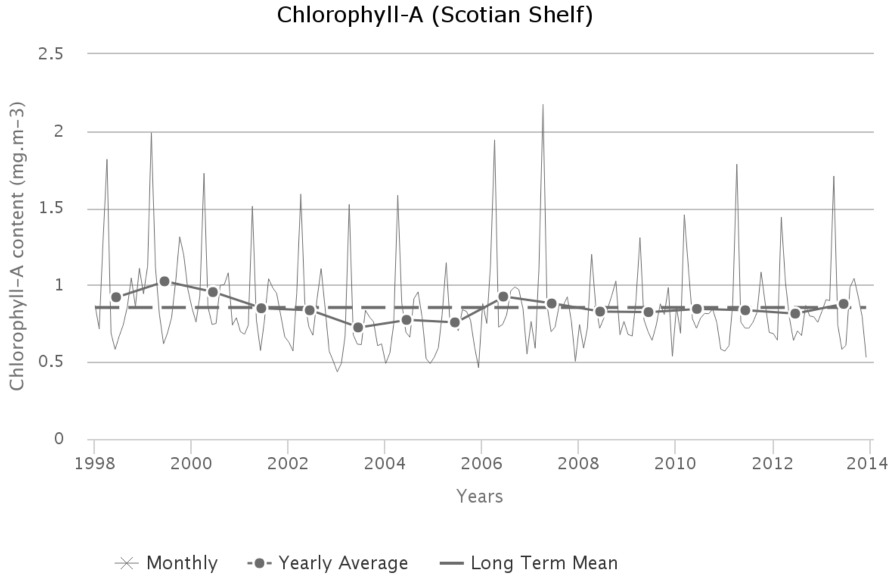
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥
	▲			

Productivity

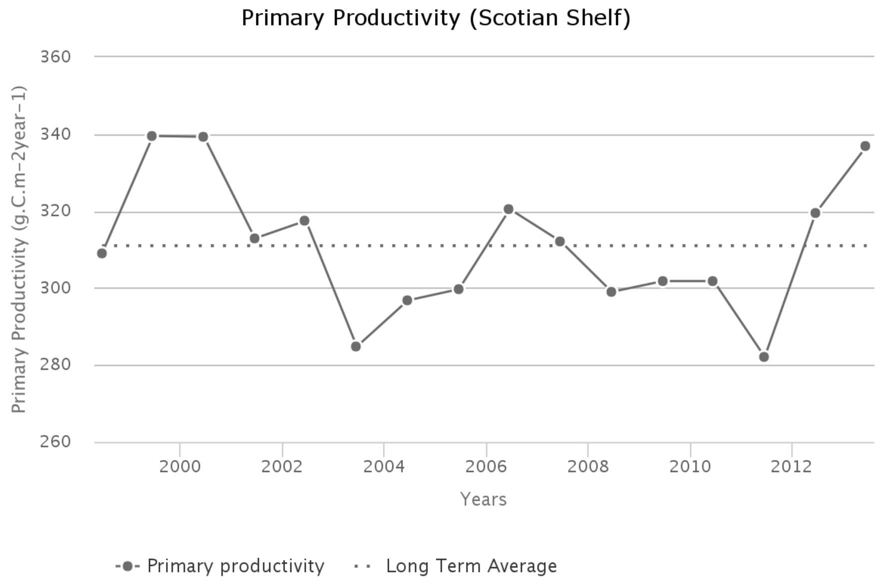
Chlorophyll-A

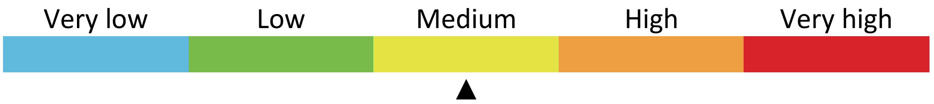
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (1.46 mg.m^{-3}) in April and a minimum (0.674 mg.m^{-3}) during June. The average CHL is 0.854 mg.m^{-3}. Maximum primary productivity (340 g.C.m^{-2}.y^{-1}) occurred during 1999 and minimum primary productivity (282 g.C.m^{-2}.y^{-1}) during 2011. There is a statistically significant increasing trend in Chlorophyll of 20.1 % from 2003 through 2013. The average primary productivity sis 311 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).



Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥
		▲		

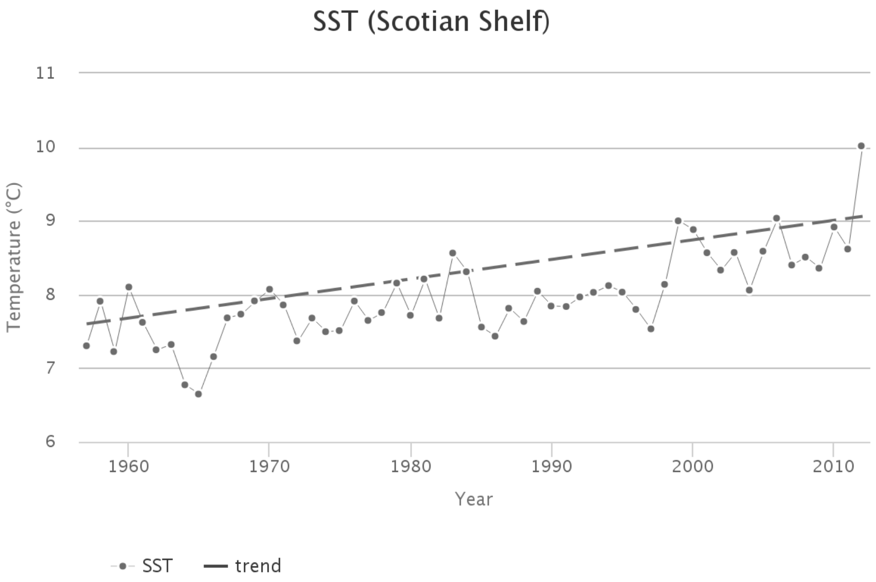
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Scotian Shelf LME #08 has warmed by 1.46°C, thus belonging to Category 1 (super-fast warming LME). The thermal history of the Scotian Shelf LME #08 is similar to that of the Northeast U.S. Continental Shelf LME #07. These LMEs are connected by the Slope Current, which flows southwestward along the shelf break and upper continental slope. This connection explains the observed similarities between thermal histories of these LME: first, the cold spell of the mid-1960s, with the all-time minimum of 6.7°C in 1965 over the Scotian Shelf; and the most recent warming until present. As in LME #07, the year of 1965 can be considered a true breakpoint between two regimes characterized by long-term cooling before 1965 and long-term warming after 1965. The post-1965 warming led to the all-time maximum of 10.0°C in 2012, hence a 3.3°C warming in 37 years, making the Scotian Shelf one of the fastest warming LMEs. Over the late 1990s, the Scotian Shelf's interannual variability was synchronized with that of the Northeast U.S. Continental Shelf LME #07 as evidenced by simultaneous minima in 1997, maxima in 1999, minima in 2004, and sharp increases from 2004 until present, in both LMEs. The most recent SST increase after 2004 led to the all-time maximum of 10.0°C in 2012, consistent and concurrent with the all-time maximum of 14.3°C in 2012 in the Northeast U.S. Shelf Continental LME #07 and the all-time maximum of 6.8°C in 2012 in the Newfoundland-Labrador Shelf LME #09.

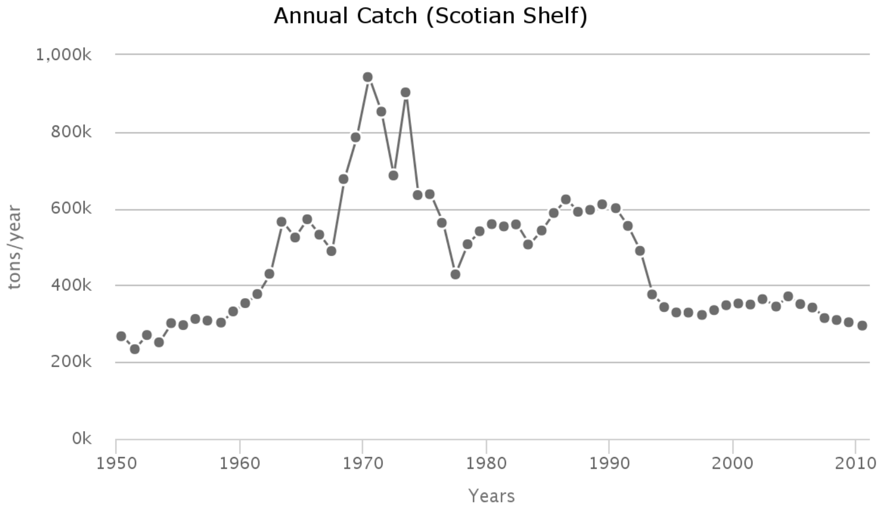


Fish and Fisheries

The commercially exploited species in this LME include capelin, turbot, Atlantic halibut, white hake, silver hake, cod, haddock and Pollock, while pelagic species include Atlantic herring and Atlantic mackerel. Invertebrates include snow crab, northern shrimp and short fin squid.

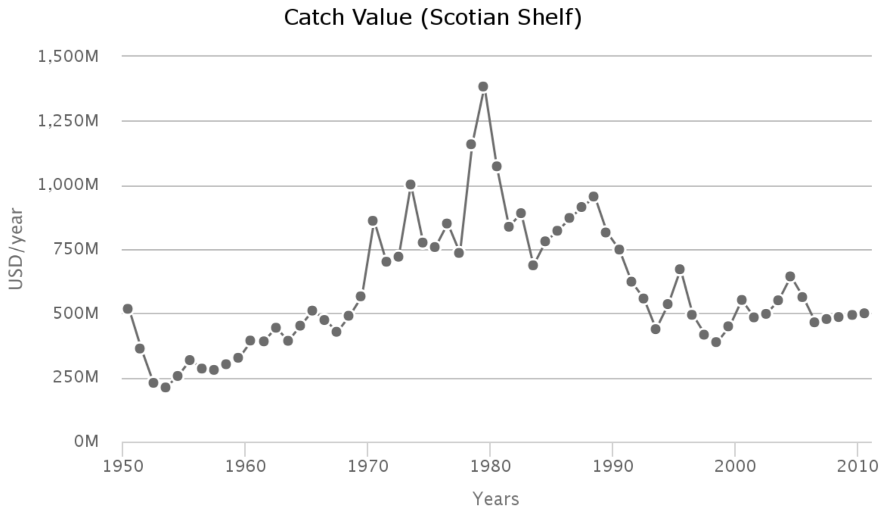
Annual Catch

Total reported landings recorded a peak of 940,000 t in 1970 and declined to about one third of this level or 300,000 t in recent few years. Major changes include a dramatic decline in landings of cod, sliver hake and redfish.



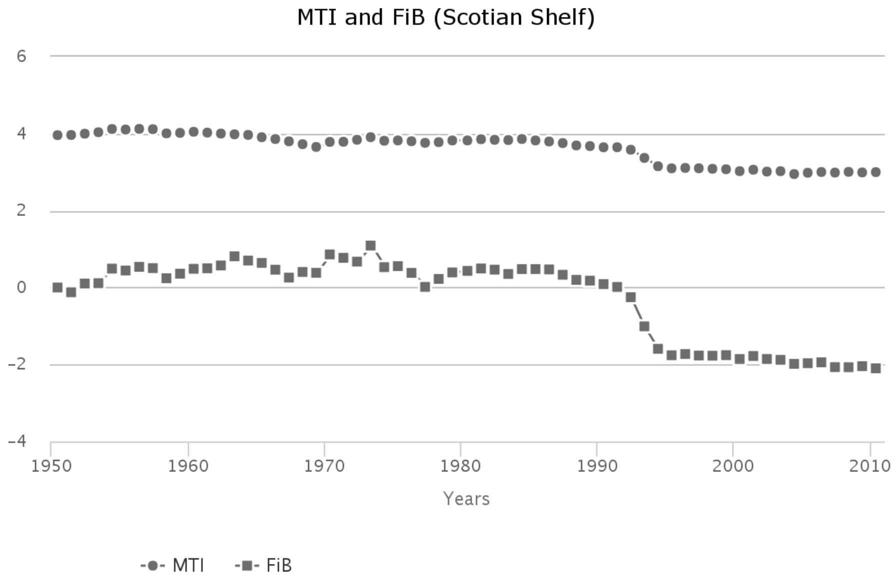
Catch value

However, the value of the reported landings reached its peak of 1.4 billion US$ (in 2005 real US$) in 1979, as a result of high value commanded by its landings of crustaceans.



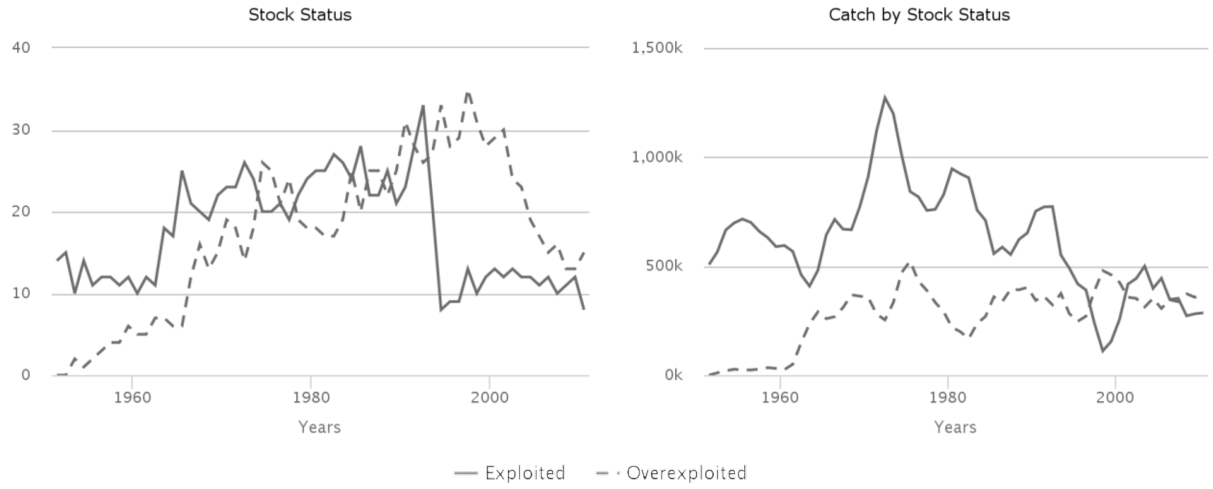
Marine Trophic Index and Fishing-in-Balance index

The MTI remained high until the early 1990s, when the cod stock collapsed, a clear case of ‘fishing down’ of the food web. The FiB index showed a similar trend, suggesting that the reported landings of lower-trophic level organisms did not compensate for the decline in the MTI over that period.



Stock status

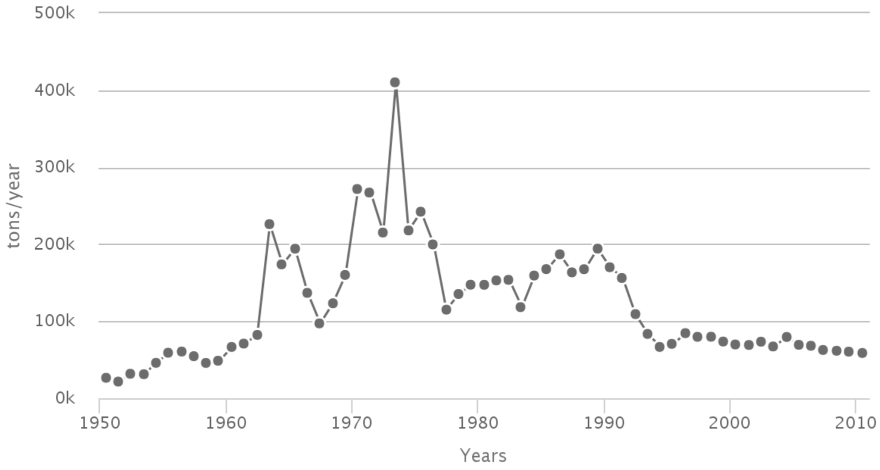
The Stock-Catch Status Plot shows that over 70% of commercially exploited stocks in the LME are either overexploited or have collapsed, with about 40% of the reported landings biomass supplied by fully exploited stocks.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 45% in 1973 and then this percentage fluctuated around 20% in the recent decade.

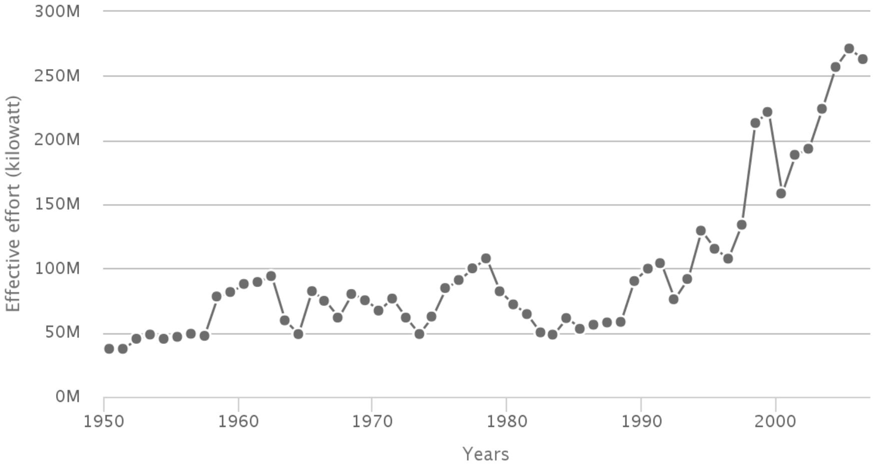
Catch from bottom impacting gear (Scotian Shelf)



Fishing effort

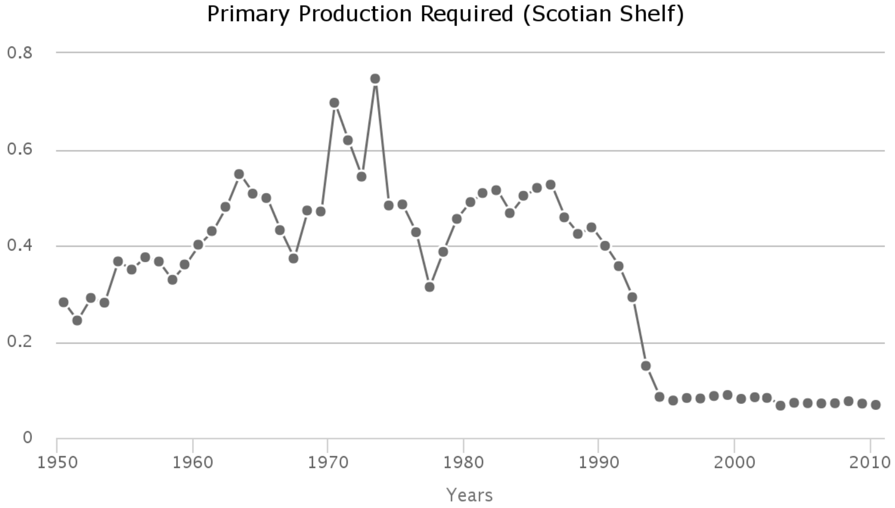
The total effective effort increased steadily from around 10 million kW in the mid-1950s to its peak at 270 million kW in 2005.

Fishing effort (Scotian Shelf)



Primary Production Required

The primary production required (PPR) to sustain the reported landings in this LME exceeded the observed primary production in the mid-1970s, but has declined in recent years. The extremely high PPR recorded in the mid-1970s was likely due to the accumulated biomass of cod stocks being exploited and not from exploitation of annual surplus production.



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 1of 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 very low (1). According to the Global Orchestration scenario, this increased to low in 2030 and decreased back to very low in 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	1	1	1	2	1	1	1	1

Legend:

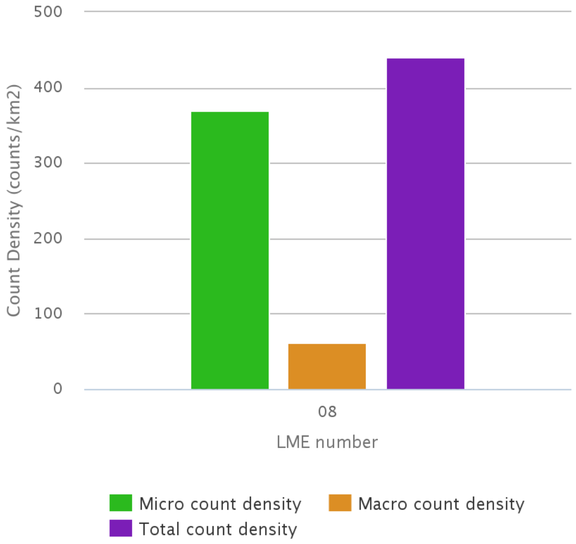
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

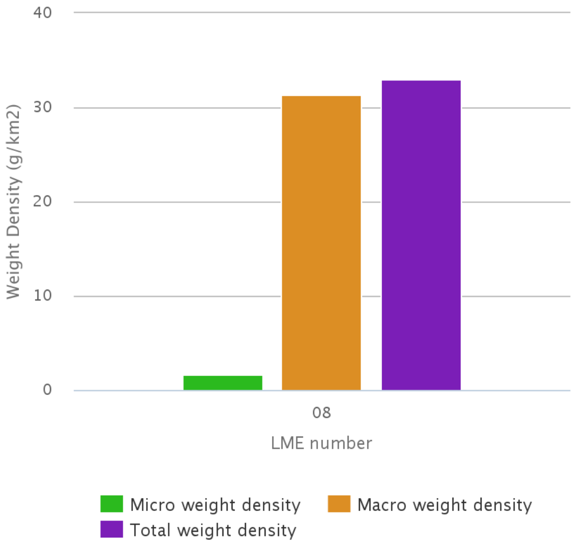
POPs

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

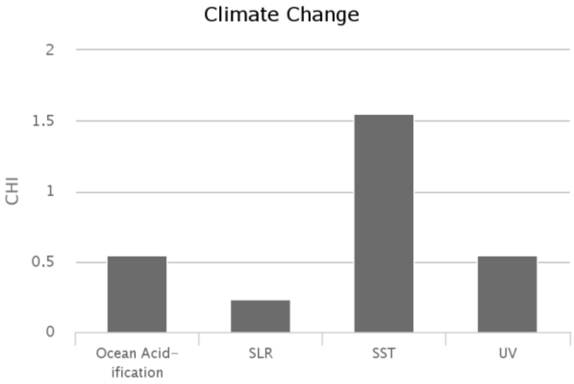
Not applicable

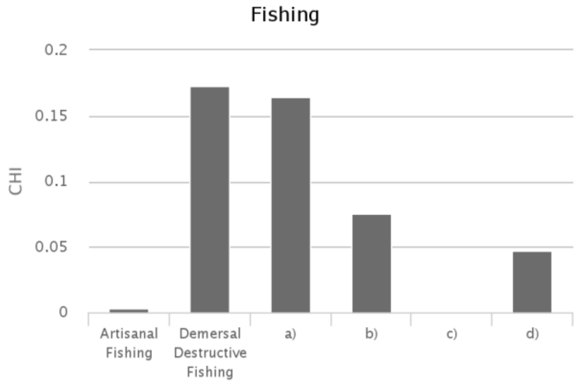
Marine Protected Area change

The Scotian Shelf LME experienced an increase in MPA coverage from 70 km^2 prior to 1983 to 1,576 km^2 by 2014. This represents an increase of 2,154%, within the medium category of MPA change.

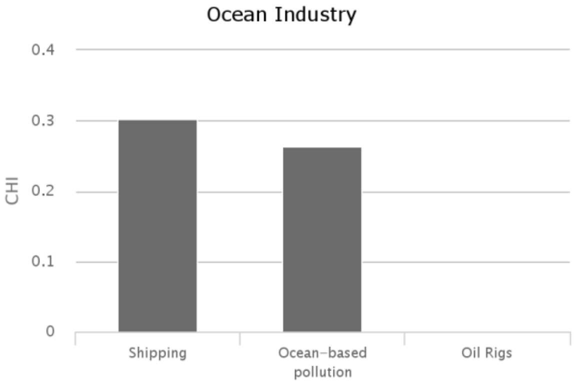
Cumulative Human Impact

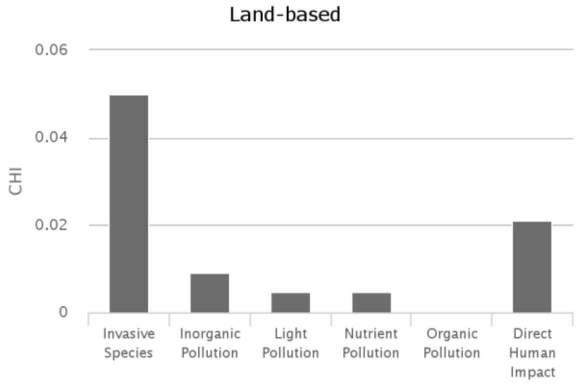
The Scotian Shelf LME experiences an above average overall cumulative human impact (score 4.0; maximum LME score 5.22), which is well above the LME with the least cumulative impact. It falls in risk category 4 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.55; maximum in other LMEs was 1.20), UV radiation (0.55; maximum in other LMEs was 0.76), and sea surface temperature (1.56; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, sea level rise, ocean based pollution, demersal destructive commercial fishing, and demersal non-destructive high-bycatch commercial fishing.



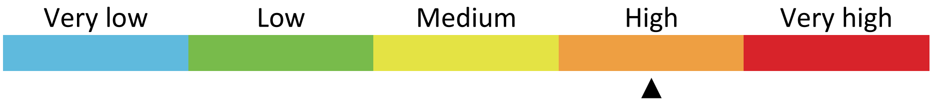


a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing



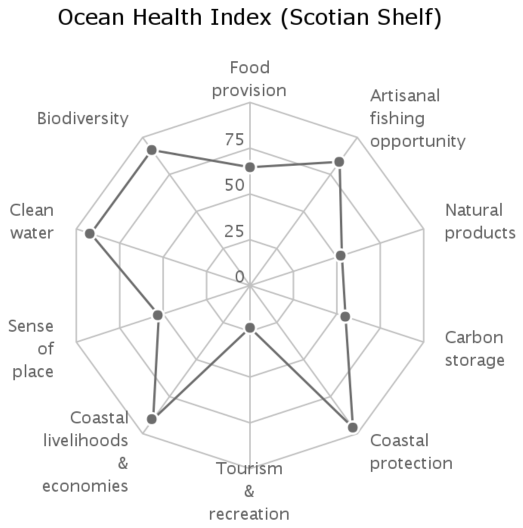


CHI: 4.00



Ocean Health Index

The Scotian Shelf 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 well below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 2 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on natural products, carbon storage, tourism & recreation, and lasting special places goals and highest on mariculture, artisanal fishing opportunities, coastal protection, coastal economies, and 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).



OHI: 70.09

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 the Scotian Shelf 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 includes those of Nova Scotia, Cape Breton and Prince Edward Islands, stretching over 130,408 km^2. A current population of 1.7 million is projected to decrease to 914,000 in 2100, and a density decreasing from 13 persons per km^2 in 2010 to 7 per km^2 by 2100. About 27% of coastal population lives in rural areas, and is projected to decrease to 25% in 2100.

Total population		Rural population	
2010	**2100**	**2010**	**2100**
1,700,948	913,809	453,719	230,087

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 12% of the LME's coastal dwellers. The Scotian Shelf places in the low-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
202,883

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Scotian Shelf LME ranks in the medium revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $613 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 2013 $5,173 million places it in the low revenue category. On average, LME-based tourism income contributes 5% 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 the Scotian Shelf LME falls in the category with low risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
613,964,143	9.7	5,173,178,265	5.2	0.6740

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 Scotian Shelf LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.899, this LME has an HDI Gap of 0.101, 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). The Scotian Shelf LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is estimated to place in the low risk category (low HDI) because of reduced income level and smaller population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
0.8986	0.9740	0.7712

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 to the Scotian Shelf 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 low. In a sustainable development scenario, the risk index from sea level rise in 2100 is lowest, and which increases to low risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.3948	0.2457	0.2368	0.4765

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

None of the four transboundary fisheries agreements (NAFO, ICCAT, NAMMCO and NASCO) in this LME have formal linkages identified across the different stages of the policy cycle.

The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
63	**50**	**0**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 09 – Newfoundland-Labrador Shelf

Bordering countries: Canada, France (Saint Pierre et Miquelon)
LME Total area: 674,862 km^2

List of indicators

LME overall risk

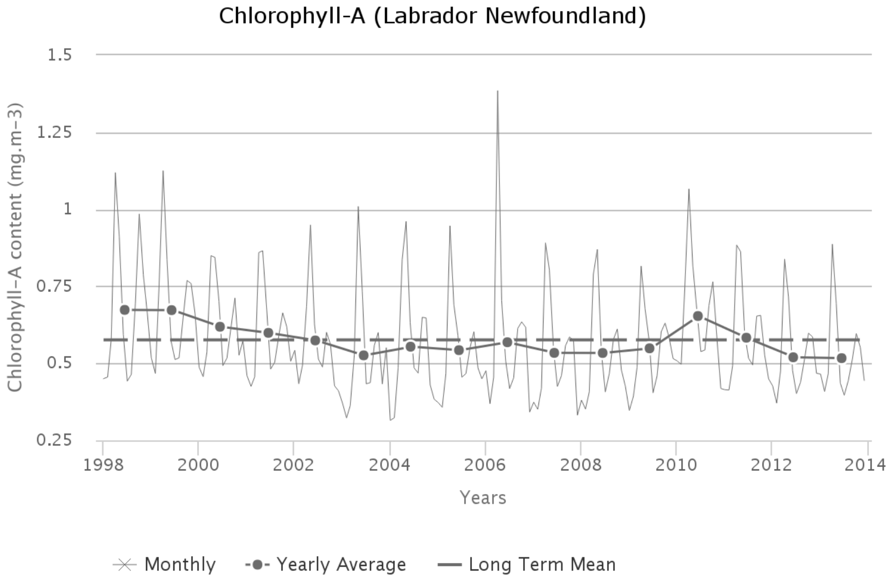
This LME falls in the cluster of LMEs that exhibit medium numbers of collapsed and overexploited fish stocks, as well as very high proportions of catch from bottom impacting gear.

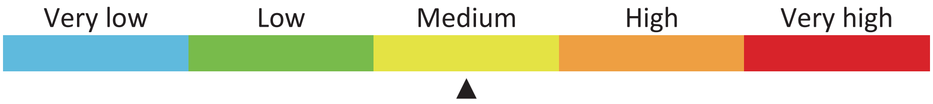
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Productivity

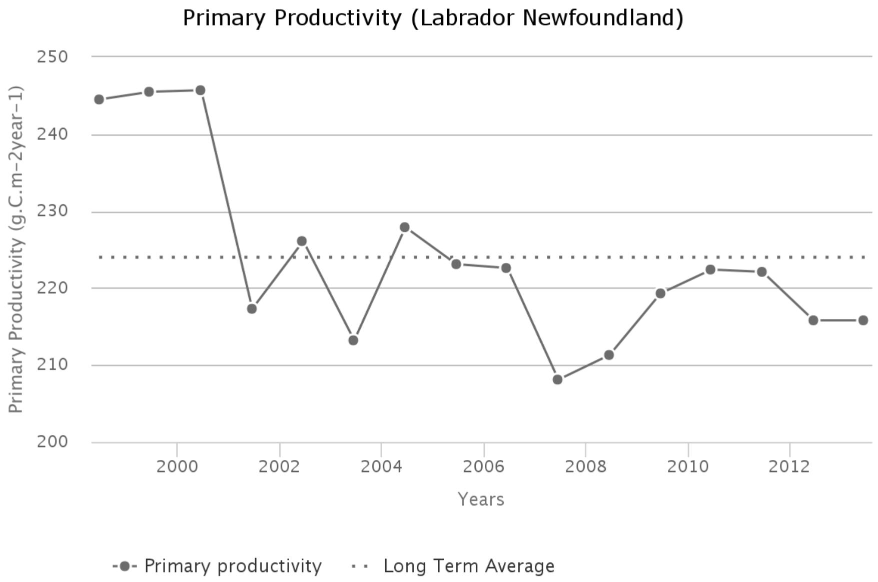
Chlorophyll-A

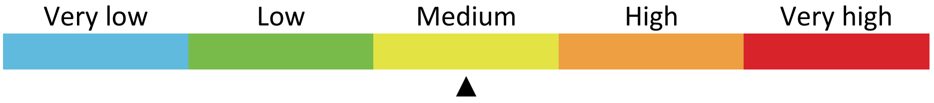
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.802 mg.m^{-3}) in April and a minimum (0.385 mg.m^{-3}) during February. The average CHL is 0.576 mg.m^{-3}. Maximum primary productivity (246 g.C.m^{-2}.y^{-1}) occurred during 2000 and minimum primary productivity (208 g.C.m^{-2}.y^{-1}) during 2007. There is a statistically significant increasing trend in Chlorophyll of 13.4 % from 2003 through 2013. The average primary productivity is 224 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





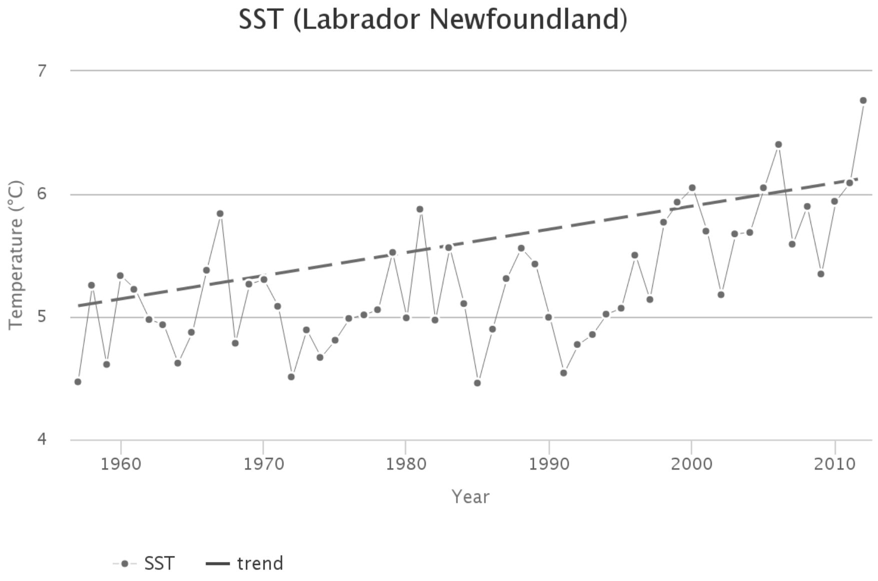
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Newfoundland-Labrador Shelf LME #9 has warmed by 1.04°C, thus belonging to Category 2 (fast warming LME). During this period, two epochs transpired. The first, relatively stable epoch lasted through 1991. During that time, SST remained rather cold, between 4.5°C and 5.9°C, after which, during the second, warming epoch, SST rose from 4.6°C in 1991 to the all-time maximum of 6.8°C in 2012, an increase of 2.2°C in 21 years. The rapid SST increase over the Newfoundland-Labrador Shelf in the 1990s-2000s is a local manifestation of a large-scale Subarctic Gyre warming, which is amply documented (Stein, 2005, 2007; Hughes and Holliday, 2007; DFO, 2007; Petrie et al., 2007a, 2007b). The long-term variability of SST in LME #9 correlates strongly with that in LME #8 (Scotian Shelf) since these two LMEs are linked by the Labrador Current. The minima of 1972, 1985 and 1991 may have been associated with large-scale cold, fresh anomalies termed "Great Salinity Anomalies" or GSAs (Dickson et al., 1988; Belkin et al., 1998; Belkin, 2004).

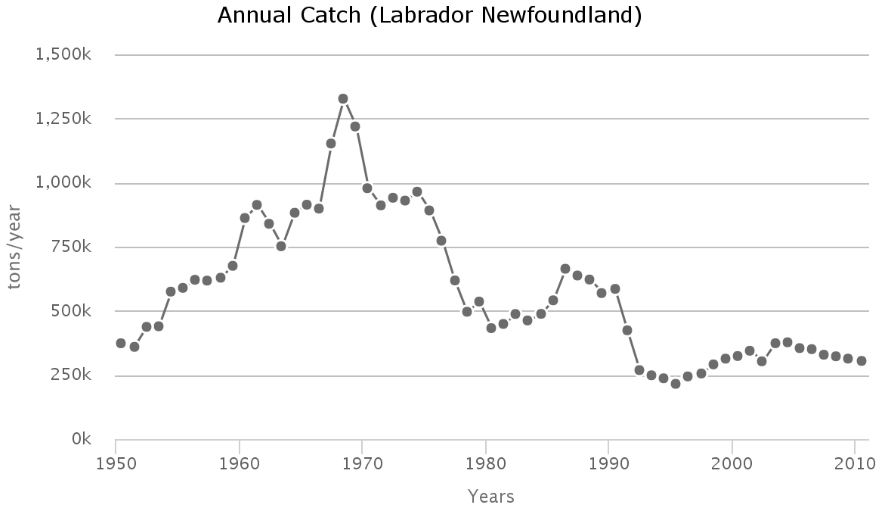


Fish and Fisheries

Commercially exploited fish species in this LME include cod, haddock, salmon, American plaice, redfish, yellowtail and halibut. Also harvested are lobster, shrimp and crab.

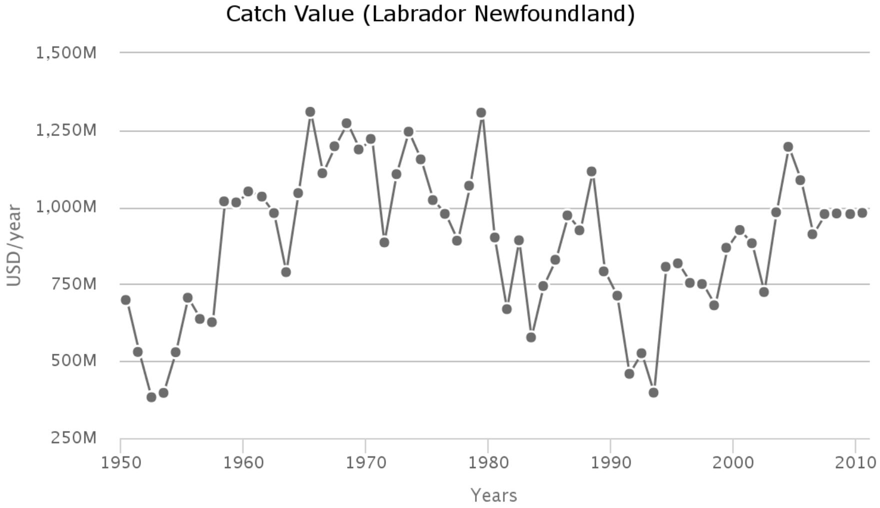
Annual Catch

Total reported landings, which were dominated by cod until the 1990s, exceeded 1 million t from 1967 to 1969, but have since declined to around 320,000 t in recent years. Cod landings, in particular, declined from a historic high of over 1 million t in 1968 to less than 15,000 t per year in recent years (2006 – 2010) with landings of less than 10,000 t recorded in 1995 and 1996.



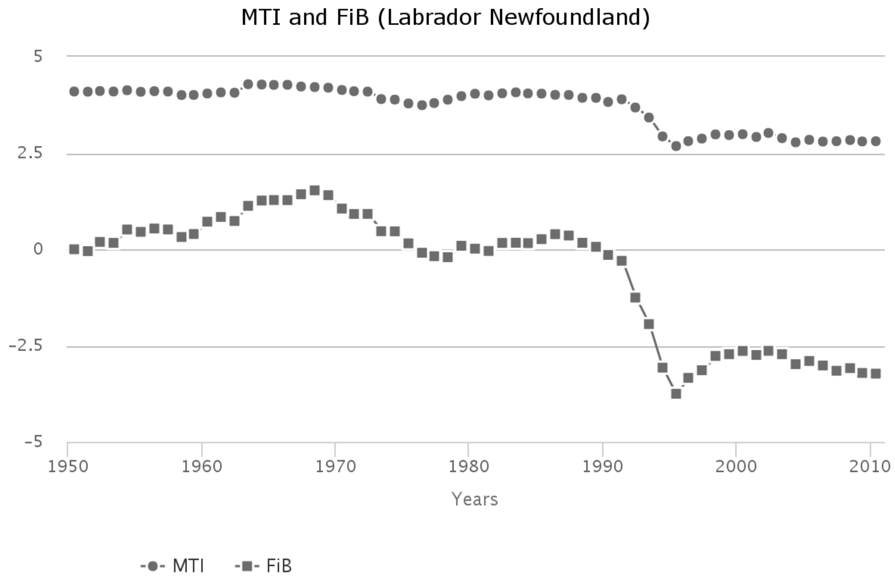
Catch value

The reported landings of the LME were valued at over 1.2 billion US$ (in 2005 real US$) in the late 1960s, most of which was attributed to cod landings; in recent years, similarly high values are generated by its invertebrate landings.



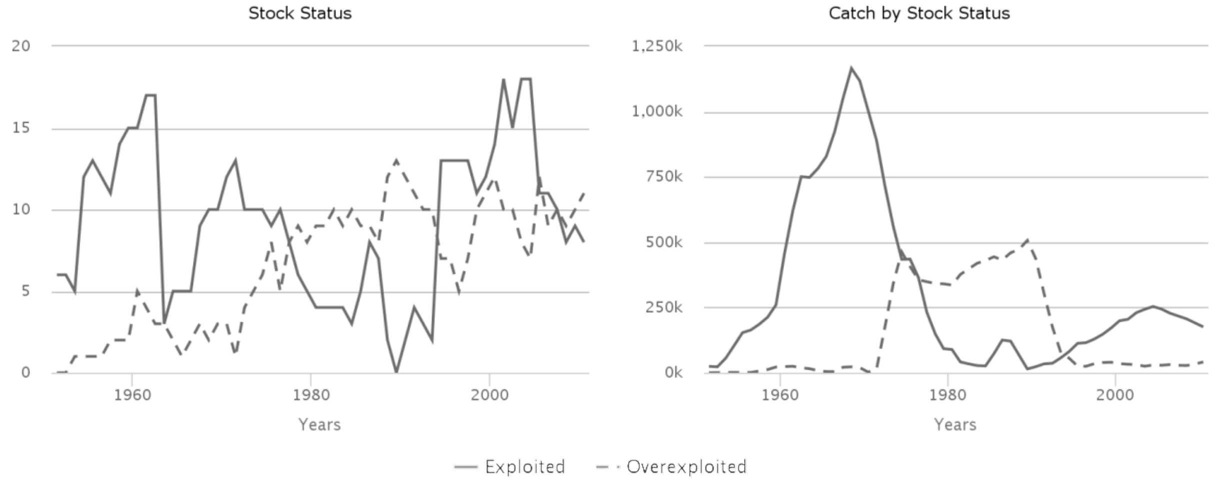
Marine Trophic Index and Fishing-in-Balance index

The MTI remained high until the 1990s, when the cod stock began to collapse, a clear case of 'fishing down' the food web in the LME. The FiB index shows a similar trend, indicating that the reported landings did not compensate for the decline in the MTI over that period.



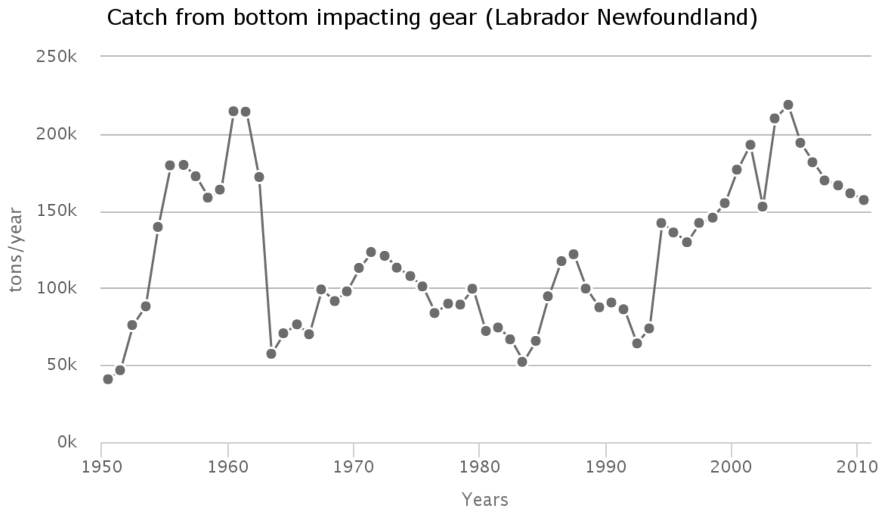
Stock status

The Stock-Catch Status Plots shows that about 50% of commercially exploited stocks in the LME have collapsed with another 20% overexploited. Over 50% of the reported landings biomass is now supplied by fully exploited stocks.



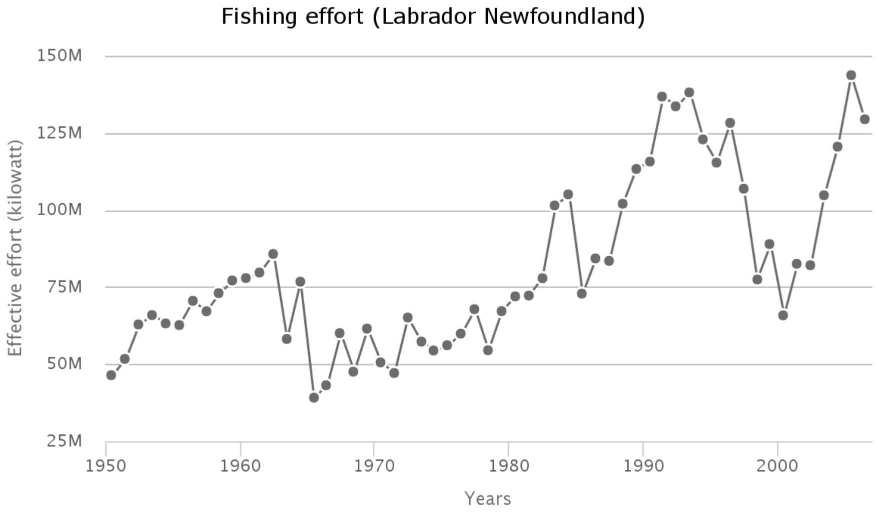
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch ranged between 6 to 30% from 1950 to early 1990s. Then, this percentage increased sharply to its peak at 60% in 1994. After that, this percentage dropped slightly and fluctuated between 50 and 60% in the recent two decades.



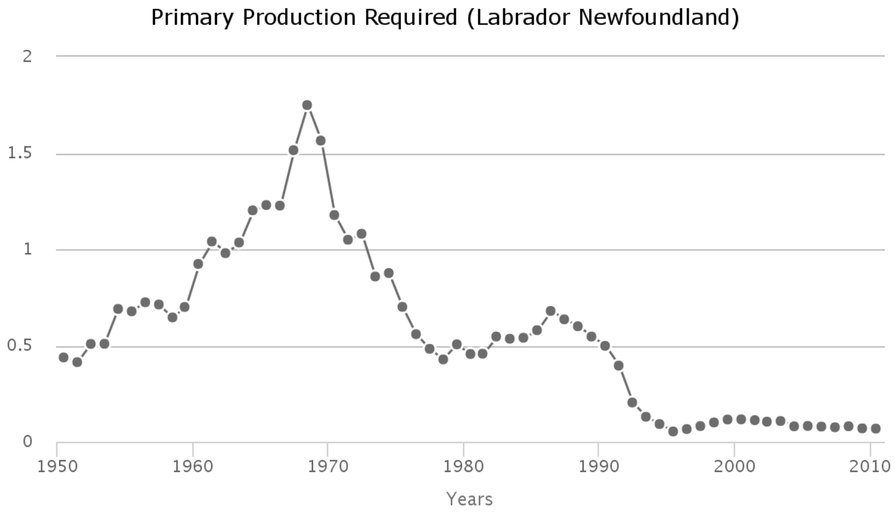
Fishing effort

The total effective effort increased steadily from around 60 million kW in the 1950s to its peak at 143 million kW in the mid-2000s.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME reached 60 % of the observed primary production in the mid-1960s, but has declined in recent years.


Primary Production Required (Labrador Newfoundland)

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 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 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 moderate (3). 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
3	3	3	3	3	3	3	3	3

Legend:

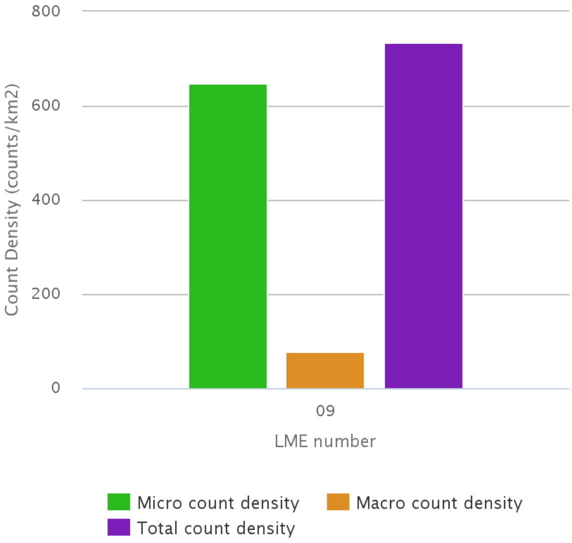
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

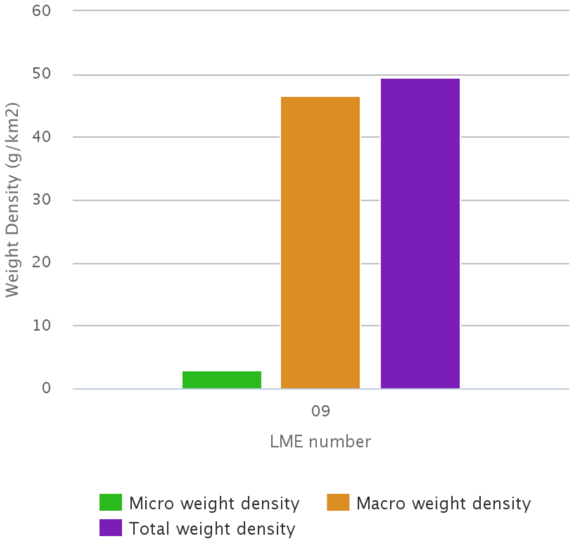
POPs

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 relatively low levels of 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 relative remoteness of this LME from significant sources of plastic. The abundance of floating plastic in this category is estimated to be on average over 40 times lower that 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

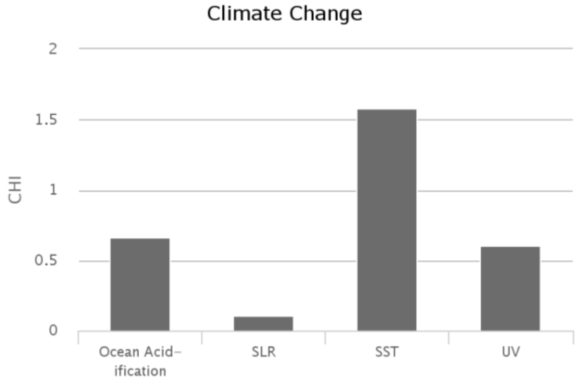
Not applicable.

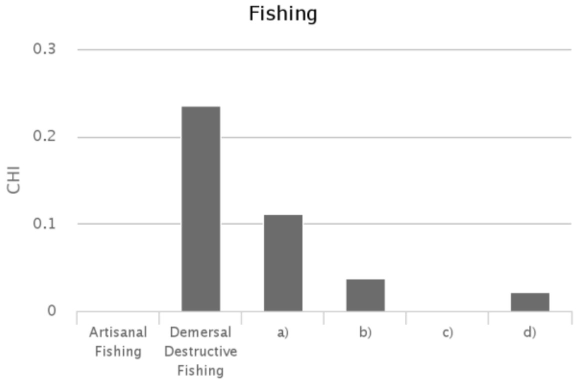
Marine Protected Area change

The Labrador, Newfoundland LME experienced an increase in MPA coverage from 541 km^2 prior to 1983 to 2,882 km^2 by 2014. This represents an increase of 432%, within the low category of MPA change.

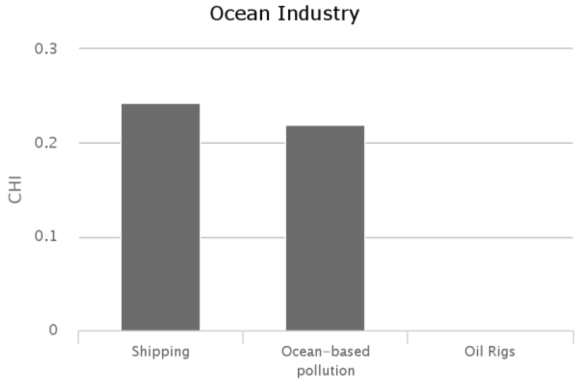
Cumulative Human Impact

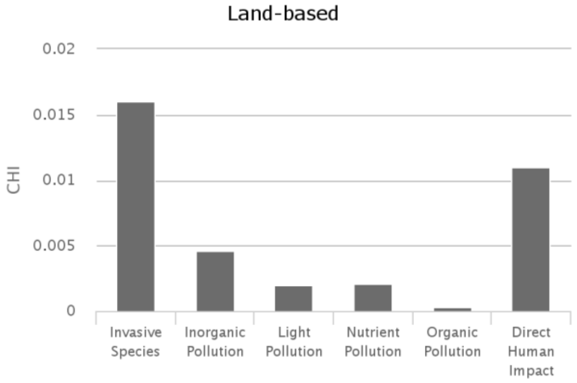
The Labrador – Newfoundland LME experiences an above average overall cumulative human impact (score 3.86; maximum LME score 5.22), which is well above the LME with the least cumulative impact. It falls in risk category 4 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.67; maximum in other LMEs was 1.20), UV radiation (0.61; maximum in other LMEs was 0.76), and sea surface temperature (1.58; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, ocean based pollution, demersal destructive commercial fishing, and demersal non-destructive high-bycatch commercial fishing.

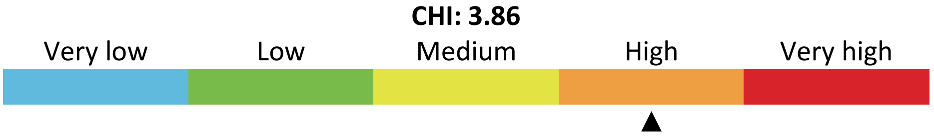




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

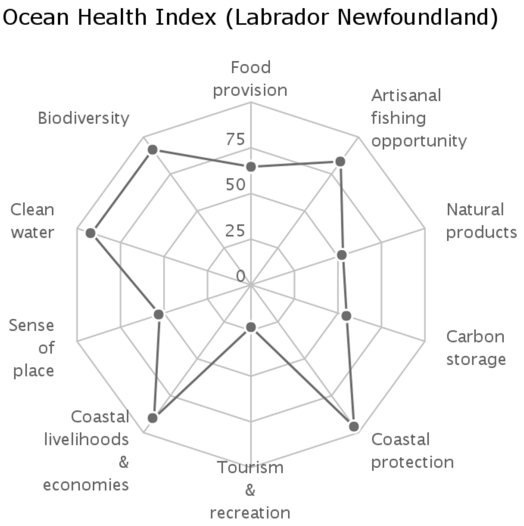






Ocean Health Index

The Labrador – Newfoundland 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 well below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 2 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on natural products, carbon storage, tourism & recreation, and lasting special places goals and highest on mariculture, artisanal fishing opportunities, coastal protection, coastal economies, and 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).



OHI: 70.09

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 the Newfoundland-Labrador Shelf 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 includes Newfoundland Island, the coast of mainland Labrador, and the eastern shore of Quebec, stretching over 510,676 km^2. A current population of 2.5 million is projected to decrease to 1.8 million in 2100, with density decreasing from 5 persons per km^2 in 2010 to 4 per km^2 by 2100. About 24% of coastal population lives in rural areas, and is projected to increase to 25% in 2100.

Total population		Rural population	
2010	2100	2010	2100
2,534,731	1,844,035	618,707	472,500

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 12% of the LME's coastal dwellers. The Newfoundland-Labrador Shelf places in the medium-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
301,613

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Newfoundland-Labrador Shelf LME ranks in the high revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $1154 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 2013 $1483 million places it in the lowest revenue category. On average, LME-based tourism income contributes 5% 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 the Newfoundland-Labrador Shelf LME falls in the category with low risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
1,154,435,733	9.7	1,483,428,330	5.2	🟩 0.6794

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 Newfoundland-Labrador Shelf LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.899, this LME has an HDI Gap of 0.101, 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). The Newfoundland-Labrador Shelf LME is projected to maintain its position in the lowest risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is estimated to place in the low risk category (low HDI) because of reduced income level and smaller population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.8986	🟦 0.9740	🟩 0.7712

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 to the Newfoundland-Labrador Shelf LME is within the lowest-risk (lowest 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 lowest, and remains the same under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.3988	0.2465	0.2359	0.4746

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

None of the four transboundary fisheries agreements (NAFO, ICCAT, NAMMCO and NASCO) in this LME have formal linkages identified across the different stages of the policy cycle.

The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
63	**50**	**0**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 11 – Pacific Central American Coastal

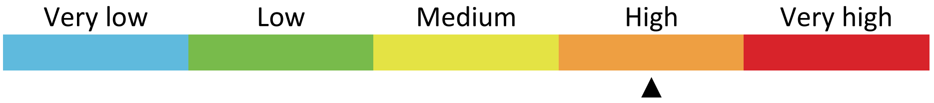
Bordering countries: Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru
LME Total area: 1,996,659 km^2

List of indicators

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.

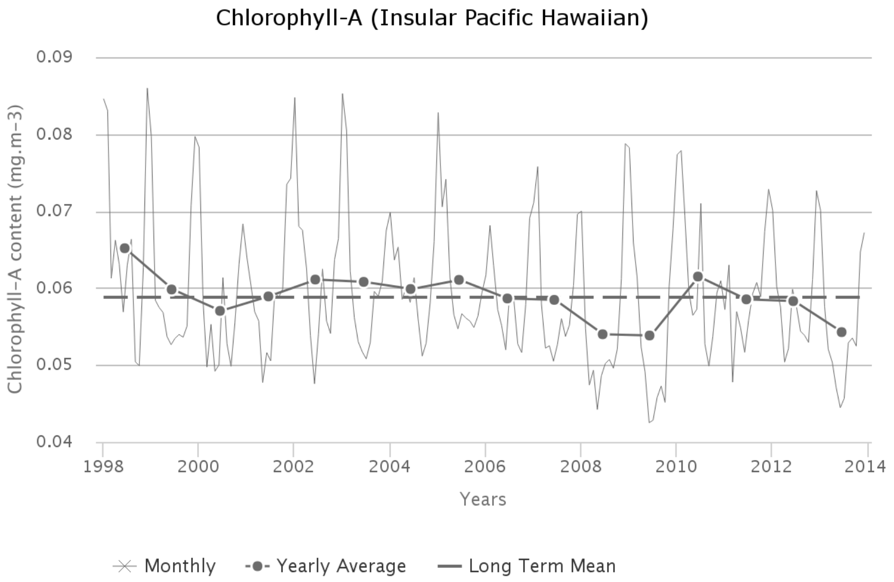
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is high.



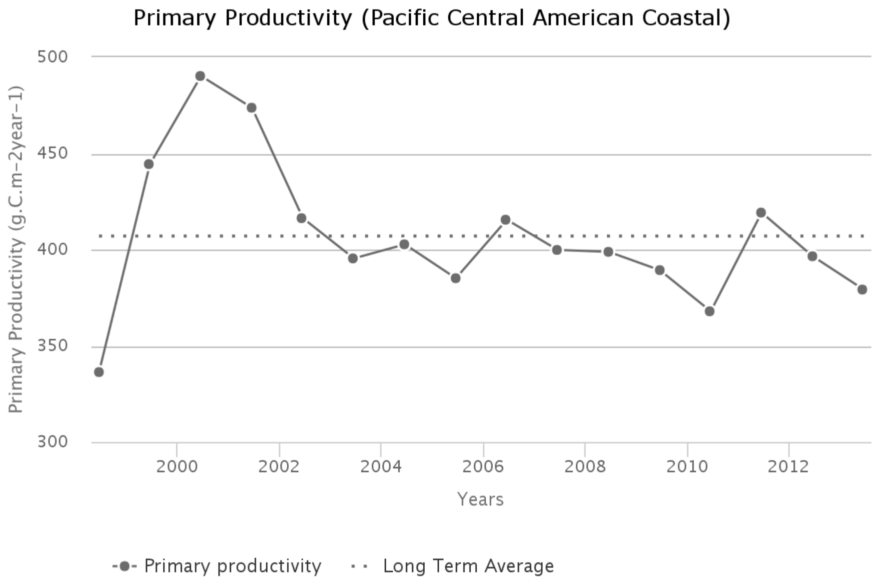
Productivity

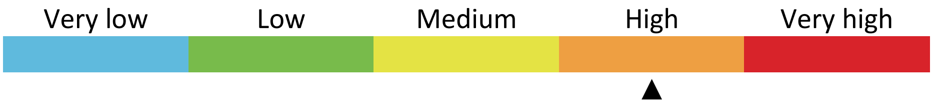
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.343 mg.m^{-3}) in March and a minimum (0.230 mg.m^{-3}) during August. The average CHL is 0.281 mg.m^{-3}. Maximum primary productivity (490 g.C.m^{-2}.y^{-1}) occurred during 2000 and minimum primary productivity (336 g.C.m^{-2}.y^{-1}) during 1998. There is a statistically insignificant increasing trend in Chlorophyll of 15.2 % from 2003 through 2013. The average primary productivity is 407 g.C.m^{-2}.y^{-1}, which places this LME in Group 4 of 5 categories (with 1 = lowest and 5= highest).



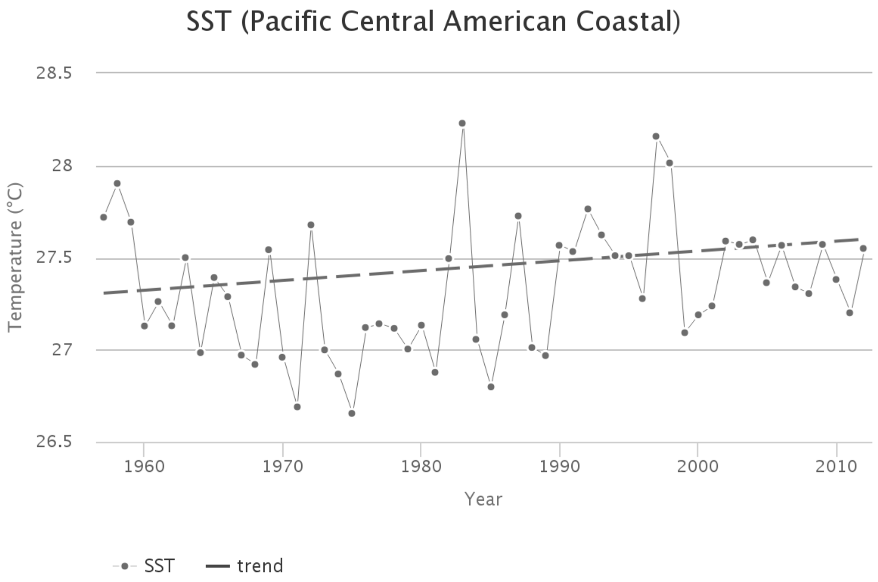
Primary productivity





Sea Surface Temperature

Between 1957 and 2012, the Pacific Central-American Coastal LME #11 has warmed by 0.27C, thus belonging to Category 4 (slow warming LME). The thermal history of this LME was non-monotonous. The cooling phase culminated in two minima, in 1971 and 1975, both associated with major La Niñas (National Weather Service/Climate Prediction Center, 2007), after which SST rose by approximately 1°C over the next 30 years. The absolute minimum of 1975 was synchronous with absolute minima in two other East Pacific LMEs: California Current LME #3 and Gulf of California LME #4. It also was roughly synchronous with the absolute minimum of 1974-1976 on the other side of the Central American Isthmus, in the Caribbean LME #12. The warming phase was accentuated by two sharp peaks, in 1983 and 1997, both associated with major El Niños (National Weather Service/Climate Prediction Center, 2007). Similar warm events were observed in other East Pacific LMEs, namely the Humboldt Current LME #13, Gulf of California LME #4, and California Current LME #3. All significant maxima and minima of SST observed in the Pacific Central-American Coastal LME #11 are associated with El Niños and La Niñas respectively (National Weather Service/Climate Prediction Center, 2007).

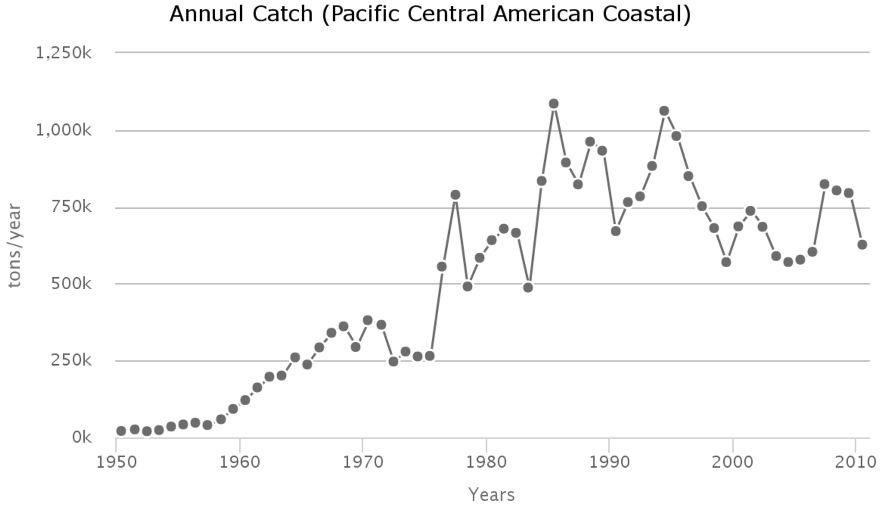


Fish and Fisheries

The Pacific Central-American Coastal LME is rich in both pelagic and demersal fisheries resources. The most valuable fisheries in the region are offshore tunas and coastal penaeid shrimps, whose landed fish bycatch is usually not reported. More than 50% of the reported shelf catches consists of small coastal pelagic species such as anchoveta (*Engraulis ringens* and *Cetengraulis mysticetus*), Pacific sardine (*Sardinops sagax*) and Pacific thread herring (*Opisthonema libertate*), most of which are used for fishmeal and fish-oil.

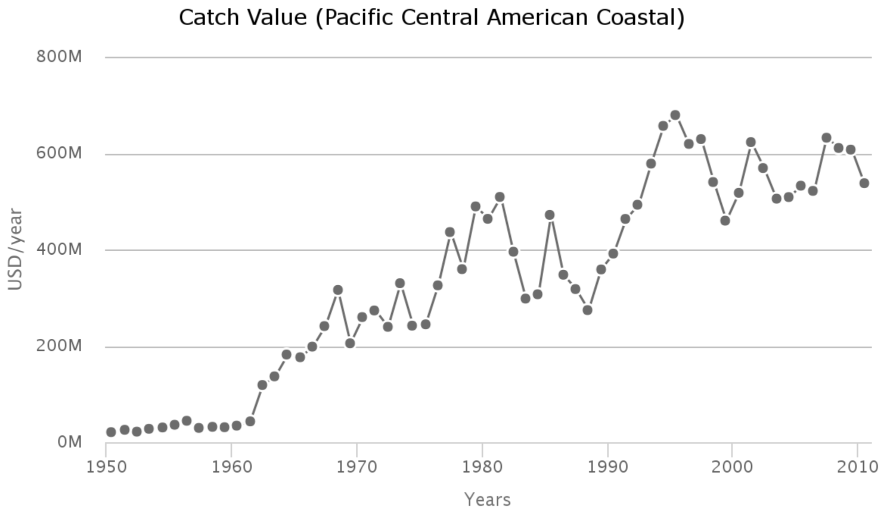
Annual Catch

Total reported landings have risen, with some fluctuations, to peak landings of 1 million t in 1985.



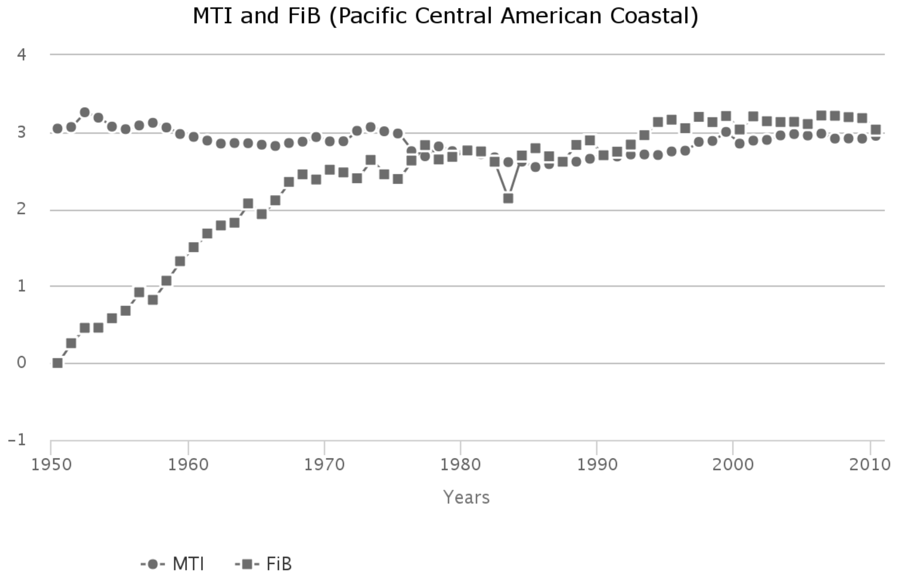
Catch value

Fluctuations in the value of the reported landings correspond with the landings, with a peak of 680 million US$ (in 2005 real US$) recorded in 1995.



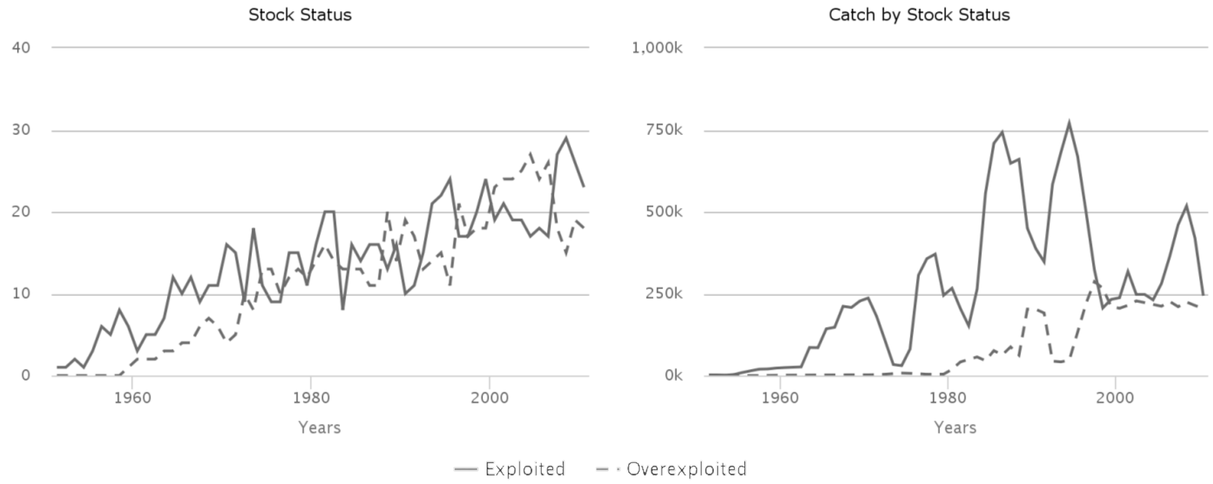
Marine Trophic Index and Fishing-in-Balance index

The MTI is relatively low, and shows a declining trend until the mid-1980s, after which a slight increasing trend became apparent. The FiB index has increased, indicating that whatever "fishing down" may be occurring in the LME would be masked by either the geographic (offshore) expansion of the fisheries or the incompleteness of the underlying catch statistics.



Stock status

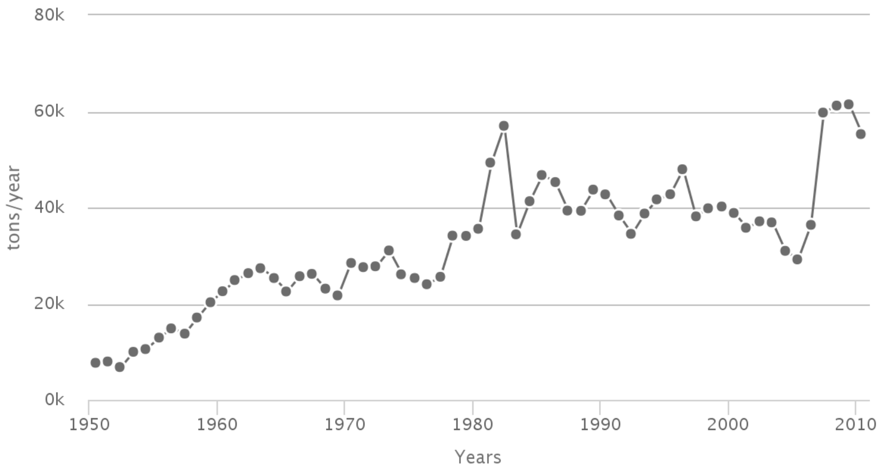
The Stock-Catch Status Plots indicate that the number of collapsed and overexploited stocks are rapidly increasing in the LME. Approximately 40% of the reported landings are supplied by fully exploited stocks.


Stock Status

Catch by Stock Status

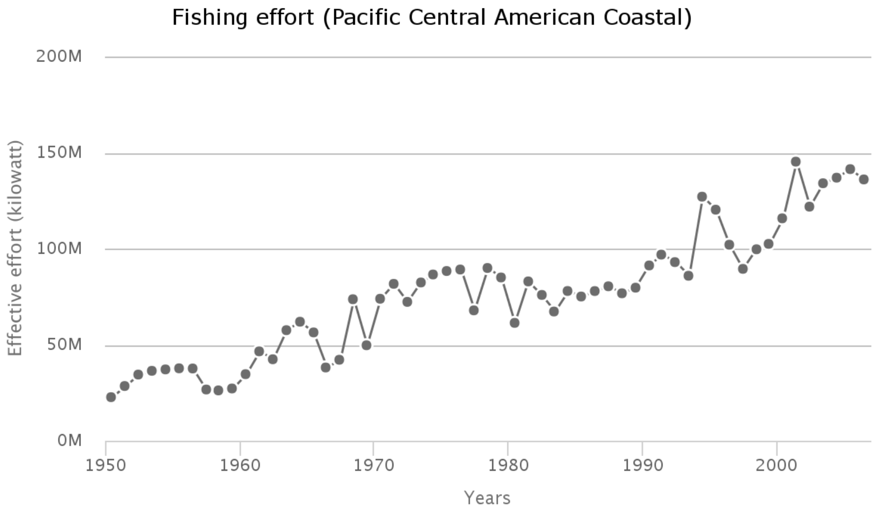
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its maximum at 40% in 1953 and then this percentage declined steadily. This percentage ranged between 5 and 9% in the recent decade.


Catch from bottom impacting gear (Pacific Central American Coastal)

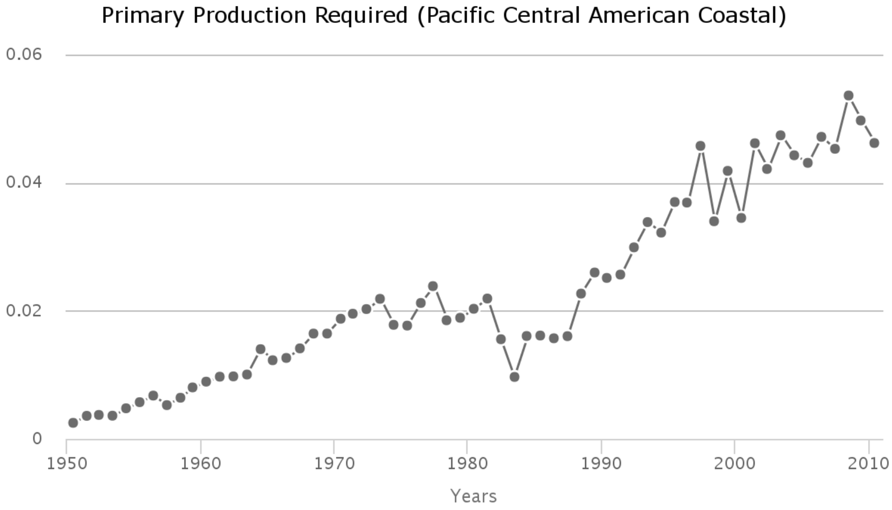
Fishing effort

The total effective effort increased steadily from around 30 million kW in the 1950s to its peak at 145 million kW in early 2000s.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in this LME reached 5% of the observed primary production in 2002.



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 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 very low (1). 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 moderate (3). 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
3	1	3	3	1	3	3	1	3

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

Data are available for only two samples at two locations in Costa Rica and Panama. These locations show low concentration for all the indicators. The average concentration (ng.g-1 of pellets) was 5 (range 2 – 7 ng.g-1) for PCBs, 5 (range 5 – 6 ng.g-1) for DDTs, and 0.1 (range 0.04 – 0.3 ng.g-1) for HCHs. The PCBs and HCHs averages correspond to risk category 1 and DDTs average corresponds to risk category 2, of the five risk categories (1 = lowest risk; 5 = highest risk). This is probably due to minimal anthropogenic activities involving the use of POPs (PCBs in industries and DDT and HCH pesticides in agriculture). More samples and locations are necessary to properly evaluate this LME.

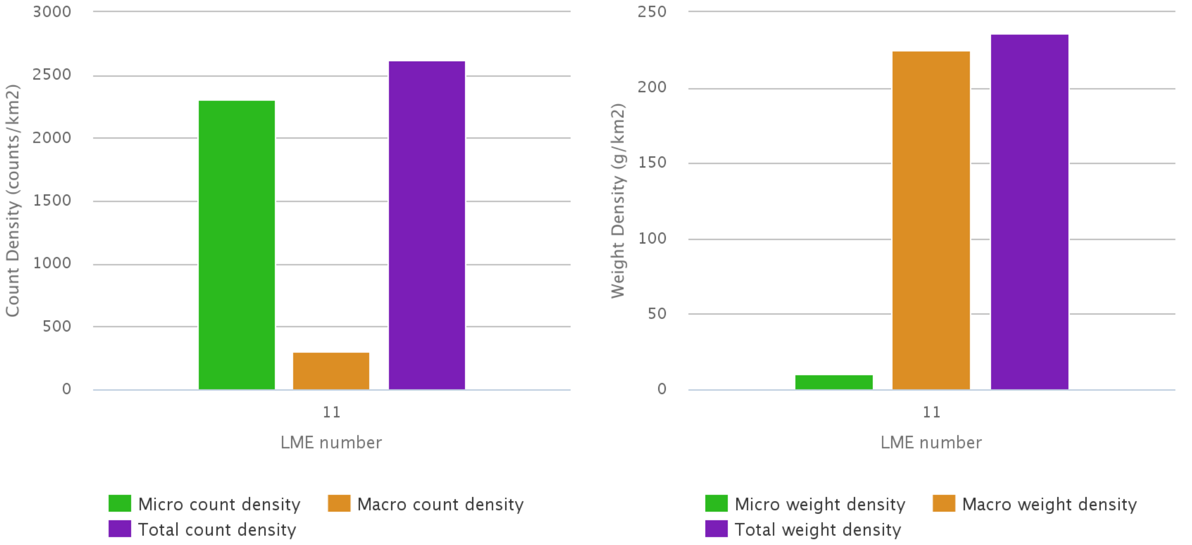
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
2	5	**1**	5	**2**	0.1	**1**

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 relatively moderate levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 12 times lower that those LMEs with lowest values. There is limited evidence from sea-based direct observations and towed nets to support this conclusion.



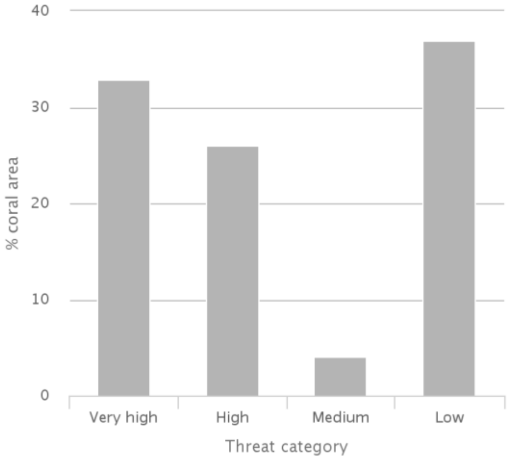
Ecosystem Health

Mangrove and coral cover

0.39% of this LME is covered by mangroves (US Geological Survey, 2011) and 0.03% by coral reefs (Global Distribution of Coral Reefs, 2010).

Reefs at risk

This LME has a present (2011) integrated threat index (combining threat from overfishing and destructive fishing, watershed-based and marine-based pollution and damage) of 235. 7% of coral reefs cover is under very high threat, and 26% under high threat (of the 5 possible threat categories, from low to critical). When combined with past thermal stress (between 1998 and 2007), these values increase to 20% and 60% for very high and high threat categories respectively. By year 2030, 39% of coral cover in this LME is predicted to be under very high to critical level of threat from warming and acidification; this proportion increases to 42% by 2050.

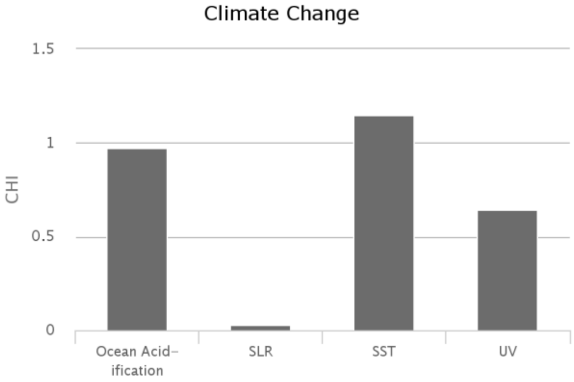


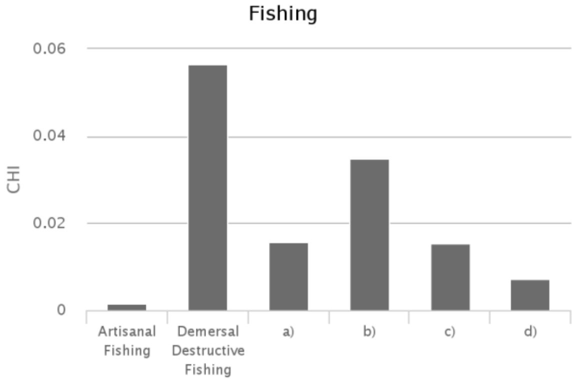
Marine Protected Area change

The Pacific Central-American Coastal LME experienced an increase in MPA coverage from 2,040 km^2 prior to 1983 to 29,444 km^{2}by 2014. This represents an increase of 1,343%, within the low category of MPA change.

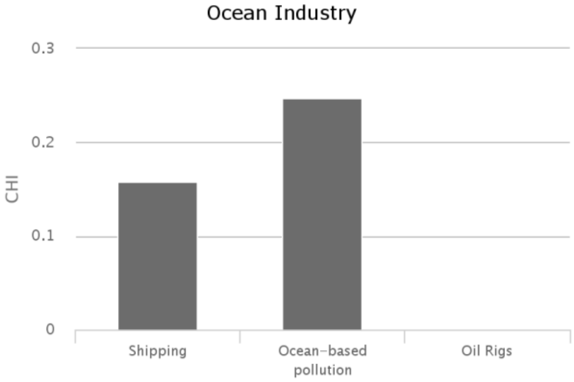
Cumulative Human Impact

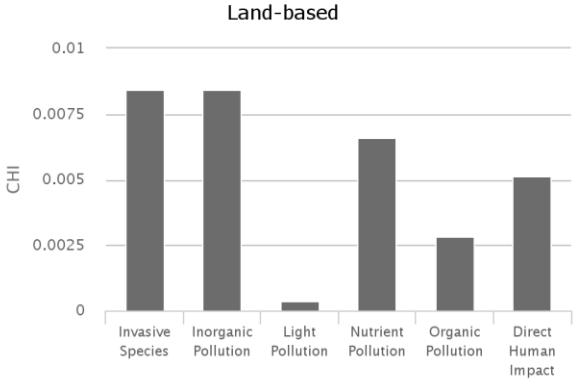
The Pacific Central-American Coastal LME experiences an average overall cumulative human impact (score 3.36; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This 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 (0.97; maximum in other LMEs was 1.20), UV radiation (0.64; maximum in other LMEs was 0.76), and sea surface temperature (1.15; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, ocean based pollution, and demersal destructive commercial fishing.

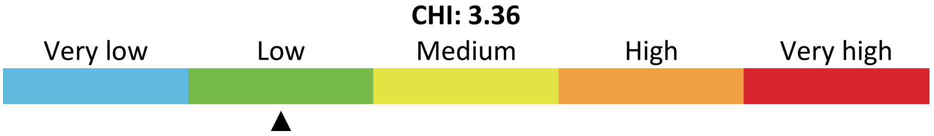

Climate Change


Fishing

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

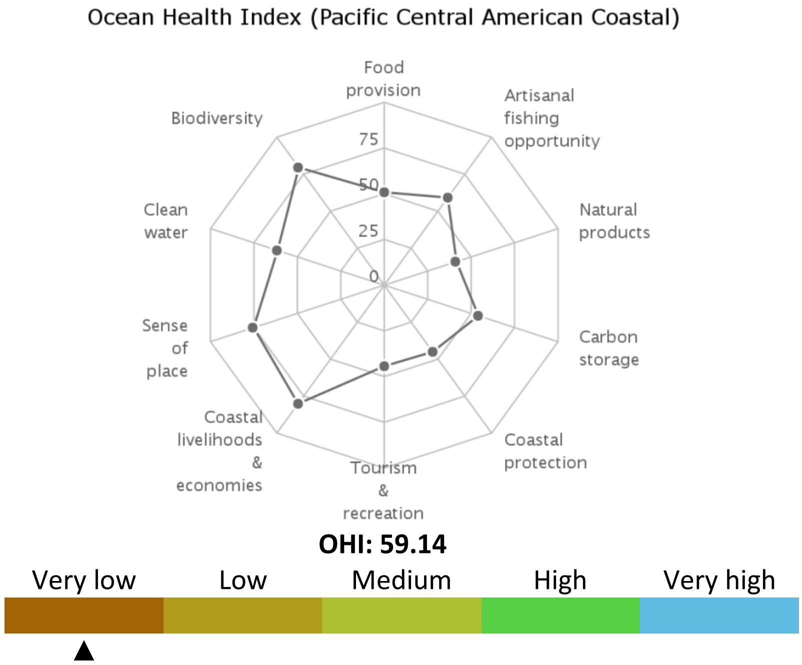

Ocean Industry


Land-based



Ocean Health Index

The Pacific Central-American Coastal LME scores well below average on the Ocean Health Index compared to other LMEs (score 66 out of 100; range for other LMEs was 57 to 82). This score indicates that the LME is far from its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 remained unchanged compared to the previous year. This LME scores lowest on food provision, coastal protection, carbon storage, tourism & recreation, and iconic species goals and highest on artisanal fishing opportunities, coastal economies, and lasting special places goals. It falls in risk category 5 of the five risk categories, which is the highest level of risk (1 = lowest risk; 5 = highest risk).



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 the Pacific Central American Coastal 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 littoral area includes the Pacific coasts of southern Mexico, Central America, and the South American nations of Colombia, Ecuador and northernmost portion of Peru, covering a total of 585,973 km^2. A current population of 50 million is projected to almost double to 98 million in 2100, as reflected in density increasing from 86 persons per km^2 in 2010 to 167 per km^2 by 2100. About 47% of coastal population lives in rural areas, and is projected to increase in share to 52% in 2100.

Total population		**Rural population**	
2010	**2100**	**2010**	**2100**
50,320,369	97,859,738	23,824,558	50,535,113

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 44% of the LME's coastal dwellers. The Pacific Central American Coastal LME places in the very high-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
21,995,749

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Pacific Central American Coastal LME ranks in the medium revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $672 million for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $48,482 million places it in the high revenue category. On average, LME-based tourism income contributes 12% 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 the Pacific Central American Coastal LME falls in the category with high risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
672,041,692	6.9	48,482,410,060	11.9	🟧 0.8253

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 Pacific Central American Coastal LME HDI belongs to the low HDI and high-risk category. Based on an HDI of 0.693, this LME has an HDI Gap of 0.307, 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). The Pacific Central American Coastal LME is projected to assume a place with the very low risk category (very high HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is estimated to place in the very high-risk category (very low HDI) because of reduced income level and increased population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
🟧 0.6926	🟦 0.8934	🟥 0.5259

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 to the Pacific Central American Coastal LME is within the very high-risk (very 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 high. In a sustainable development scenario, the risk index from sea level rise in 2100 is lowest, and increases to very high risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.8157	0.4398	0.3978	0.6583

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

There are three separate transboundary arrangements for fisheries in general within the EEZ (CPPS, OLDESPECA and OSPESCA) as well as the arrangement for tuna and tuna-like species (IATTC). No integrating mechanisms, such as an overall policy coordinating organization for the LME, could be found. However, somewhat unique among LMEs, is the Secretariat for the Regional Seas Convention being housed at the Permanent Commission for the South Pacific (CPPS). While specific formal integration is not mentioned in the two Conventions, it is likely that the two Commissions have considerable informal linkages since the secretariats for both CPPS and the Lima Convention are within the same organization. Governance arrangements for this LME appear to be split along geographic lines with arrangements for the southern part of the LME being distinct from those for the northern part.

The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
53	**65**	**0.1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 12 – Caribbean Sea

Bordering countries: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, British Virgin Islands, Cayman Islands, Colombia, Commonwealth of Dominica, Costa Rica, Cuba, Dominican Republic, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, France (Martinique), Mexico, Montserrat, Netherland Antilles, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, United States Virgin Islands, Venezuela

LME Total area: 3,305,077 km^2

This LME is GEF eligible

List of indicators

LME overall risk

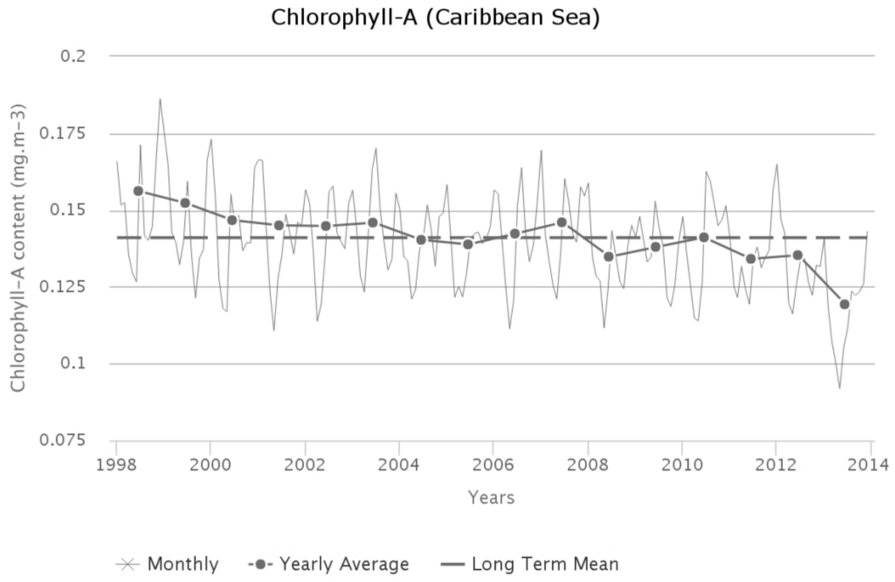
This LME falls in the cluster of LMEs that exhibit low to medium levels of economic development (based on the night light development index) and medium levels of collapsed and overexploited fish stocks.

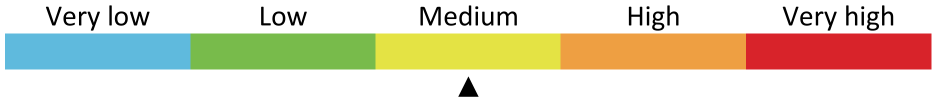
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is high.

Productivity

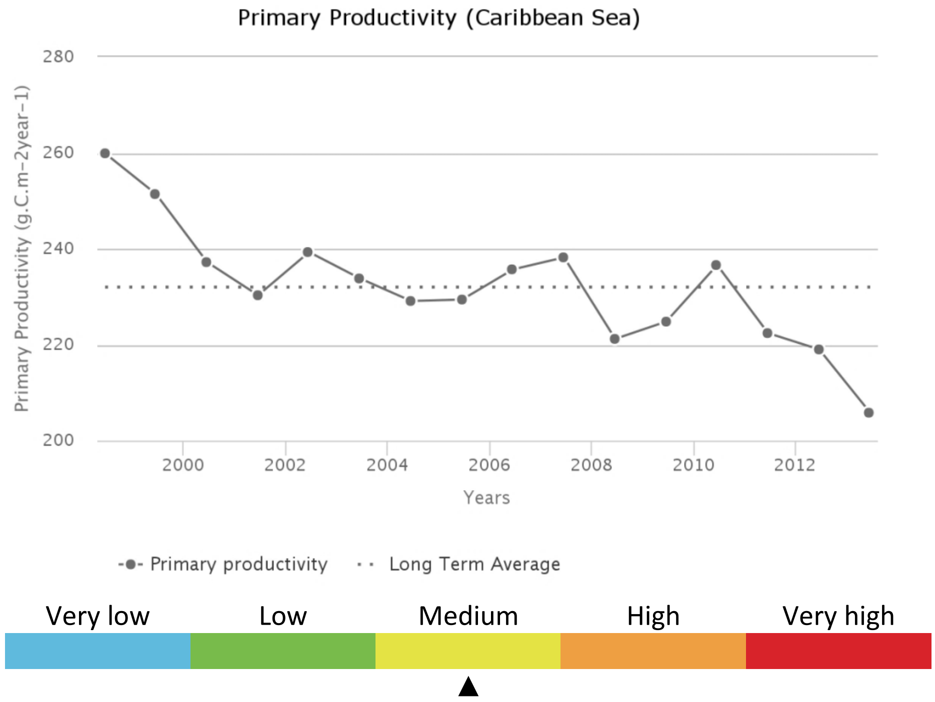
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.159 mg.m^{-3}) in January and a minimum (0.121 mg.m^{-3}) during May. The average CHL is 0.141 mg.m^{-3}. Maximum primary productivity (260 g.C.m^{-2}.y^{-1}) occurred during 1998 and minimum primary productivity (206 g.C.m^{-2}.y^{-1}) during 2013. There is a statistically insignificant increasing trend in Chlorophyll of 5.29 % from 2003 through 2013. The average primary productivity is 232 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).



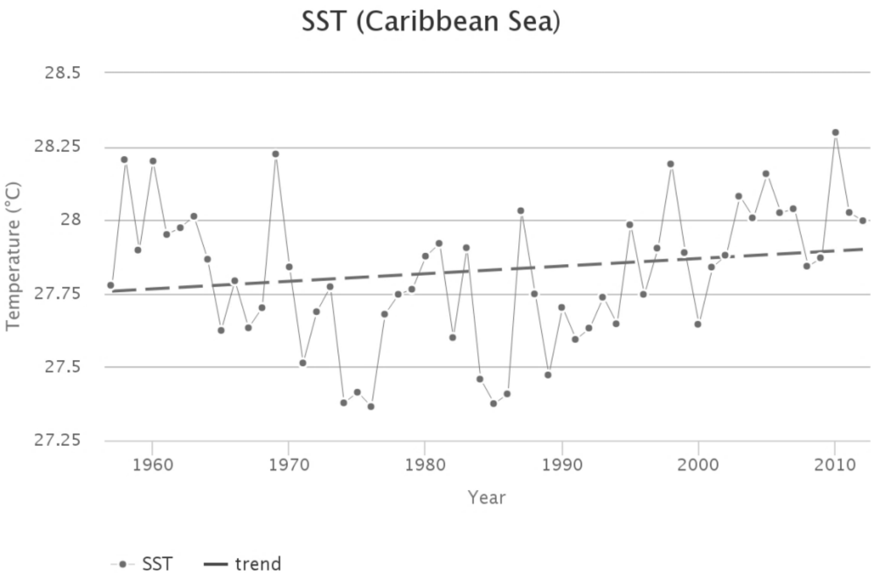


Primary productivity



Sea Surface Temperature

Between 1957 and 2012, the Caribbean Sea LME #12 has warmed by 0.15°C, thus belonging to Category 4 (slow warming LME). This LME went through three phases over the last 50 years: (1) cooling until 1974; (2) a cold phase with two cold spells, in 1974-1976 and 1984-1986; (3) warming since 1986. Using the year of 1985 as a true breakpoint, the post-1985 warming exceeded 0.9°C, from <27.4°C in 1985 to 28.3°C in 2010. Both cold spells were synchronous with cold events across the Central American Isthmus, in the Pacific Central-American Coastal LME #11. The first cooling period was interrupted by a major warm event (peak) of 1968-1970, when SST peaked at 28.2°C in 1969. This event was confined to the Caribbean Sea. None of adjacent LMEs experienced a pronounced warming in 1968-1970. All significant maxima and minima of SST in the Caribbean Sea correlate strongly with El Niños and La Niñas respectively (National Weather Service/Climate Prediction Center, 2007). This strong correlation is a good example of atmospheric teleconnections across the Central American Isthmus. This link is so strong that El Niños' and La Niñas' effects in the Caribbean Sea have comparable magnitudes with their counterparts in the Pacific Central-American Coastal LME #11 on the other side of the Isthmus.

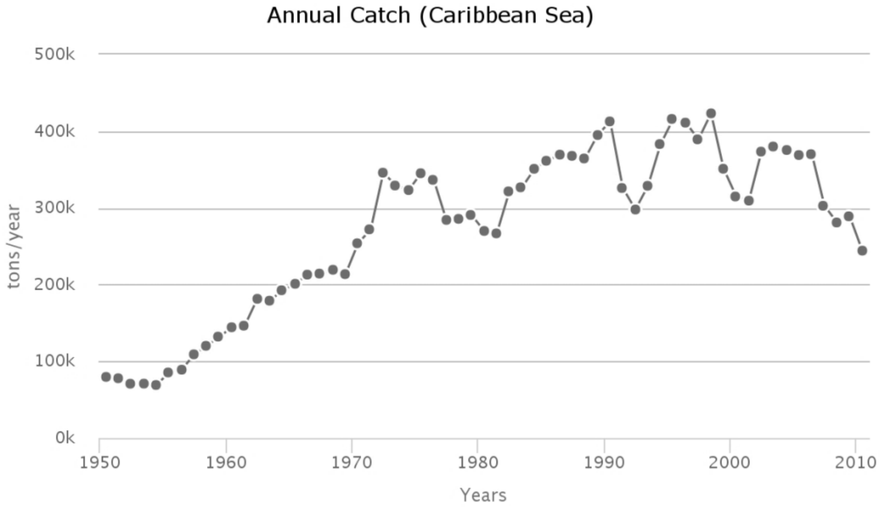


Fish and Fisheries

The fisheries of the Caribbean Sea LME are based on a diverse array of resources, and those of greatest importance are spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), penaeid shrimps, reef fish, continental shelf demersal fish, deep slope and bank fish and large coastal pelagics such as king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculatus*), dolphinfish (*Coryphaena hippurus*) and amberjack (*Seriola spp.*). In addition, fisheries based on stocks of large oceanic fish such as yellowfin tuna, skipjack tuna, Atlantic blue marlin and swordfish, have expanded considerably.

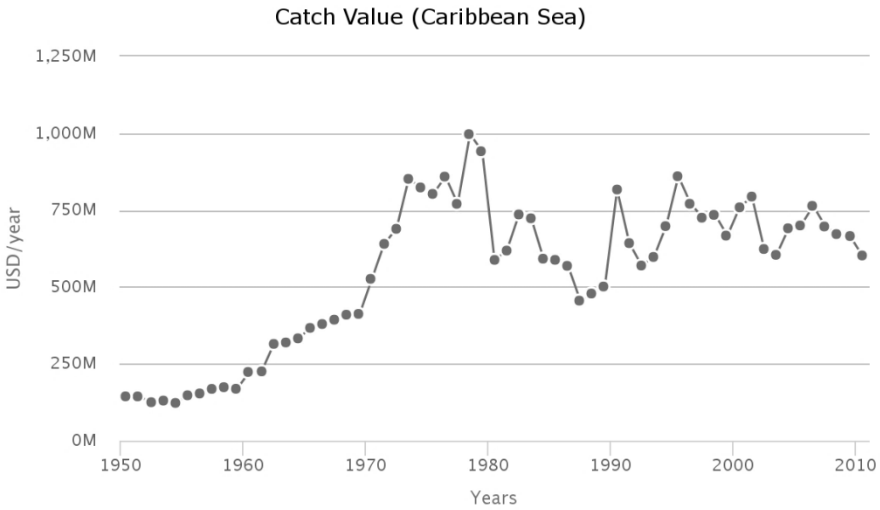
Annual Catch

Total reported landings in this LME, which is probably underestimated showed a general increase to about 430,000 t in the 1998, followed by a slight decline.



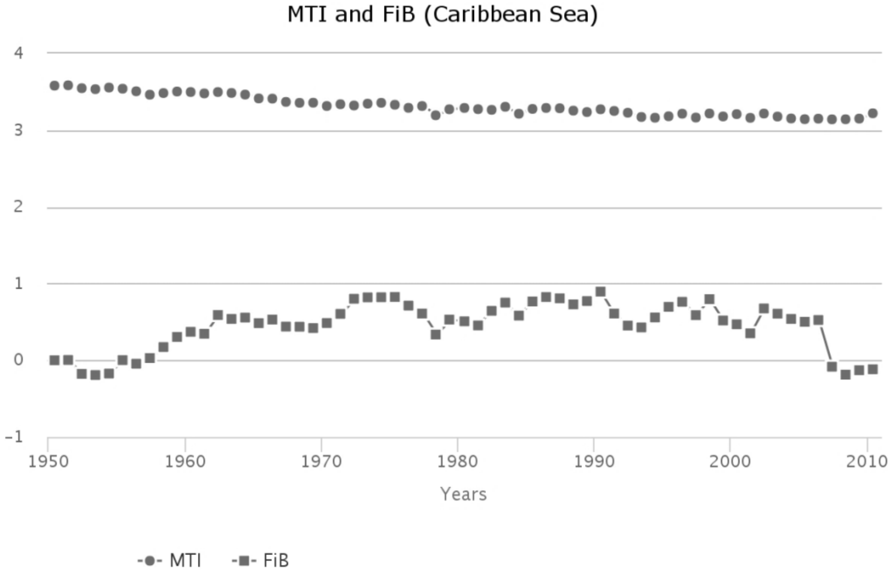
Catch value

The reported landings peaked at just under 1 billion US$ (in 2005 value) in 1978.



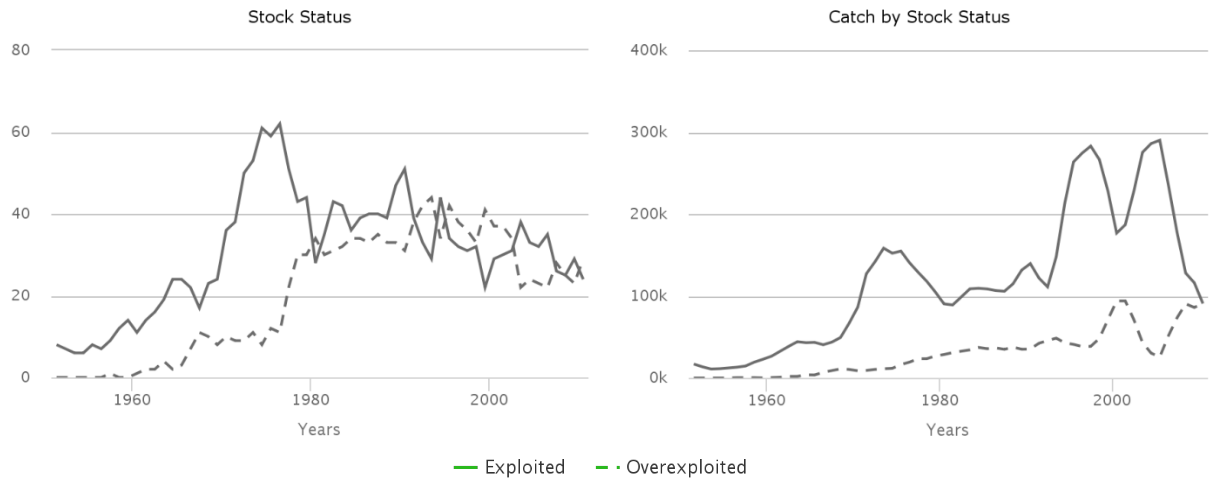
Marine Trophic Index and Fishing-in-Balance index

The decline of the MTI is almost linear over the reported period, representing a classic case of 'fishing down' of the food web in the LME. Indeed, the decline in the mean trophic level would have been greater than the expansion of the fisheries from the mid-1950 to the mid-1980s as implied by the increasing FiB index.



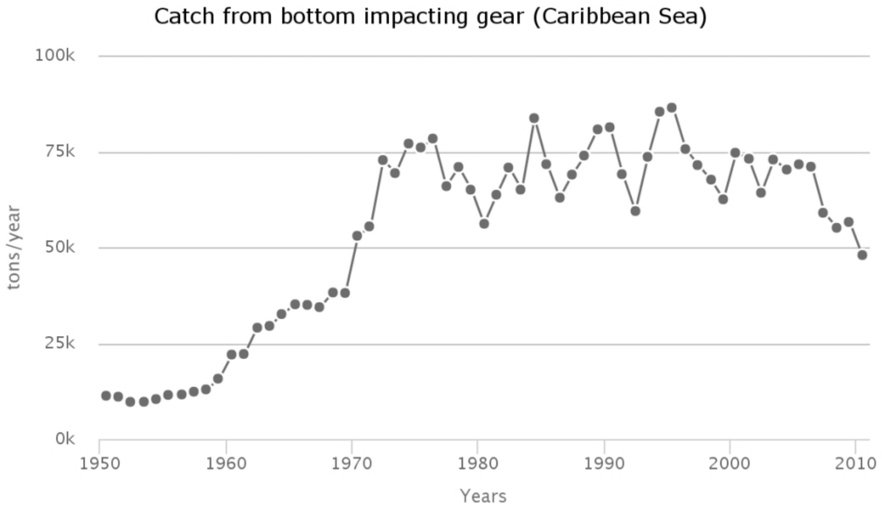
Stock status

The Stock-Catch Status Plots indicate that nearly 60% of the commercially exploited stocks in the LME are either overexploited or have collapsed and these stocks now contribute 50% of the reported landings.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch increased slightly from 11% in late 1950s to the peak at 25% in 1978. Then, this percentage fluctuated around 20% in the recent few decades.

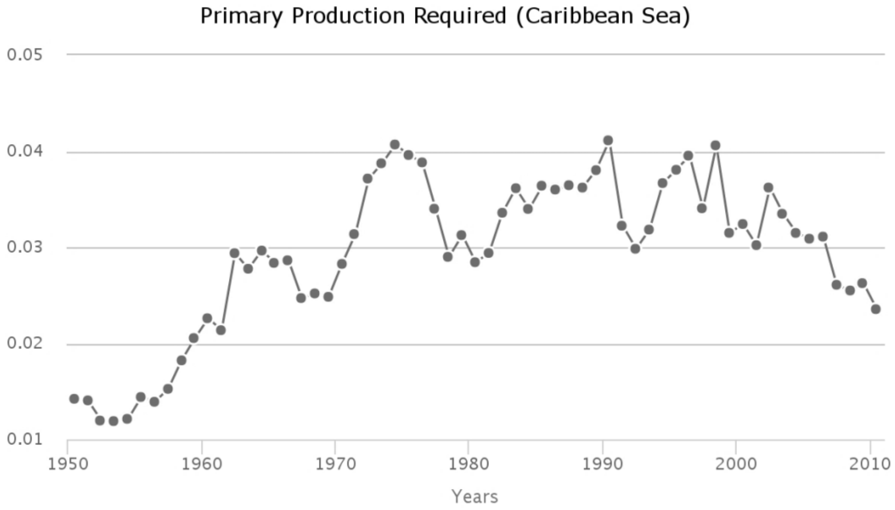


Fishing effort

The total effective effort continuously increased from around 40 million kW in the 1950s to its peak at 240 million kW in the mid- 2000s.

Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME reached 3% of the observed primary production in 1994, and fluctuated between 2.5 to 3% in recent years.



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 moderate (level 3 of the five risk categories, where 1 = lowest risk; 5 = highest risk). Based on a "current trends" scenario (Global Orchestration), this increased to high in 2030 and remained high in 2050.

Nutrient ratio

The Nutrient Ratio (ICEP) risk level for contemporary (2000) conditions was very low (1). 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 moderate (3). According to the Global Orchestration scenario, this increased to high in 2030 and remained the same in 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**
3	1	3	4	1	4	4	1	4

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

POPs

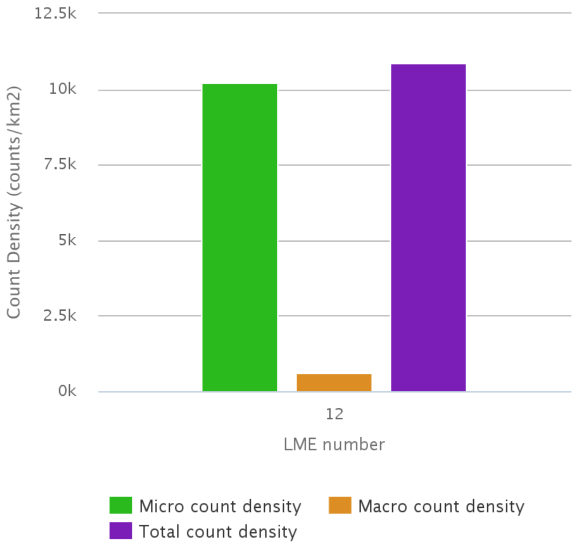
Data are available only for two samples at two locations in Barbados and Trinidad & Tobago. These locations show minimal concentration for all the indicators. The average concentration (ng.g^{-1} of pellets) was 4 (range 2 – 6 ng.g^{-1}) for PCBs, 3 (range 2 – 3 ng.g^{-1}) for DDTs, and 0.9 (range 0.8 – 1.1 ng.g^{-1}) for HCHs. All three averages correspond to risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This is probably due to minimal anthropogenic activities involving the use of POPs (PCBs in industries and DDT and HCH pesticides in agriculture).

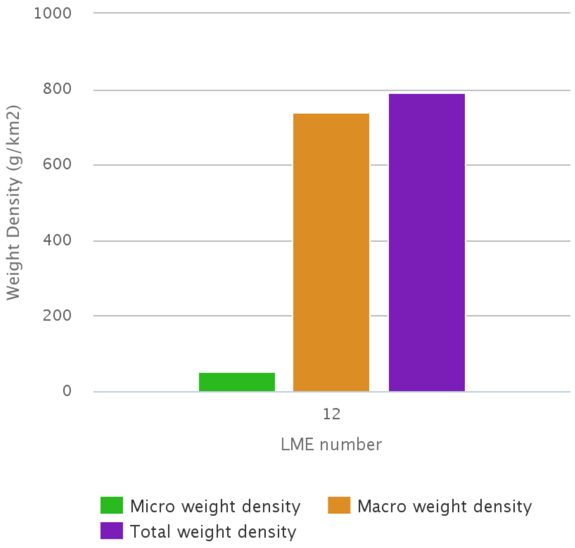
	PCBs		DDTs		HCHs	
Locations	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk	Avg. (ng/g)	Risk
2	4	**1**	3	**1**	0.9	**1**

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 relatively high levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category there is good evidence from sea-based direct observations and towed nets to support this conclusion.





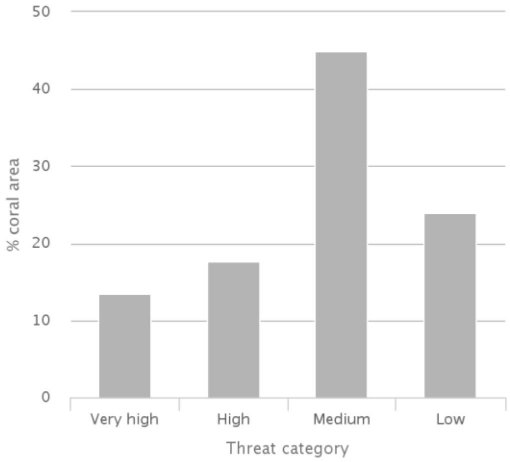
Ecosystem Health

Mangrove and coral cover

0.35% of this LME is covered by mangroves (US Geological Survey, 2011) and 0.64% by coral reefs (Global Distribution of Coral Reefs, 2010).

Reefs at risk

This LME has a present (2011) integrated threat index (combining threat from overfishing and destructive fishing, watershed-based and marine-based pollution and damage) of 221. 13% of coral reefs cover is under very high threat, and 18% under high threat (of the 5 possible threat categories, from low to critical). When combined with past thermal stress (between 1998 and 2007), these values increase to 23% and 32% for very high and high threat categories respectively. By year 2030, 29% of coral cover in this LME is predicted to be under very high to critical level of threat from warming and acidification; this proportion increases to 40% by 2050.

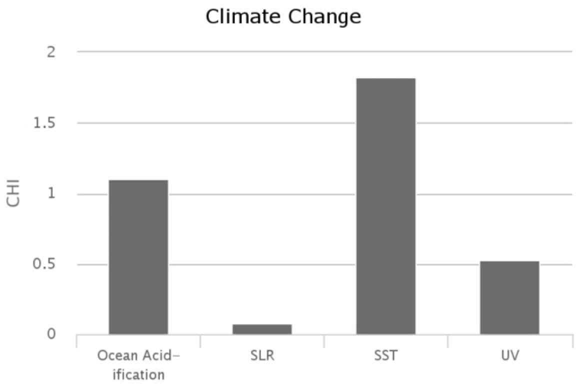


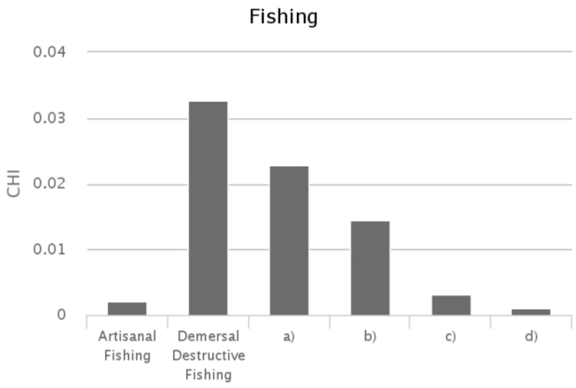
Marine Protected Area change

The Caribbean Sea LME experienced an increase in MPA coverage from 6,463 km^2 prior to 1983 to 143,096 km^2 by 2014. This represents an increase of 2,114%, within the medium category of MPA change.

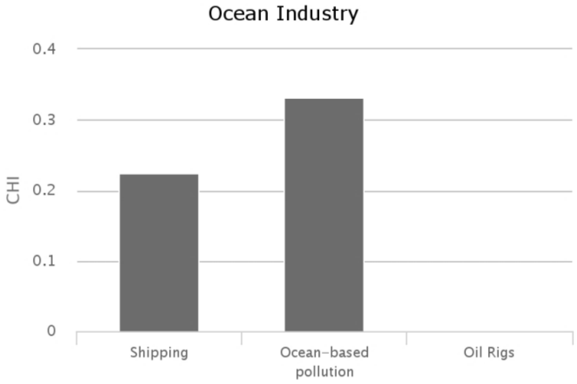
Cumulative Human Impact

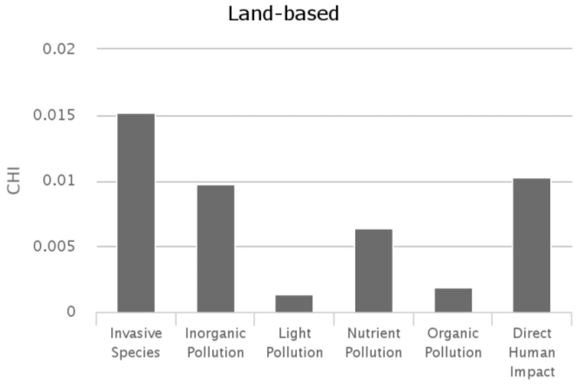
The Caribbean Sea LME experiences an above average overall cumulative human impact (score 4.21; maximum LME score 5.22), which is well above the LME with the least cumulative impact. It falls in risk category 4 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (1.11; maximum in other LMEs was 1.20), UV radiation (0.52; 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 and ocean based pollution.


Climate Change


Fishing

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

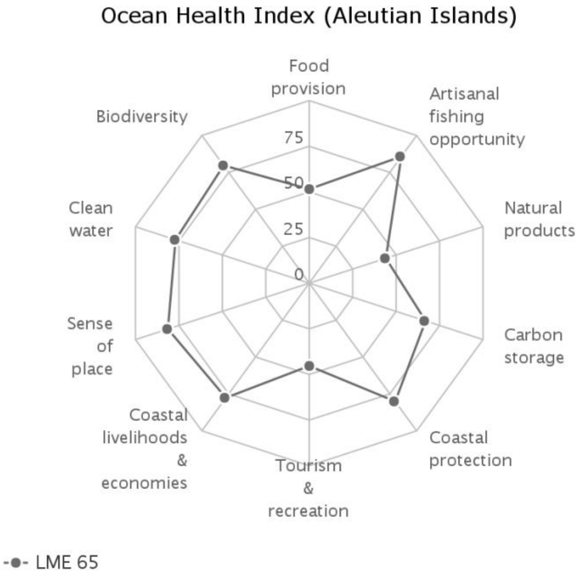

Ocean Industry

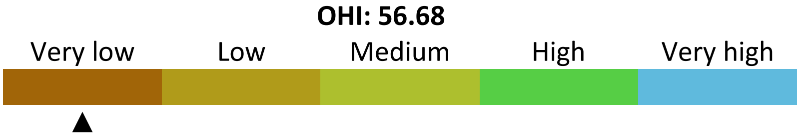

Land-based

CHI: 4.21

Ocean Health Index

The Caribbean Sea LME scores well below average on the Ocean Health Index compared to other LMEs (score 60 out of 100; range for other LMEs was 57 to 82). This score indicates that the LME is far from its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 remained unchanged compared to the previous year. This LME scores lowest on food provision, natural products, coastal protection and tourism & recreation goals and highest on artisanal fishing opportunities and coastal economies goals. It falls in risk category 5 of the five risk categories, which is the highest level of risk (1 = lowest risk; 5 = highest risk).





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 the Caribbean Sea 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 littoral area includes the eastern coast of the Yucatan Peninsula, the Atlantic coast of Central America, Colombia and Venezuela, and 24 Caribbean island states covering a total of 794,777 km^2. A current population of 84 million is projected to reach to 127 million in 2100, and density increasing from 106 persons per km^2 in 2010 to 159 per km^2 by 2100. About 42% of coastal population lives in rural areas, and is projected to increase in share to 46% in 2100.

Total population		Rural population	
2010	2100	2010	2100
84,263,359	126,576,916	35,485,511	58,003,582

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 32% of the LME's coastal dwellers. The Caribbean Sea LME places in the very high-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
26,619,339

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Caribbean Sea LME ranks in the high revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $810 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 $90,454 million places it in the very high revenue category. On average, LME-based tourism income contributes 18% 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 the Caribbean Sea LME falls in the category with medium risk.

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
810,509,428	8.7	90,454,384,76018.0	18.0	0.7499

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 Caribbean Sea LME HDI belongs to the medium HDI and high-risk category. Based on an HDI of 0.718, this LME has an HDI Gap of 0.282, 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). The Caribbean Sea LME is projected to assume a place with the very low risk category (very high HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is estimated to place in the very high-risk category (very low HDI) because of reduced income level and increased population size compared to estimated income and population values in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
0.7185	0.8970	0.5611

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 to the Caribbean Sea LME is within the very high-risk (very 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 very high. In a sustainable development scenario, the risk index from sea level rise in 2100 is lowest, and increases to high risk under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟥 0.8389	🟥 0.4807	🟦 0.3944	🟧 0.6425

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

Three arrangements for transboundary fisheries in this LME - CRFM, OSPESCA and WECAFC - are connected. OLDEPESCA is minimally connected within the LME. None of the fisheries arrangements are connected with ICCAT. The arrangements for pollution and biodiversity that fall under the Cartagena Convention are connected via the CEP, but do not appear well connected with fisheries or with the IAC. No integrating mechanisms, such as an overall policy coordinating organization 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 the ranking of risk were:

Engagement	Completeness	Integration
🟨 **53**	🟨 **60**	🟥 **0.2**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 18 – Canadian Eastern Arctic – West Greenland

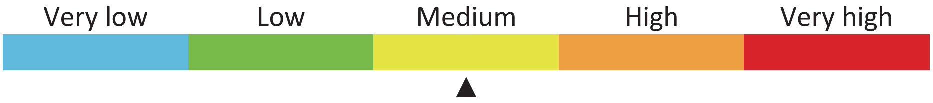
Bordering countries: Canada, Greenland
LME Total area: 359,422 km^2

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.

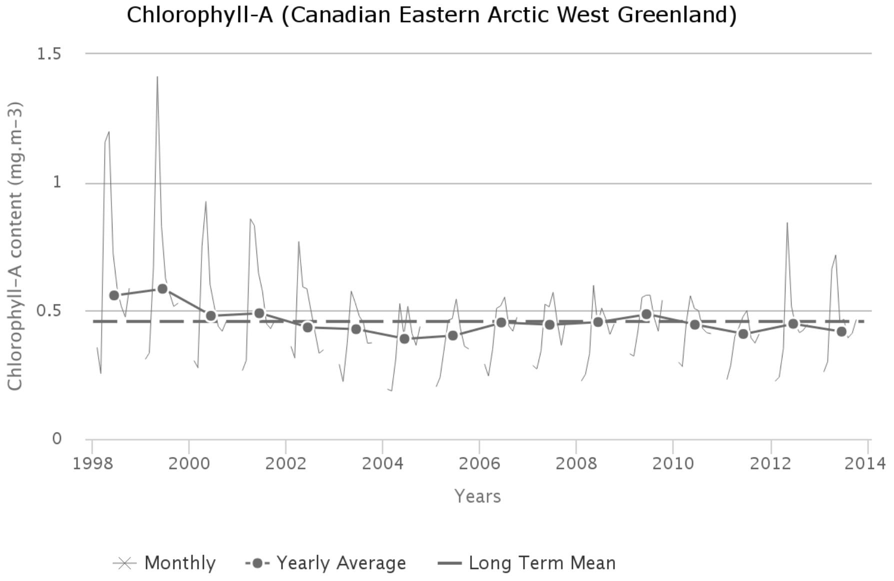
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is medium.

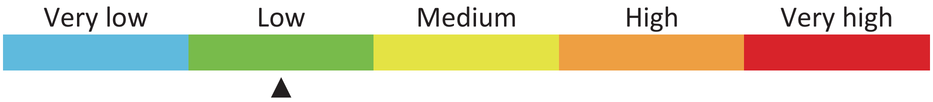


Productivity

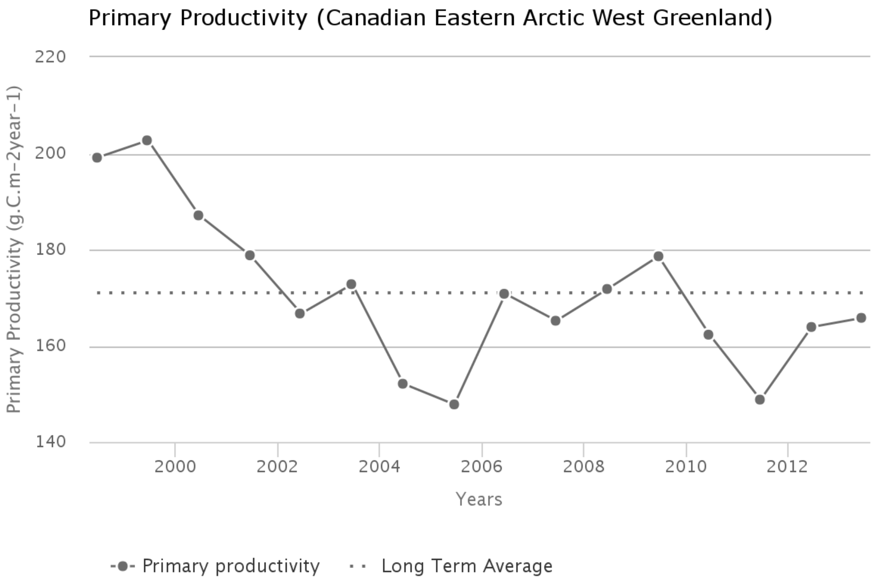
Chlorophyll-A

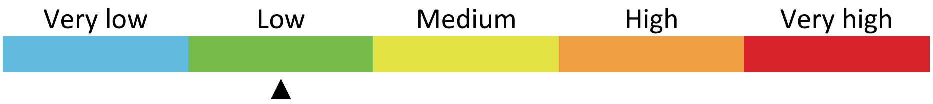
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.533 $mg.m^{-3}$) in July and a minimum (0.244 $mg.m^{-3}$) during March. The average CHL is 0.458 $mg.m^{-3}$. Maximum primary productivity (203 $g.C.m^{-2}.y^{-1}$) occurred during 1999 and minimum primary productivity (148 $g.C.m^{-2}.y^{-1}$) during 2005. There is a statistically insignificant increasing trend in Chlorophyll of 3.79 % from 2003 through 2013. The average primary productivity is 171 $g.C.m^{-2}.y^{-1}$, which places this LME in Group 2 of 5 categories (with 1 = lowest and 5= highest).





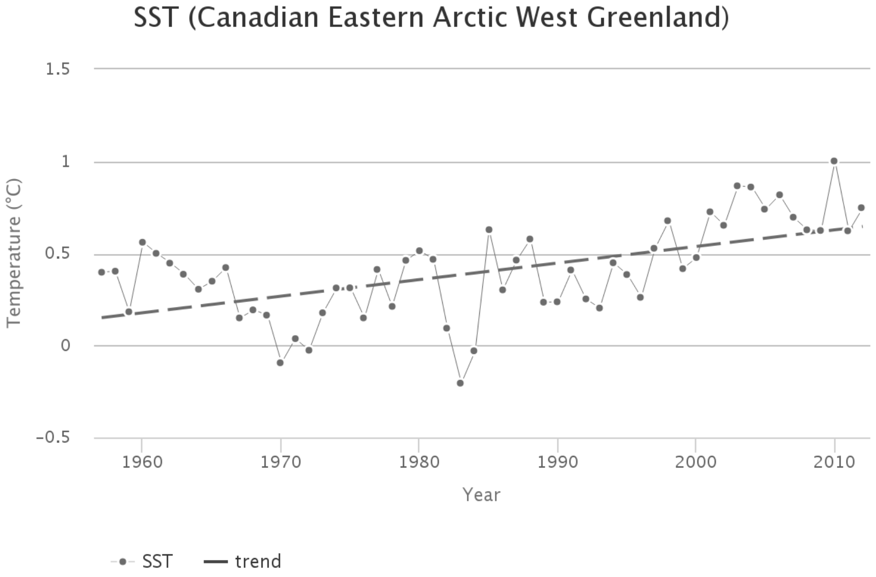
Primary productivity





Sea Surface Temperature

From 1957 to 2012, the Canadian Eastern Arctic-West Greenland LME #18 has warmed by 0.50°C, thus belonging to Category 3 (moderate warming LME). This LME featured rather cold SST (<0.6°C) through 1996. During this time, three Great Salinity Anomalies traveled through this LME, being transported by the West Greenland Current (Dickson et al., 1988; Belkin et al., 1998; Belkin, 2004). These low-salinity anomalies were accompanied by low-temperature anomalies around 1970, 1983-84, and 1996. The last anomaly has marked the end of cold epoch. Measured from the coldest event in 1970 (SST=-0.1°C) to the warmest event in 2010 (SST=1.0°C), the magnitude of SST increase is 1.1°C in 40 years. The thermal history of the West Greenland Shelf is linked by ocean currents to the thermal histories of the upstream East Greenland Shelf and downstream Newfoundland-Labrador region. These shelf areas are interconnected by a system of shelf-slope currents originating off NE Greenland and flowing equatorward.

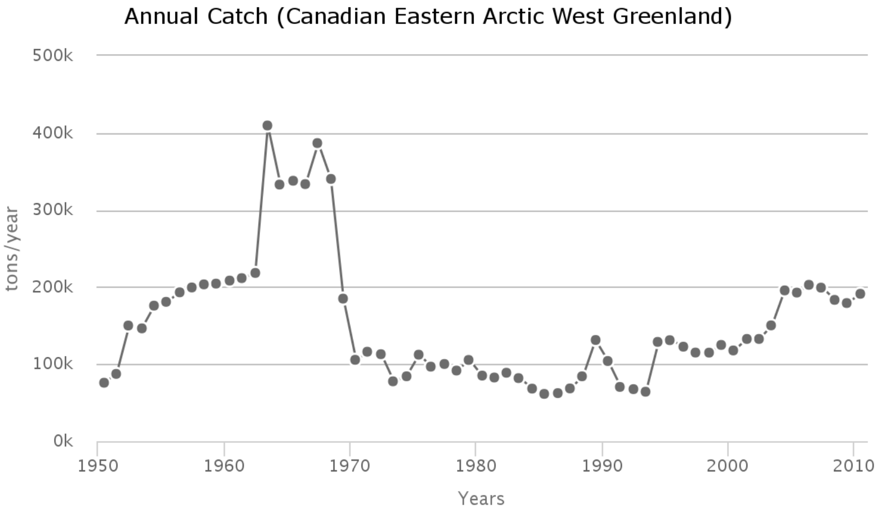


Fish and Fisheries

The most important species group in terms of shelf catches for recent years is the northern prawn (*Pandalus borealis*), representing more than two-thirds of the total catch. Another important species group is flatfish.

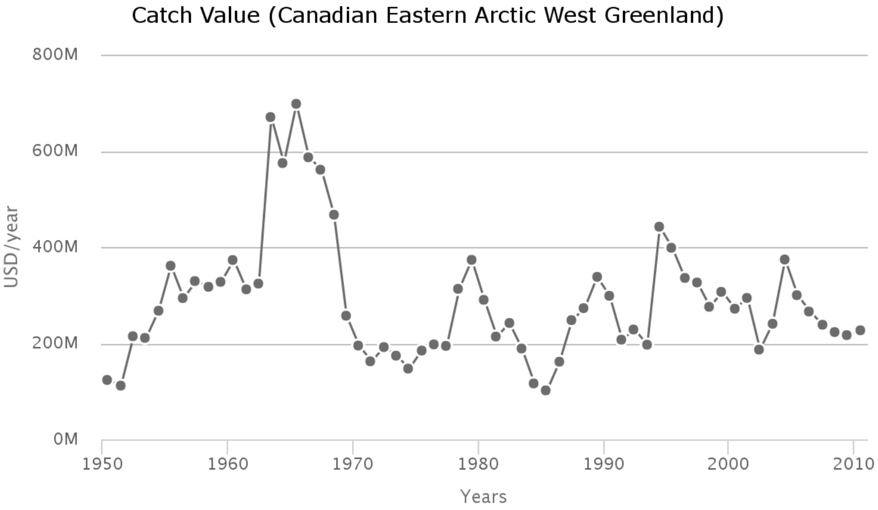
Annual Catch

Reported landings of commercial fish species show major changes over the past century, from a system dominated by Atlantic cod landings to one defined by prawn. Reported landings were at a historical peak of over 510,000 t in 1962. They subsequently declined to under 100,000 t in the 1980s, but have shown an increasing trend over the last few years. As northern prawn now contributes the majority of the reported landings, a potentially large amount of fish bycatch is unreported.



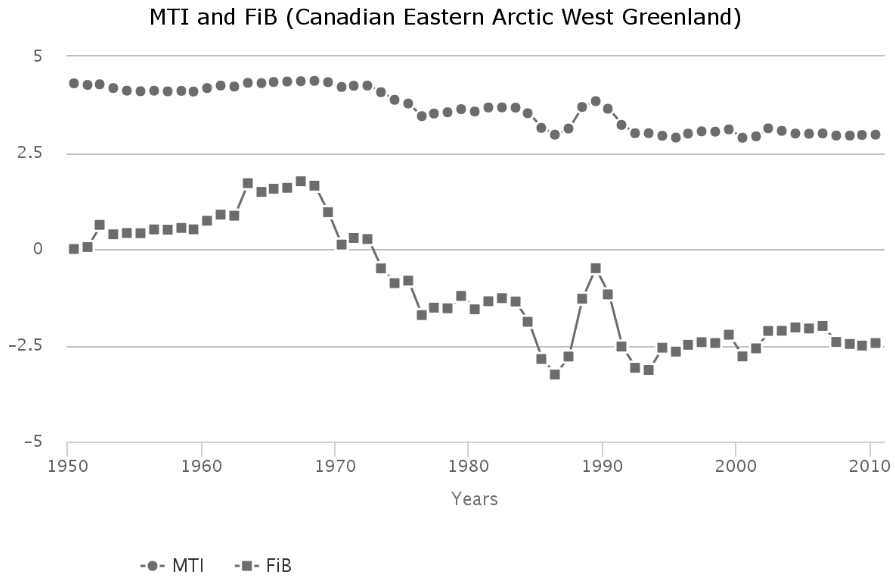
Catch value

The value of the reported landings reached 770 million US$ (in 2005 real US$) in 1965, but has since reduced to around 300 million US$ in recent years.



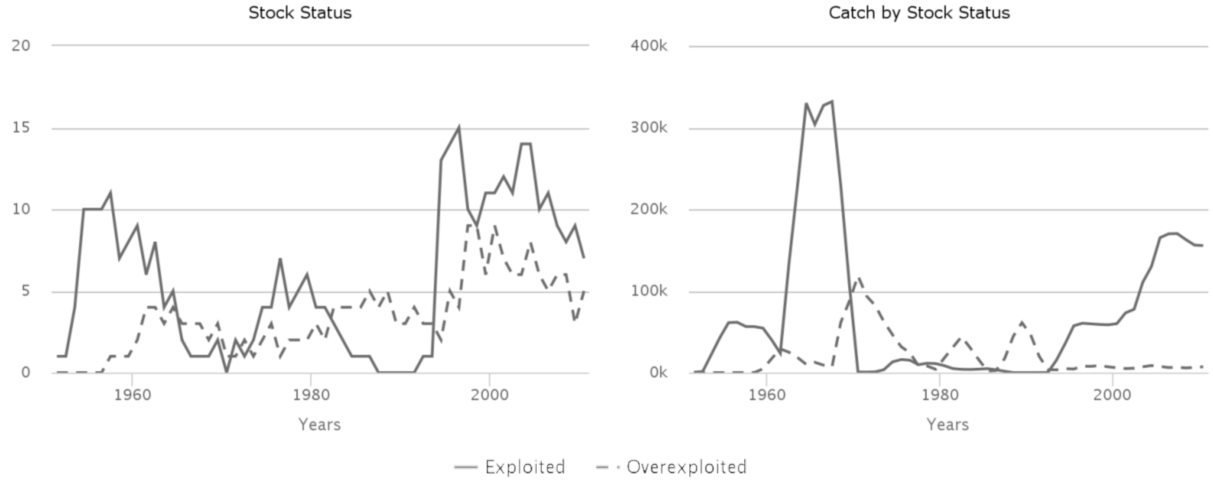
Marine Trophic Index and Fishing-in-Balance index

From 1950 to 1970, when cod was dominant in the reported landings in the LME and as a result, the MTI remained high. It then showed a decline with the change from cod to prawn dominance in the ecosystem, implying 'fishing down' of the food web. The FiB index showed a similar trend, suggesting that the reported landings did not compensate for the decline in trophic levels during that period.



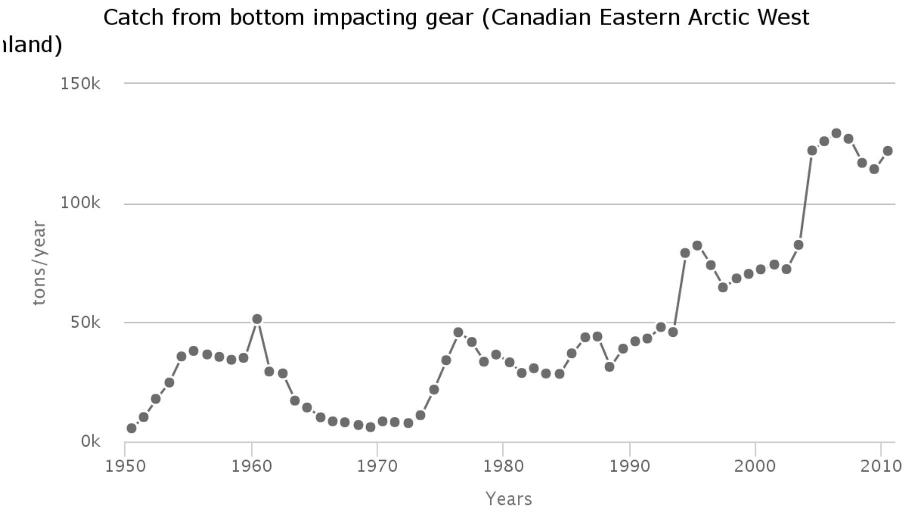
Stock status

The Stock-Catch Status Plots indicate that more than 60% of commercially exploited stocks in the LME have collapsed or are overexploited, however, with about 90% of the landings still from fully exploited, collapsed and overexploited stocks, more specifically from the northern prawn. Considering the decrease in the reported landings over the past three decades, the observed trends in these plots present a stark reminder that they must be examined as a pair, not in isolation from each other.



Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reached its first peak at 75% in 1985 and this percentage ranges between 55 to 70% in the recent decade.

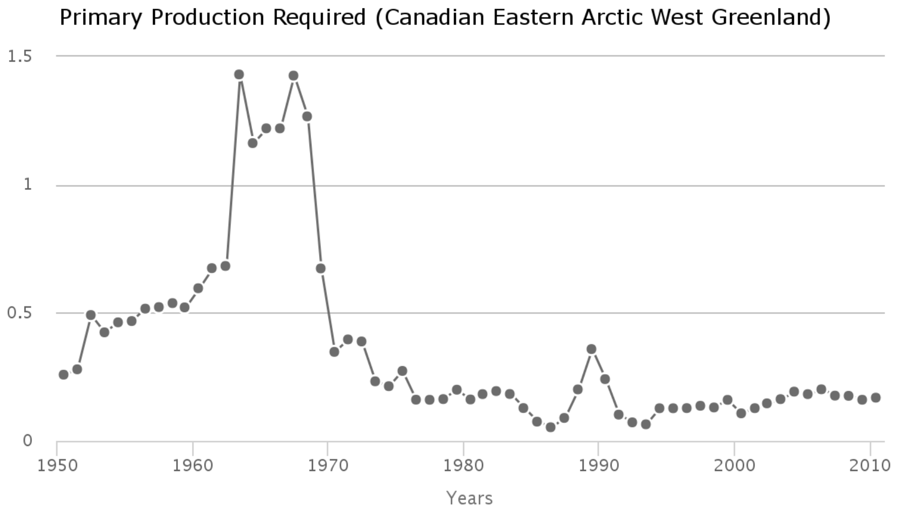


Fishing effort

The total effective effort increased steadily from around 25 million kW in the 1950s to its peak at 120 million kW in the mid-2000s.

Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME was over 70% of the observed primary production in the 1960s, before declining to around 10% in the last decade. The extremely high PPR recorded in the 1960s is likely a result of the high level of accumulated biomass of cod stocks being exploited.



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 high (4). According to the Global Orchestration scenario, this decreased to moderate in 2030 and remained moderate in 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	4	1	1	3	1	1	3	1

Legend:

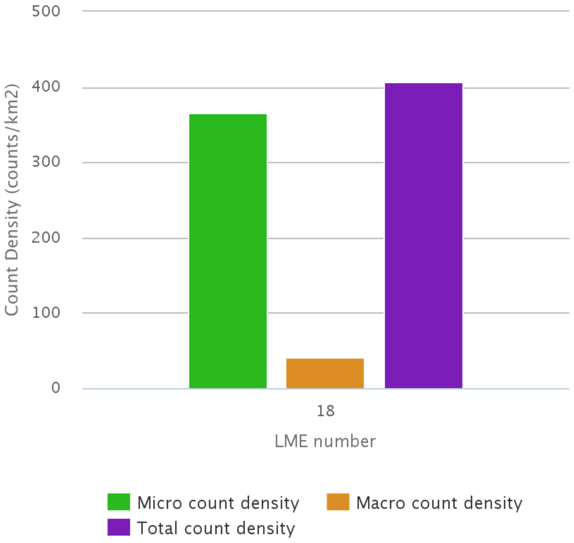
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

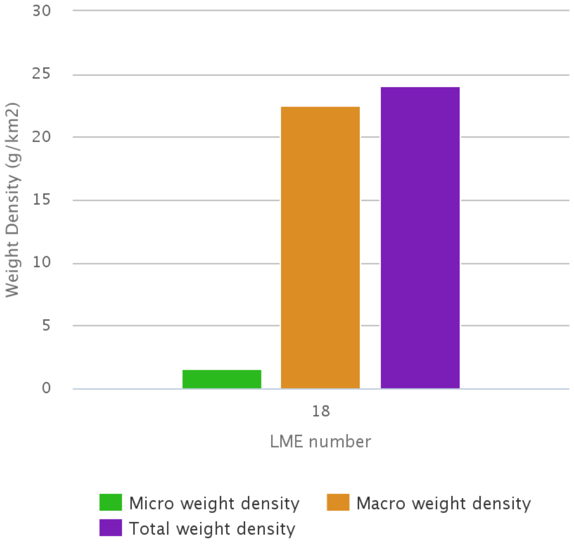
POPs

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 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

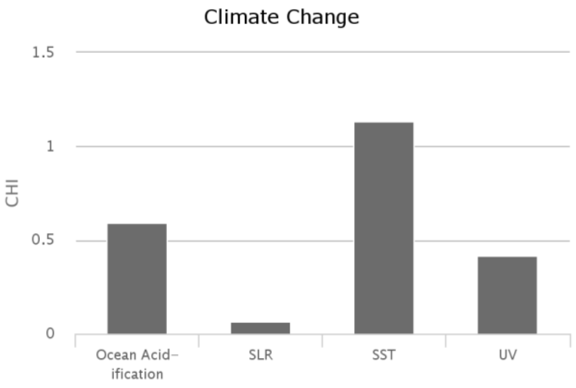
Not applicable

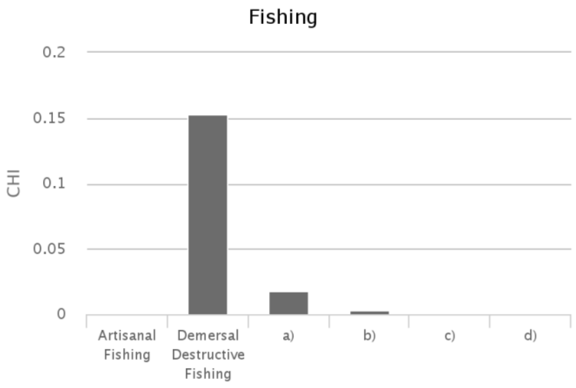
Marine Protected Area change

The Canadian Eastern Arctic - West Greenland LME experienced an increase in MPA coverage from 7,520 km^2 prior to 1983 to 13,891 km^2 by 2014. This represents an increase of 85%, within the lowest category of MPA change.

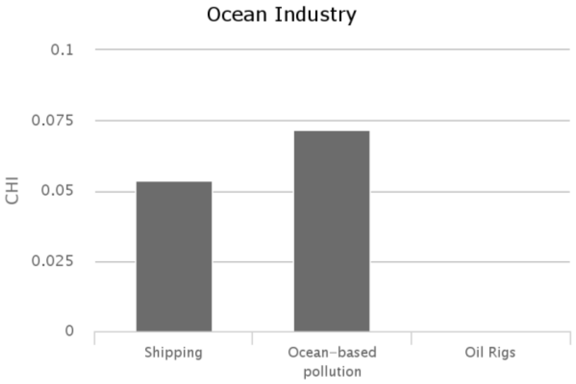
Cumulative Human Impact

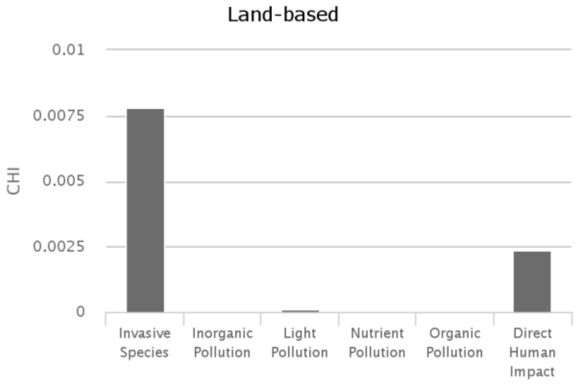
The Canadian Eastern Arctic – West Greenland LME experiences below average overall cumulative human impact (score 2.52; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.59; maximum in other LMEs was 1.20), UV radiation (0.42; maximum in other LMEs was 0.76), and sea surface temperature (1.13; maximum in other LMEs was 2.16). Other key stressors include ocean based pollution and demersal destructive commercial fishing.





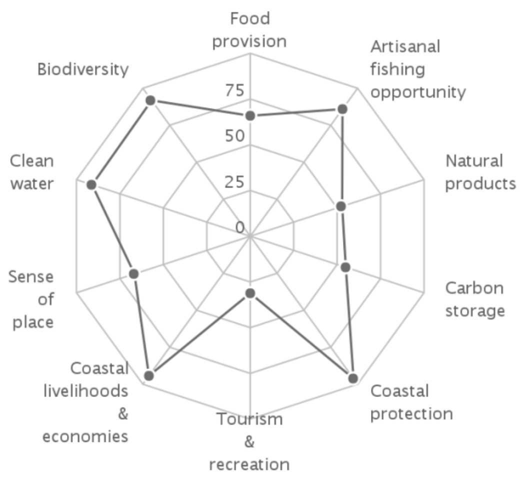
a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing





Ocean Health Index

The Canadian Eastern Arctic – West Greenland LME scores above average on the Ocean Health Index compared to other LMEs (score 77 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 many aspects that are doing well. Its score in 2013 increased 2 points compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on natural products, carbon storage, and tourism & recreation goals and highest on mariculture, artisanal fishing opportunities, coastal protection, coastal economies, and biodiversity goals. It falls in risk category 1 of the five risk categories, which is the lowest level of risk (1 = lowest risk; 5 = highest risk).


Ocean Health Index (Canadian Eastern Arctic West Greenland)

OHI: 75.52

Very low	Low	Medium	High	Very high
🟫	🟨	🟩	🟩	🟦
				▲

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 the Canadian Eastern Arctic - West Greenland 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 includes the north and eastern shores of Nunavut, and western Greenland, stretching over 743,645 km^2. A current population of 70,000 in 2010 is projected to decrease to 50,000 in 2100, with density decreasing from 9 persons per 100 km^2 in 2010 to 7 per 100 km^2 by 2100. About 81% of coastal population lives in rural areas, and is projected to decrease in share to 68% in 2100.

Total population		Rural population	
2010	2100	2010	2100
69,557	49,979	56,282	34,038

Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 10% of the LME's coastal dwellers. The Canadian Eastern Arctic - West Greenland places in the very low-risk category based on percentage and absolute number of coastal poor (present day estimate).

Coastal poor
6,737

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Canadian Eastern Arctic - West Greenland LME ranks in the medium revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $386 million for the period 2001-2010. Fish protein accounts for 34% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $124 million places it in the very low revenue category. On average, LME-based tourism income contributes 4% 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 the Canadian Eastern Arctic - West Greenland LME falls in the category with high risk (low/ modestly developed).

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
386,045,724	34.2	123,602,913	3.5	🟧 0.8274

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 Canadian Eastern Arctic - West Greenland LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.874, this LME has an HDI Gap of 0.126, 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). The Canadian Eastern Arctic - West Greenland LME has no projected values for HDI metrics in either development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.8740	No resident population	No resident population

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 to the Canadian Eastern Arctic - West Greenland 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 low. The projected sea level rise by 2100 for this LME is at 0.5525 m under a scenario where emissions continue to increase throughout the 21st century with radiation levels reaching 8.5 watts/m^2. However, the threat due to sea level rise could not be assessed in the absence of projected HDI data.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.3940	0.2661	No data	No data

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

In this LME, none of the four transboundary fisheries agreements (NAFO, ICCAT, NAMMCO and NASCO) appear to have formal linkages across the different stages of the policy cycle or with the Arctic Council. However, there is an integrated mechanism in the form of the Arctic Council for pollution (LBS and MBS) and general biodiversity issues. To this end, the LME has been assigned an overall integration score of 1.0 due to the presence of the Arctic Council with its ability to function as an overall policy coordinating organization for the key transboundary issues within the LME.

The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
80	**72**	**1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 19 – Greenland Sea

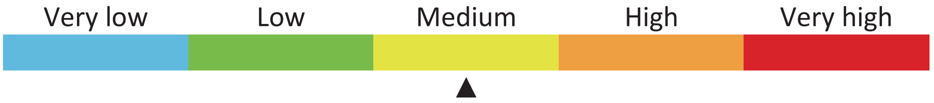
Bordering country: Greenland
LME Total area: 521,237 km^2

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.

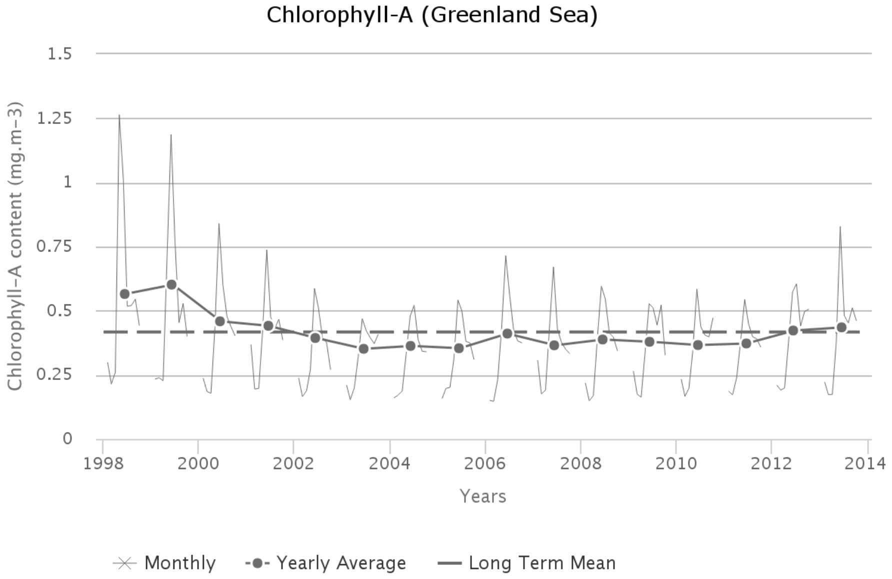
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is medium.

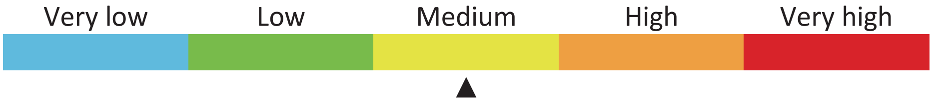


Productivity

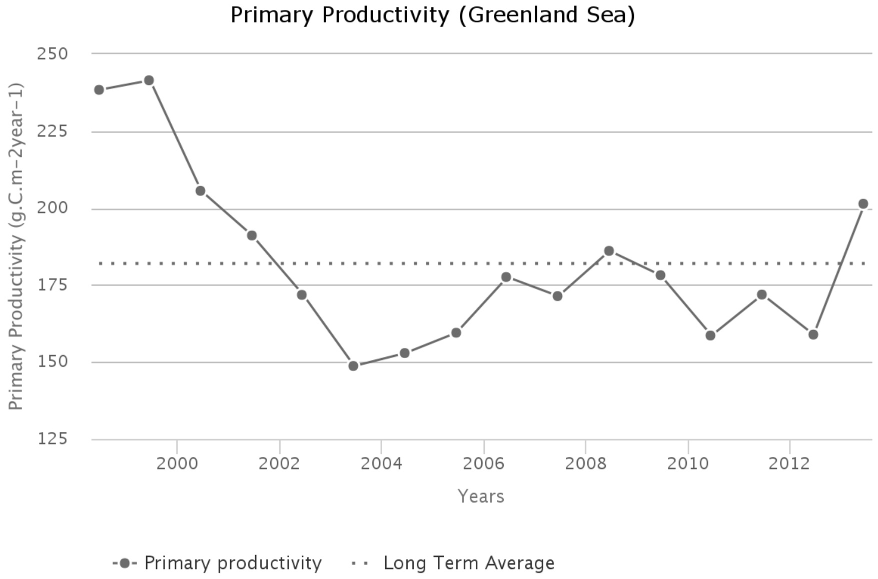
Chlorophyll-A

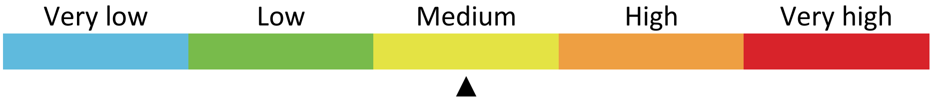
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.535 mg.m^{-3}) in June and a minimum (0.168 mg.m^{-3}) during March. The average CHL is 0.417 mg.m^{-3}. Maximum primary productivity (241 g.C.m^{-2}.y^{-1}) occurred during 1999 and minimum primary productivity (149 g.C.m^{-2}.y^{-1}) during 2003. There is a statistically insignificant increasing trend in Chlorophyll of 10.7 % from 2003 through 2013. The average primary productivity is 182 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





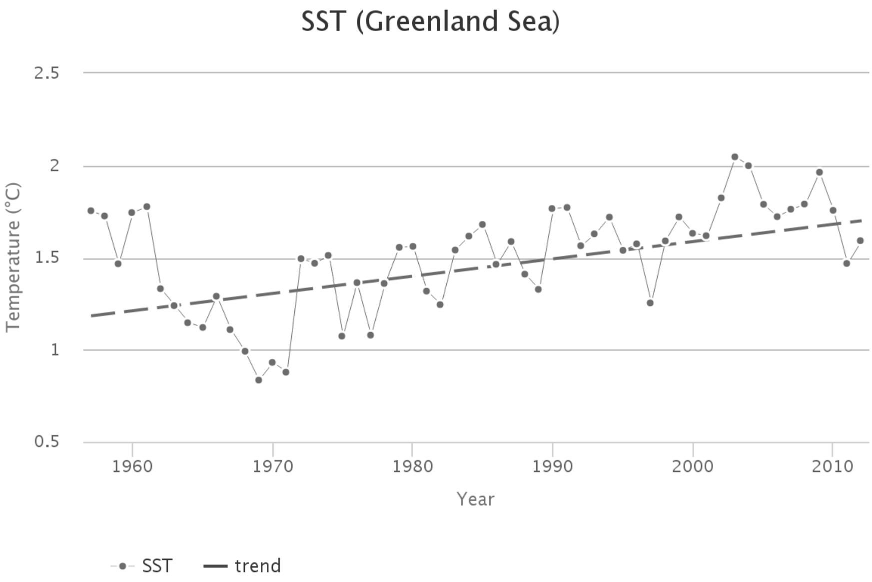
Primary productivity





Sea Surface Temperature

From 1957 to 2012, the Greenland Sea LME #19 has warmed by 0.51°C, thus belonging to Category 3 (moderate warming LME). Like many other boreal LMEs, the Greenland Sea cooled down in the 1950s-1960s until it reached the all-time minimum of just 0.8°C in 1971 during the passage of the Great Salinity Anomaly (GSA) of the 1970s (Dickson et al., 1988; Belkin et al., 1998). Later on, the GSAs of the 1980s and of the 1990s were absent over the East Greenland Shelf. After a quick recovery in 1972, SST rose steadily until the 2003 peak of >2.0°C, after which SST decreased down to 1.5°C in 2011. The record-breaking SST in 2003 is consistent with the all-time maximum near-surface annual mean air temperature of 1.5°C recorded in Ammassalik on the east coast of Greenland in 2003. The SST maximum of 2003 correlates with the all-time SST maximum of 2004-2005 observed over the West Greenland Shelf (LME #18) located downstream, which explains the time lag between the two maxima. In the two nearby LMEs, Iceland Sea and Shelf (#59) and Faroe Plateau (#60), SST also reached all-time maxima in 2003.

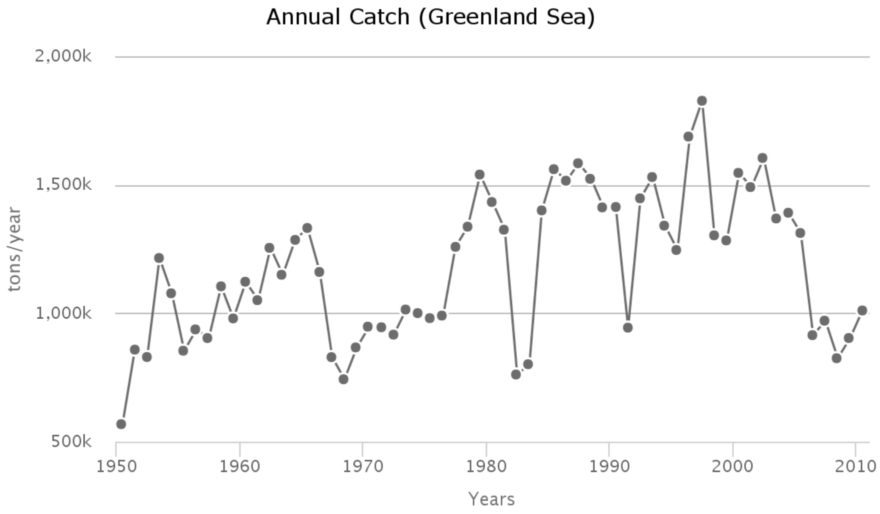


Fish and Fisheries

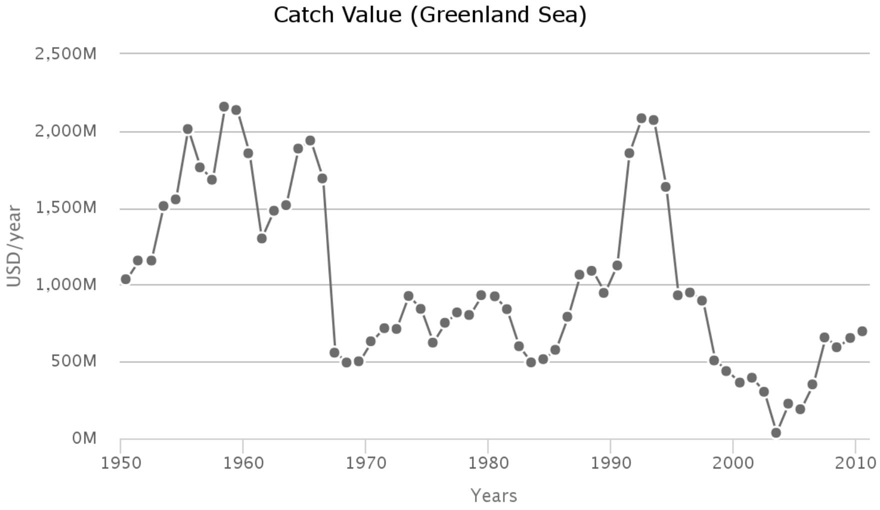
Total reported landings from the LME have increased since 1950, with occasional variations mainly driven by fluctuations in capelin landings.

Annual Catch

Total reported landings peaked in 1997 at 1.8 million t. Landings consisted mainly of Atlantic cod, and herring and capelin in the pre- and post-1970s periods, respectively. An important fishery for northern prawn shrimp has developed, with landings in the mid-1990s of over 60,000 t.

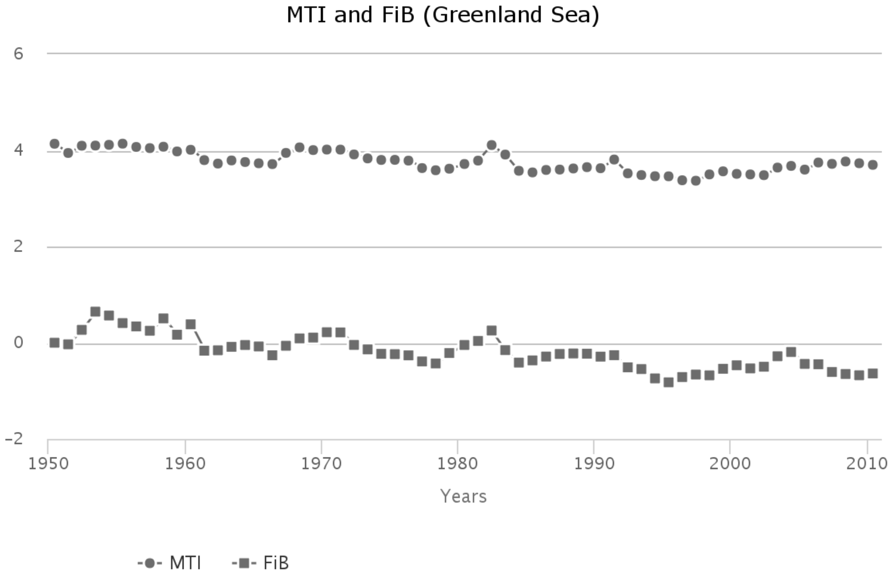


Catch value



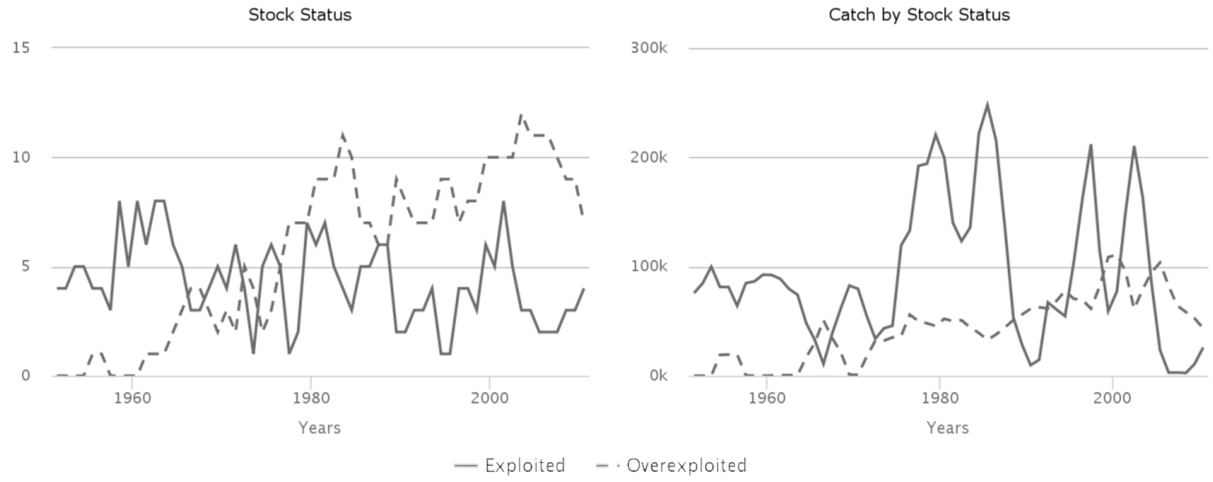
Marine Trophic Index and Fishing-in-Balance index

Both the MTI and the FiB index have declined over the reported period and represent a classic case of "fishing down marine food webs".



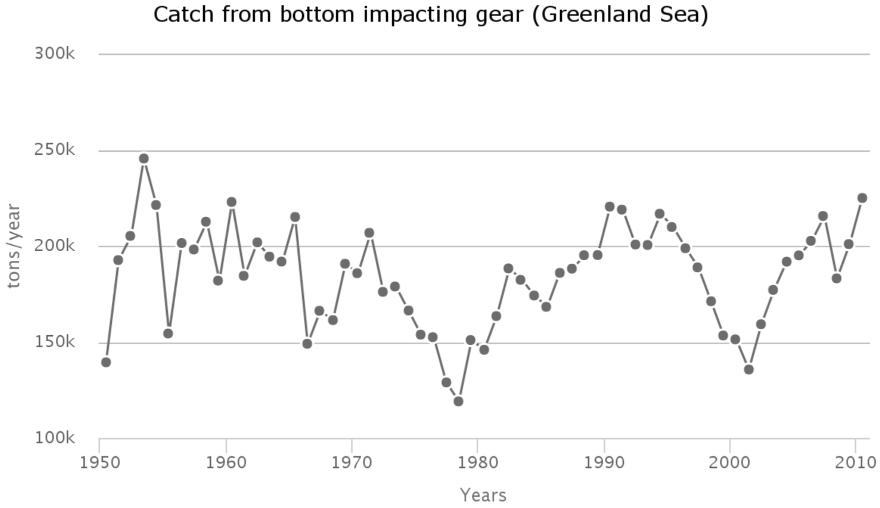
Stock status

The Stock-Catch Status Plots indicate that the number of collapsed and overexploited stocks has been increasing over the years, accounting for nearly 60% of the commercially exploited stocks in the region with the majority of the reported landings biomass supplied by overexploited stocks.



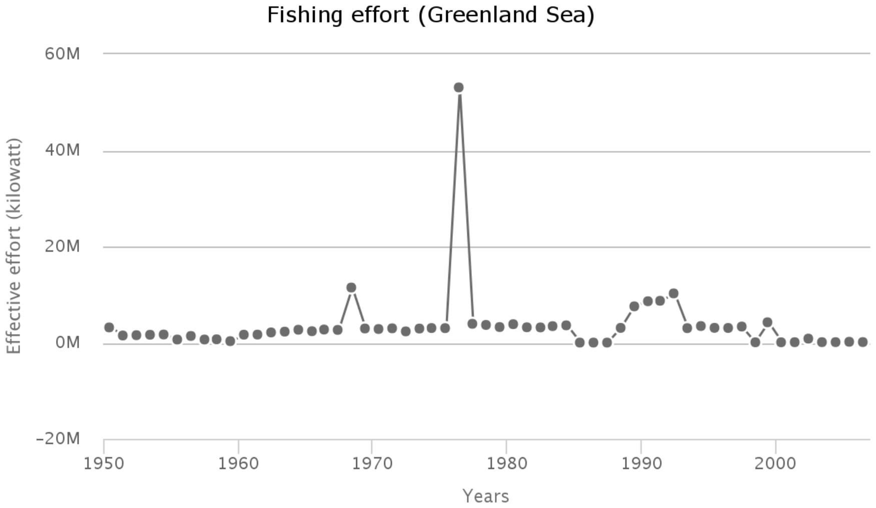
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch fluctuated between 9 and 25% in these 60 years.



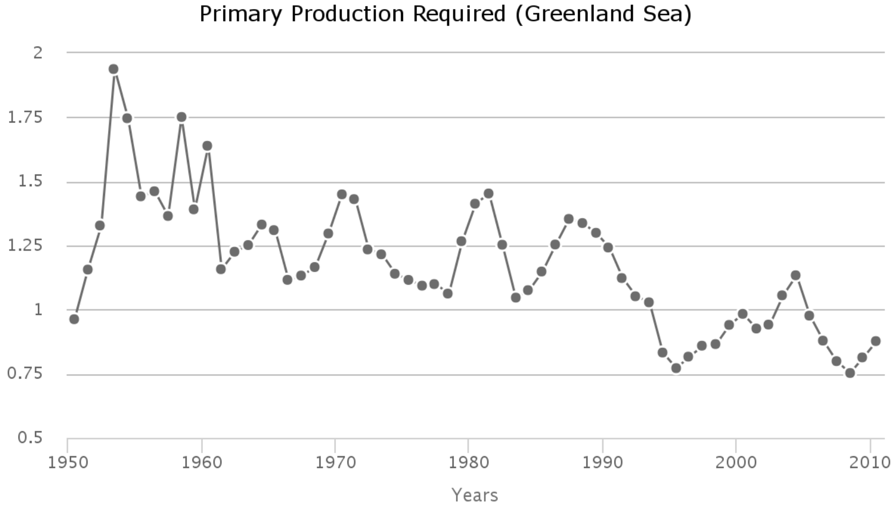
Fishing effort

The total effective effort was below 10 million kW for most of the time in the period 1950 to 2010.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in the LME exceeds the observed primary production, which likely implies that a large portion of the reported landings are supported by primary production from neighboring marine ecosystems, i.e., large groups of exploited stocks are feeding outside of the Iceland Shelf LME and migrating back in where they are caught.


Primary Production Required (Greenland Sea)

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 decreased to low in 2030 and remained low in 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	2	1	1	2	1

Legend:

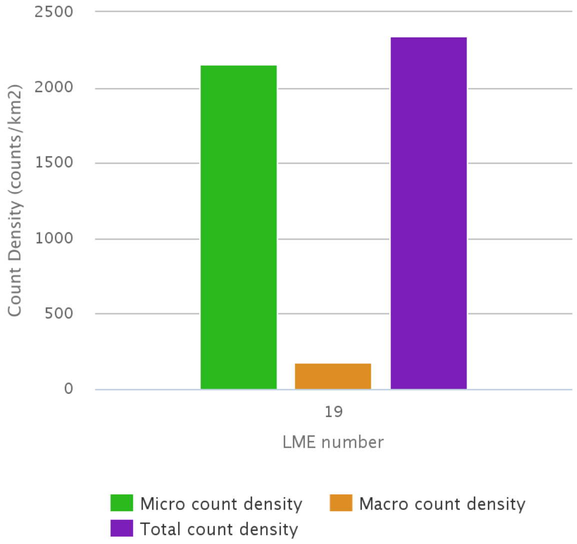
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

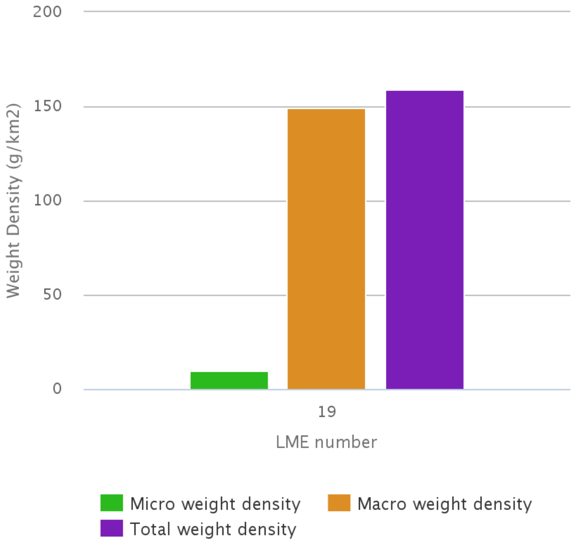
POPs

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 relatively moderate levels of 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 the relative importance of these sources in this LME. The abundance of floating plastic in this category is estimated to be on average over 12 times lower that those LMEs with lowest 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

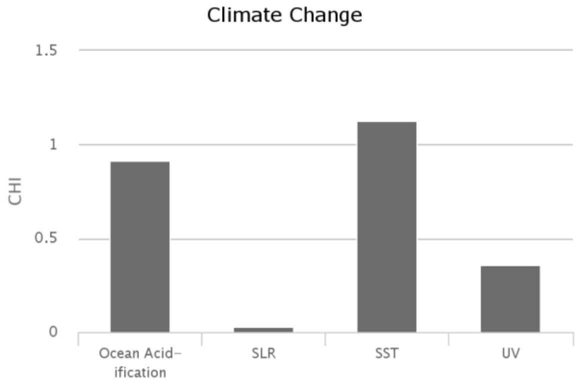
Not applicable.

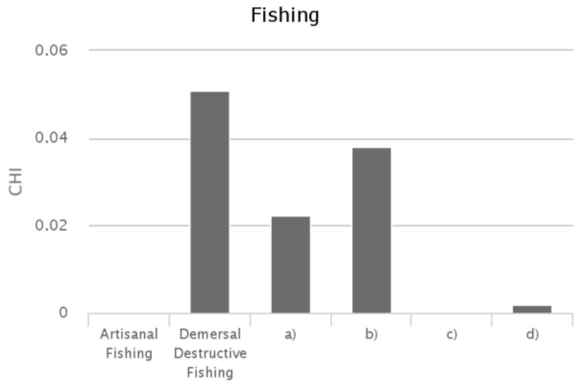
Marine Protected Area change

The Norwegian Sea LME experienced an increase in MPA coverage from 1,087 km^2 prior to 1983 to 2,076 km^2 by 2014. This represents an increase of 91%, within the lowest category of MPA change.

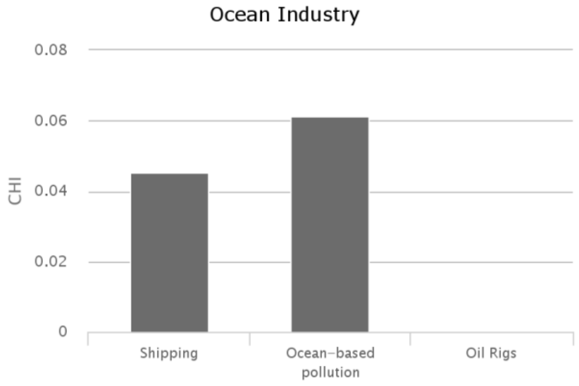
Cumulative Human Impact

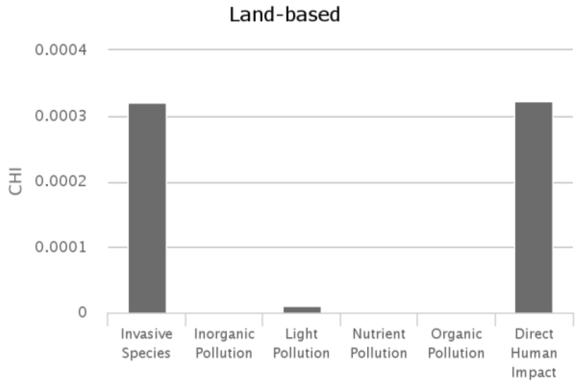
The Greenland Sea LME experiences below average overall cumulative human impact (score 2.65; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.92; maximum in other LMEs was 1.20), UV radiation (0.35; maximum in other LMEs was 0.76), and sea surface temperature (1.13; maximum in other LMEs was 2.16). Other key stressors include ocean based pollution and demersal destructive commercial fishing.

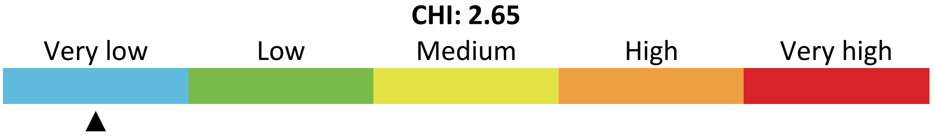




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

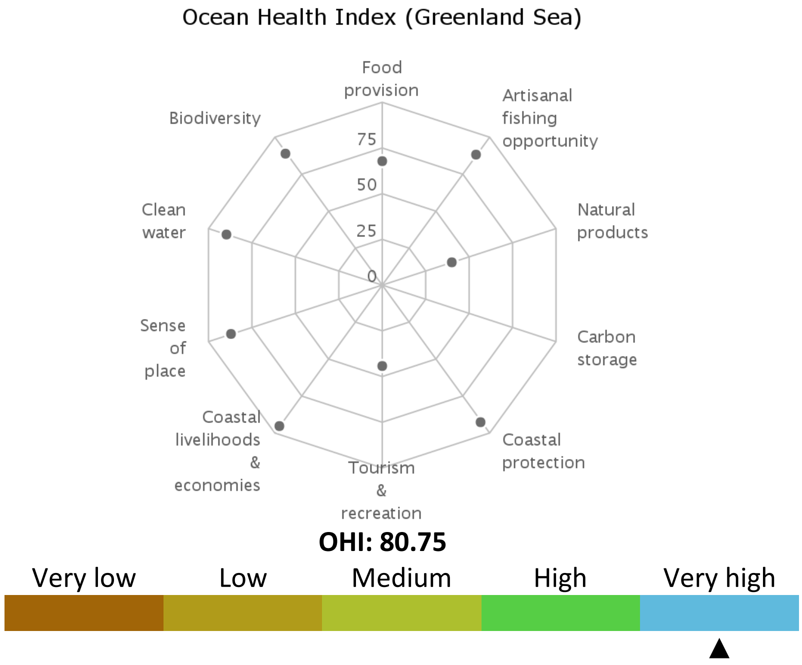






Ocean Health Index

The Greenland Sea LME scores the highest of any LME on the Ocean Health Index (score 82 out of 100; range for other LMEs was 57 to 82), although still with room for improvement. This score indicates that the LME is below its optimal level of ocean health. Its score in 2013 increased 1 point compared to the previous year, due in large part to changes in the scores for clean waters. This LME scores lowest on the tourism & recreation goal and highest on mariculture, artisanal fishing opportunities, natural products, coastal protection, coastal livelihoods & economies, and biodiversity goals. It falls in risk category 1 of the five risk categories, which is the lowest level of risk (1 = lowest risk; 5 = highest risk).



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 the Greenland Sea 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 includes the eastern shore of Greenland, stretching over 141,511 km^2. A current population of 102 in 2010 is projected to 3,588 in 2100, with density increasing from 7 persons per 10,000 km^2 in 2010 to 300 per 10,000 km^2 by 2100. A 100% of coastal population is projected to remain rural to 2100.

Total population		Rural population	
2010	2100	2010	2100
102	3,588	102	3,588

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

There is no data on impoverished population for Greenland

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. The Greenland Sea LME ranks in the very low revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $87 million for the period 2001-2010. Fish protein accounts for 40% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $40 million places it in the very low revenue category. On average, LME-based tourism income contributes 0.02% 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 the Greenland Sea LME falls in the category with very low risk (very highly developed).

Fisheries Annual Landed Value	% Fish Protein Contribution	Tourism Annual Revenues	% Tourism Contribution to GDP	NLDI
87,075,441	39.5	39,610,000	0.0	0.6505

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 Greenland Sea LME HDI belongs to the highest HDI and lowest risk category. Based on an HDI of 0.869, this LME has an HDI Gap of 0.131, 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). The Greenland Sea LME has no projected values for HDI metrics in either development pathway.

	HDI 2100	
HDI	SSP1	SSP3
0.8690	No data	No data

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.

There is no data on the Greenland Sea LME to allow for the computation of a Present day climate threat index. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, cannot be computed because of incomplete indicator data. The projected sea level rise by 2100 for this LME is at 0.5798 m under a scenario where emissions continue to increase throughout the 21st century with radiation levels reaching 8.5 watts/m^2. However, the threat due to sea level rise could not be assessed in the absence of projected HDI data.

2010		2100	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
No data	No data	No data	No data

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

None of the transboundary fisheries arrangements (NEAFC, ICCAT, NAMMCO, NASCO and EU-CFP) in this LME appear to be integrated while the three arrangements for pollution and biodiversity appear to have the Arctic Council as an integrating arrangement for one set of issues and the OSPAR Convention for a second set of similar issues relating to pollution and biodiversity. Additionally, the specific biodiversity arrangements for marine mammals and polar bears do not appear to have any formal linkages. Whereas, the Arctic Council is not a binding arrangement, so its implementation is voluntary and country dependent, it does appear to have the potential to develop into an informal overall policy coordinating organization.

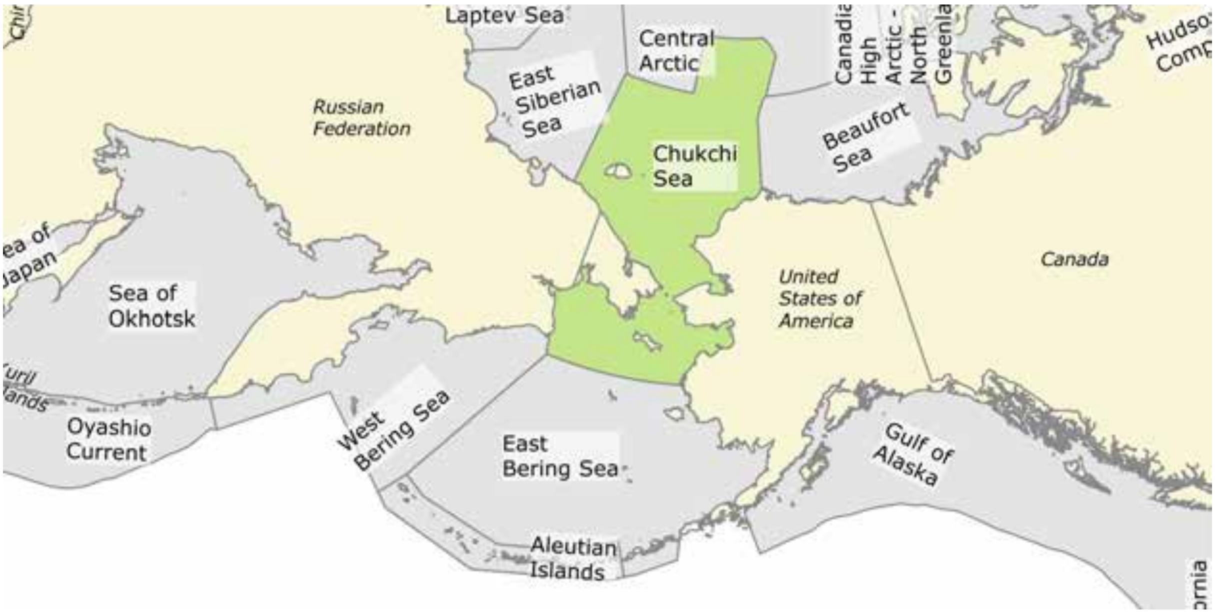
The overall scores for the ranking of risk were:

Engagement	Completeness	Integration
75	74	0.1

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 54 – Chukchi Sea



Bordering countries: United States of America, Russian Federation.
LME Total area: 783,245 km^2

List of indicators

LME overall risk

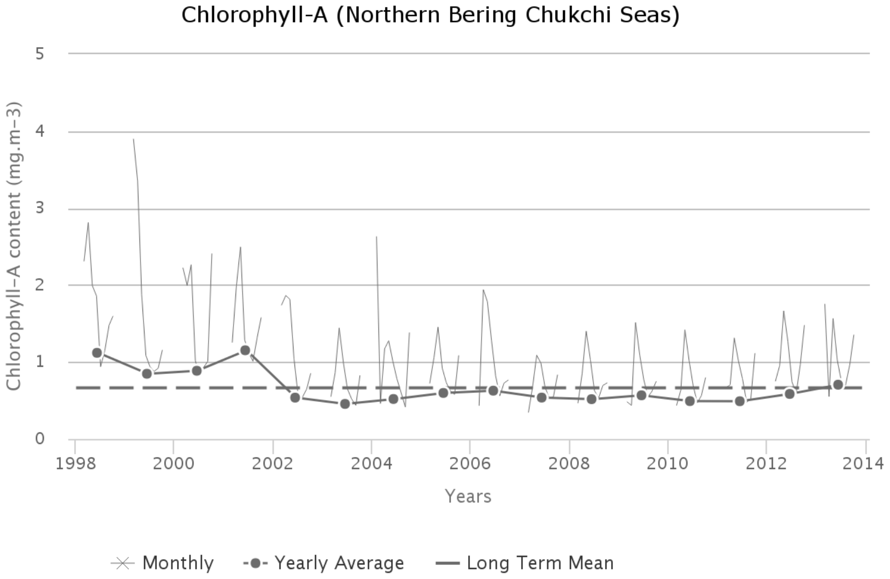
This LME falls in the cluster of LMEs that exhibit high percentages of rural coastal population, high numbers of collapsed and overexploited fish stocks, as well as high proportions of catch from bottom impacting gear.

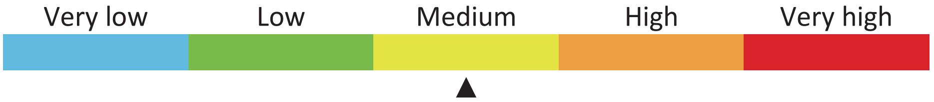
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Productivity

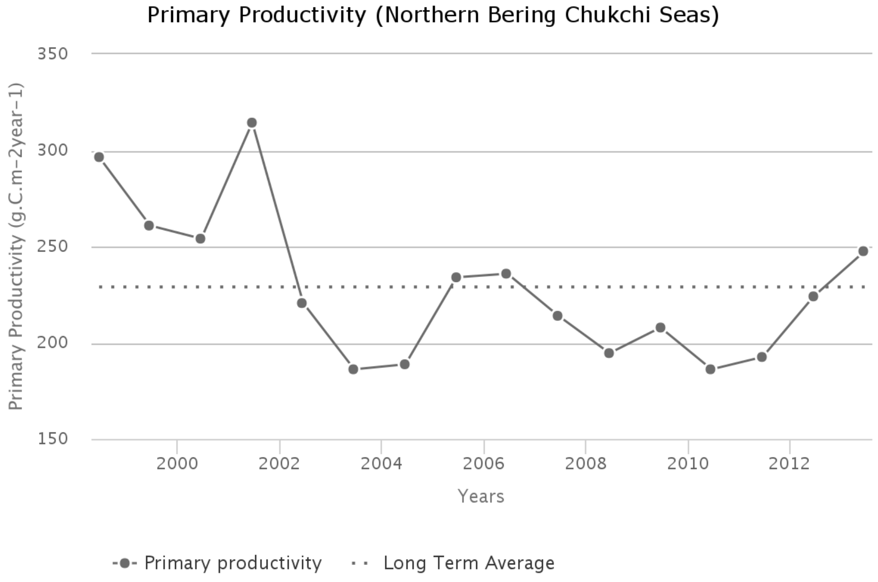
Chlorophyll-A

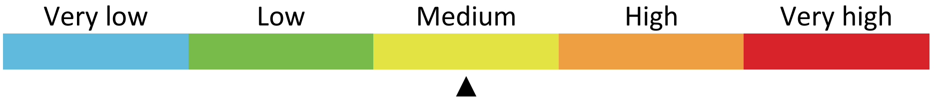
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (2.63 $mg.m^{-3}$) in February and a minimum (0.480 $mg.m^{-3}$) during September. The average CHL is 0.664 $mg.m^{-3}$. Maximum primary productivity (314 $g.C.m^{-2}.y^{-1}$) occurred during 2001 and minimum primary productivity (186 $g.C.m^{-2}.y^{-1}$) 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).





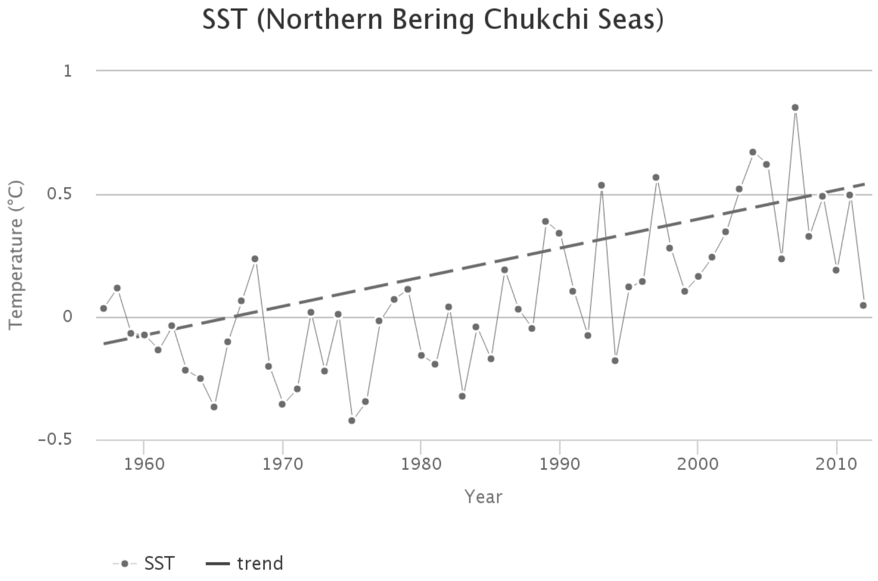
Primary productivity





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.

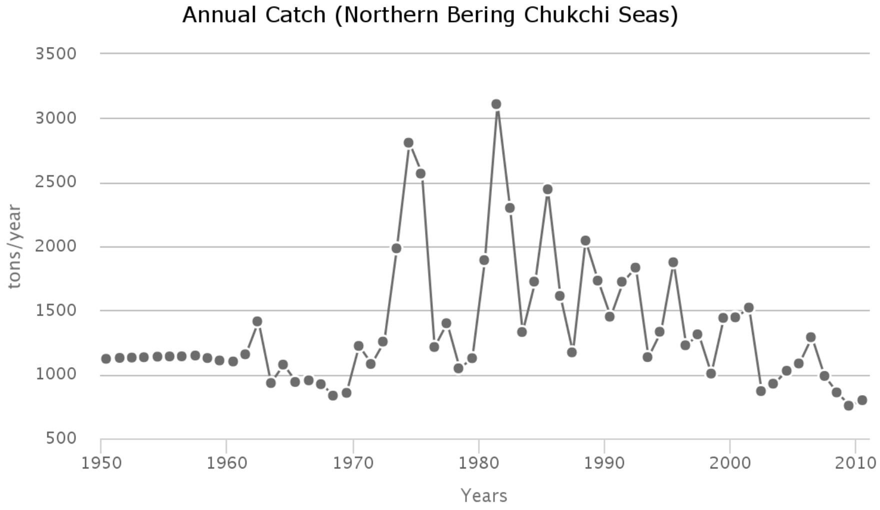


Fish and Fisheries

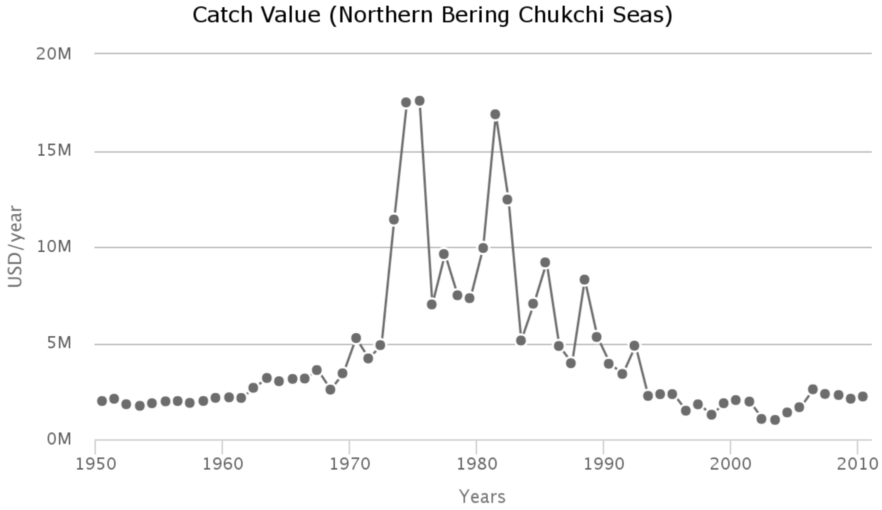
Key marine species in this LME are salmon (*Oncorhynchus spp.*), herring (*Clupea pallasii pallasii*), walrus (*Odobenus rosmarus*), seals, whales and various species of waterfowl. The key subsistence marine species are likely to undergo shifts in range and abundance due to climate change. The central 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.



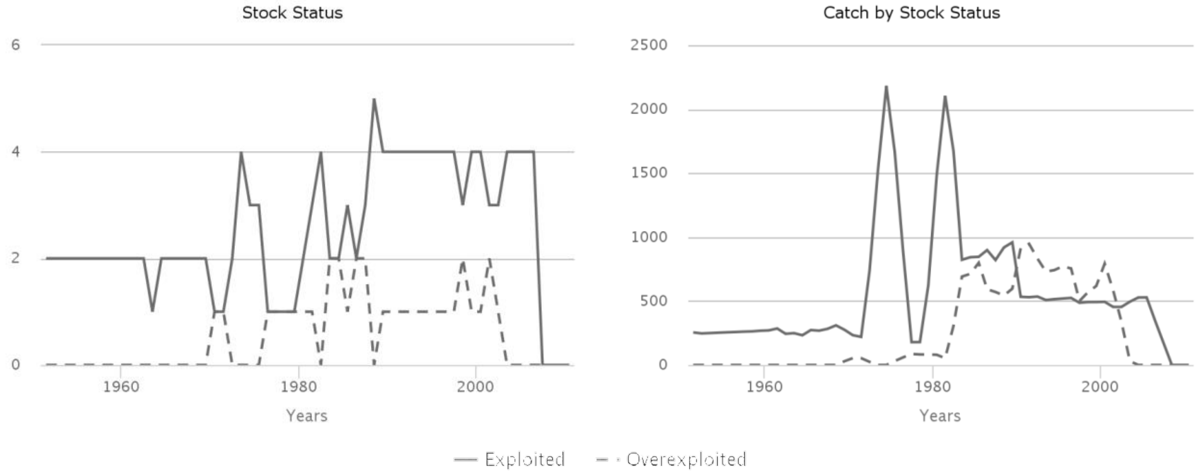
Catch value



Marine Trophic Index and Fishing-in-Balance index

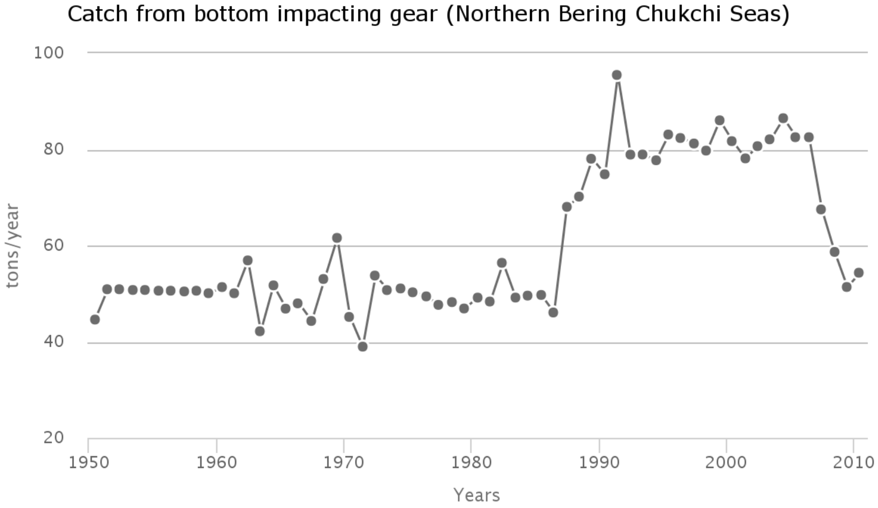
Given the very low quality of the underlying catch data, the catch-based indicators for this LME (such as PPR, MTI or FiB) are likely to be very unreliable.

Stock status



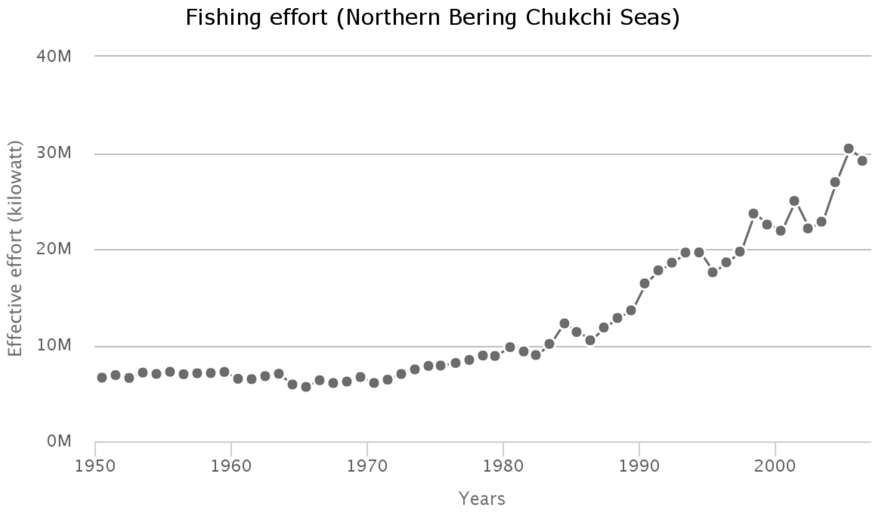
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch 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.

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	2	1	1	2	1	1	2	1

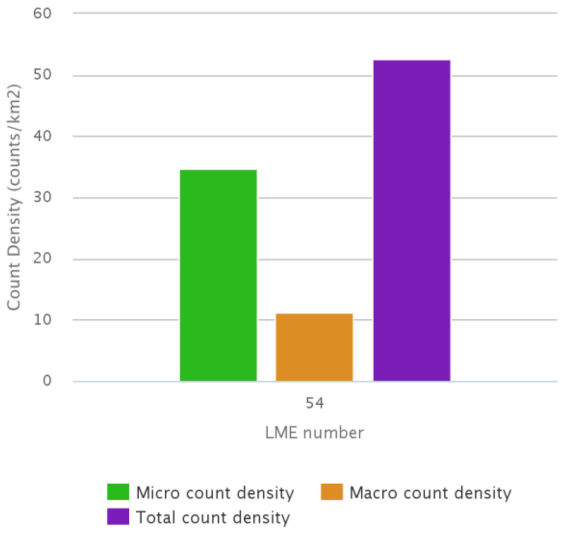
Legend:
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

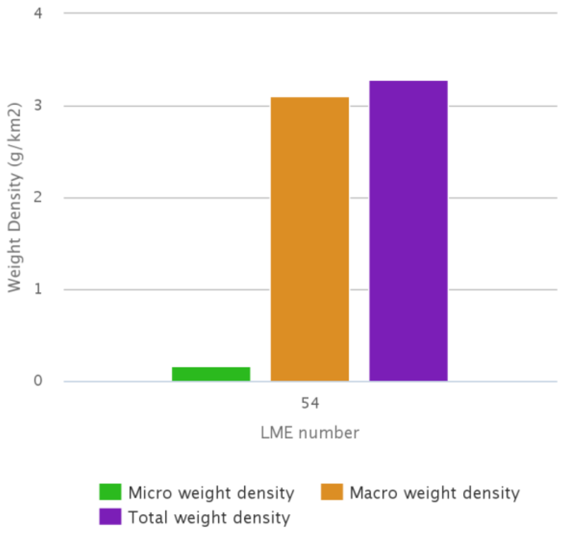
POPs

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 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

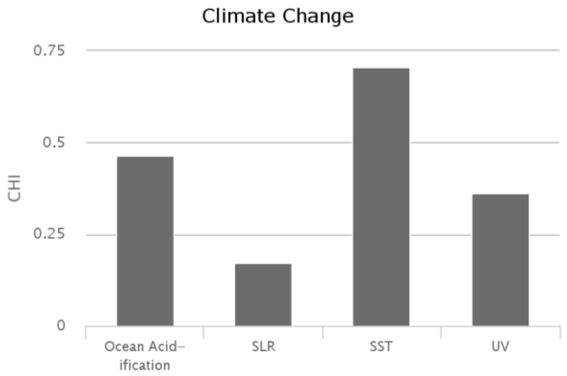
Not applicable.

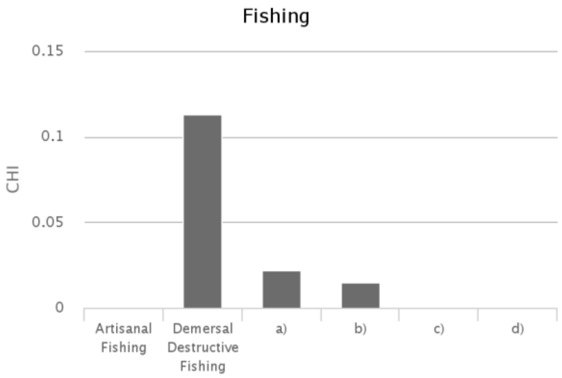
Marine Protected Area change

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.

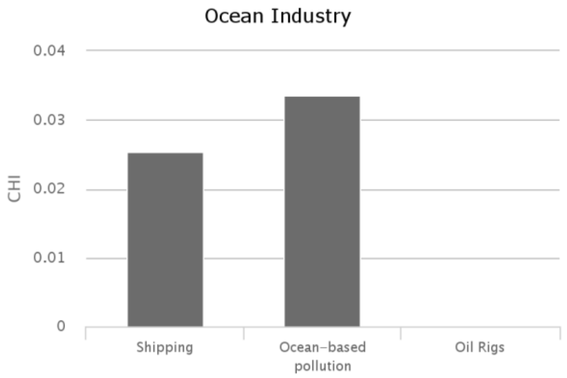
Cumulative Human Impact

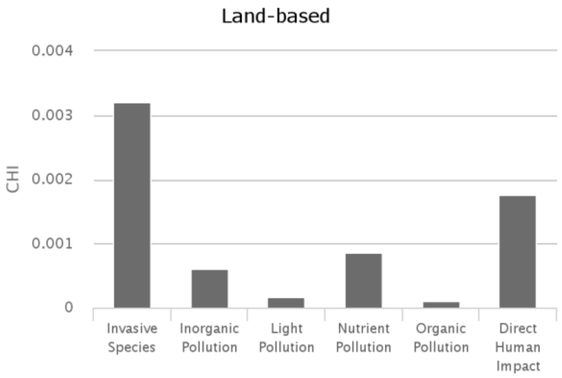
The Northern Bering – Chukchi Seas LME experiences below average overall cumulative human impact (score 1.92; maximum LME score 5.22), but which is still above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME 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.

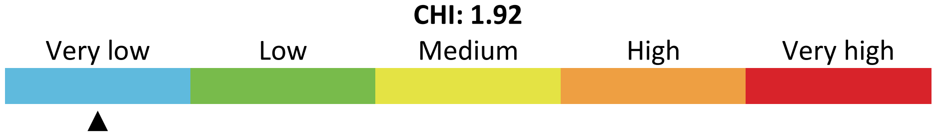




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

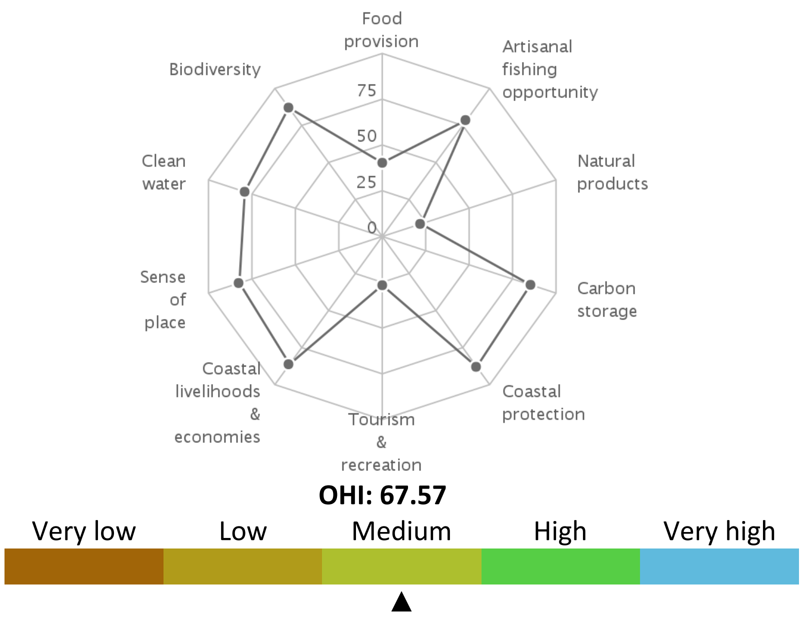






Ocean Health Index

The 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).



Ocean Health Index (Northern Bering Chukchi Seas)

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 493 726 km^2. 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 km^2 in 2010 decreasing to 9 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**
56,490	45,969	56,490	45,969

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

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).

Coastal poor
9,646

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 $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 2013

$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.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
327,890,066	10.4	4,759,031,758	8.4	🟨 0.7088

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.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.8557	🟦 0.9355	🟧 0.6588

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 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.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.5766	0.2909	0.2813	0.4857

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.

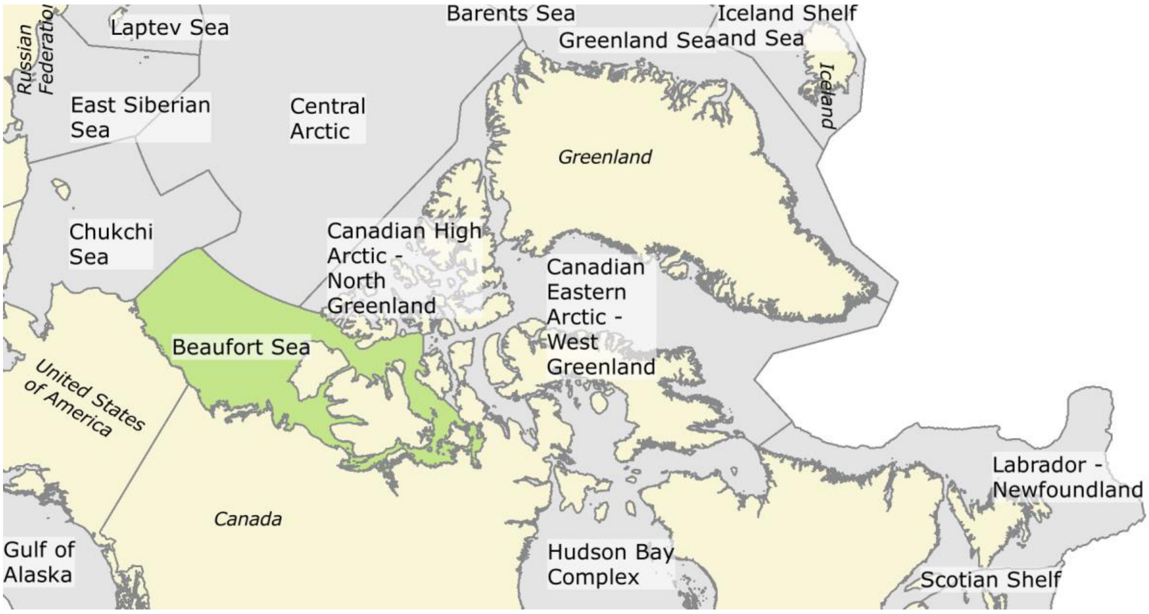
The overall scores for ranking of risk were:

Engagement	Completeness	Integration
88	**69**	**1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 54 – Beaufort Sea



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

List of indicators

LME overall risk

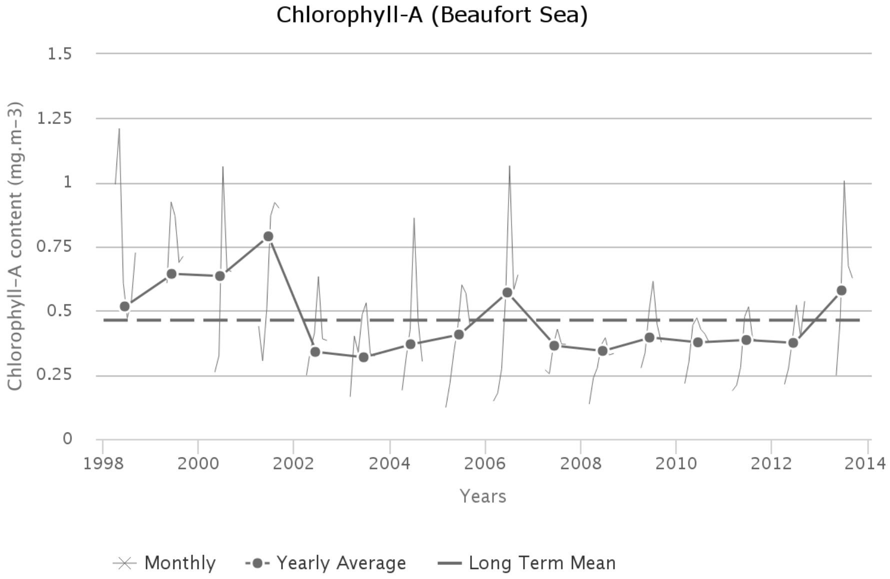
This LME falls in the cluster of LMEs that exhibit high percentages of rural coastal population, high numbers of collapsed and overexploited fish stocks, as well as high proportions of catch from bottom impacting gear.

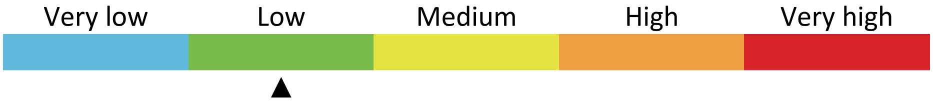
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is very low..

Productivity

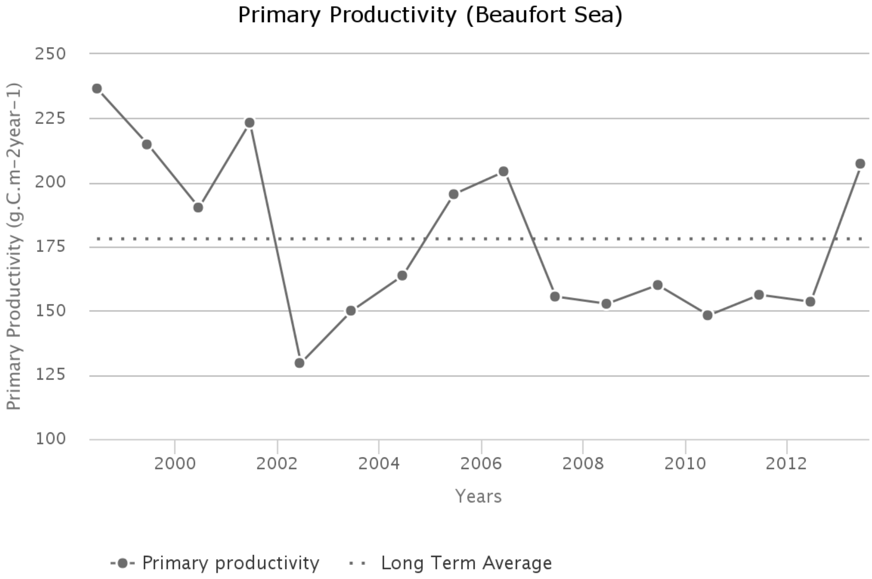
Chlorophyll-A

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).



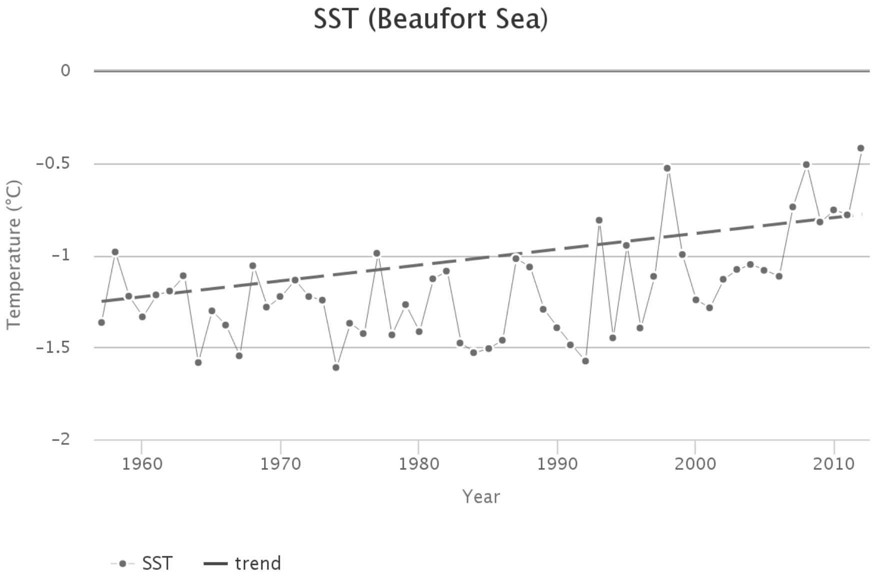


Primary productivity



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.

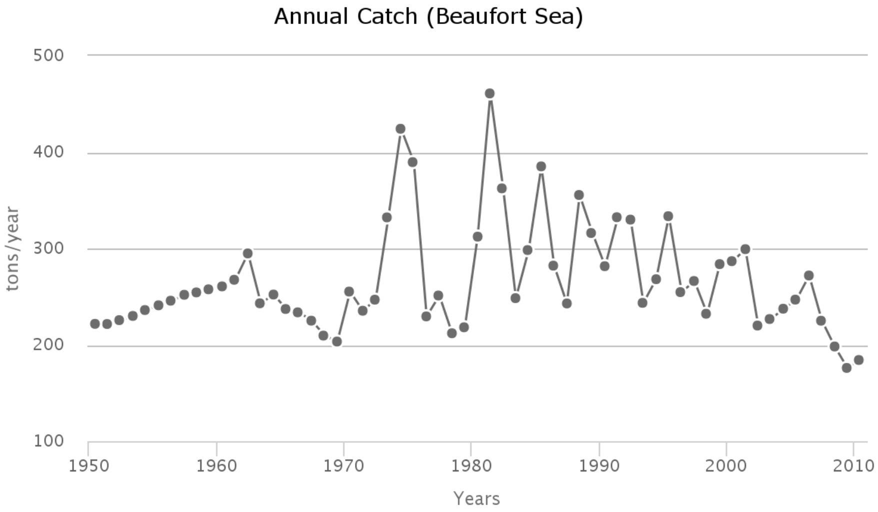


Fish and Fisheries

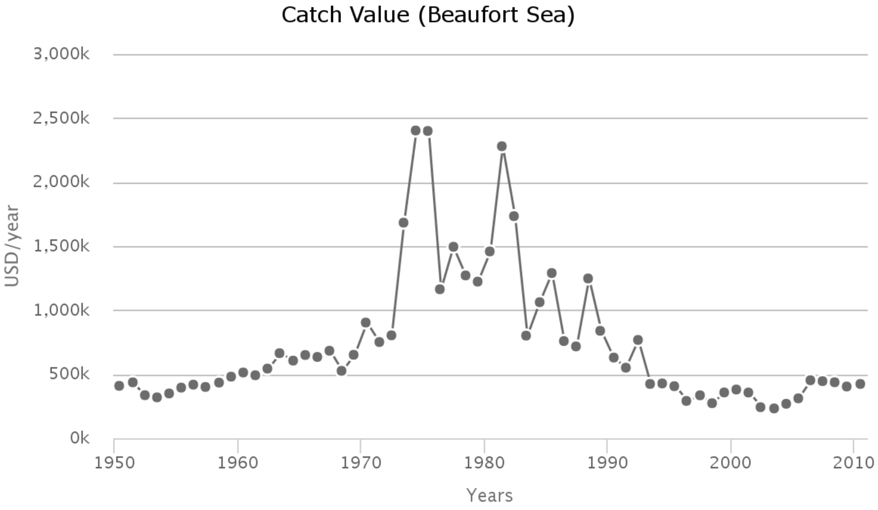
There are three coastal communities (Tuktoyaktuk, Sachs Harbour and Kaktovik) and two inland communities (Aklavik and Inuvik) that make use of the Beaufort Sea, largely for subsistence, but also some commercial fisheries occur in Canadian waters. The catch data from this LME are too crude for ecosystem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



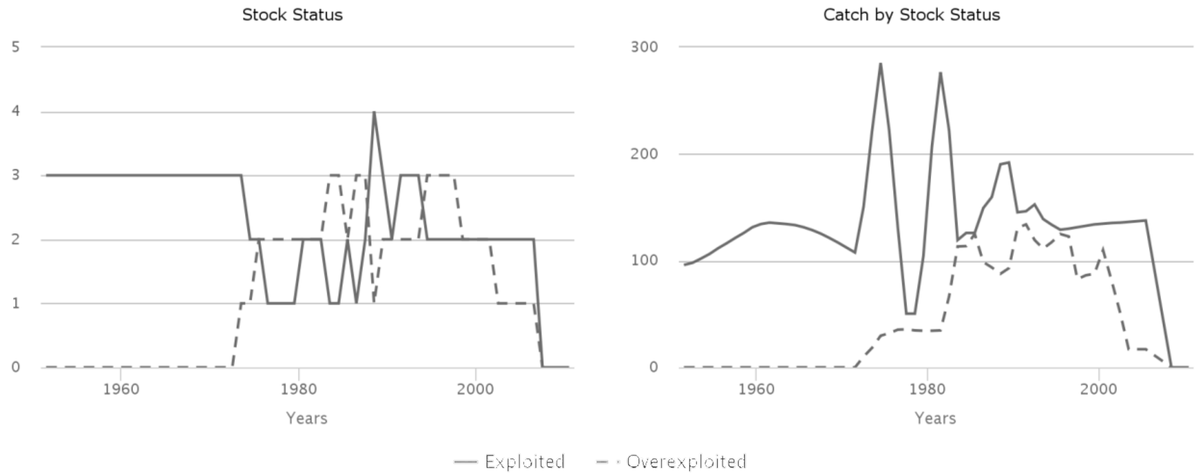
Catch value



Marine Trophic Index and Fishing-in-Balance index

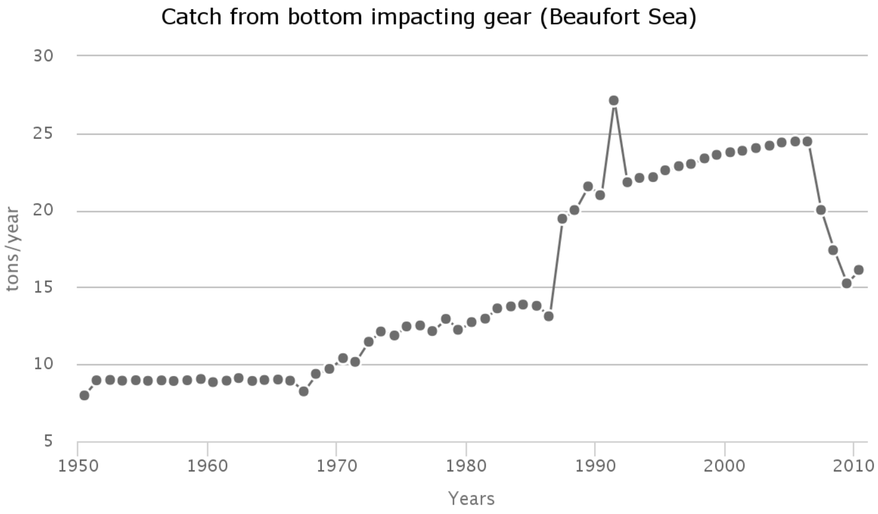
Given the very low quality of the underlying catch data, the catch-based indicators for this LME (such as PPR, MTI or FiB) are likely to be very unreliable.

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:

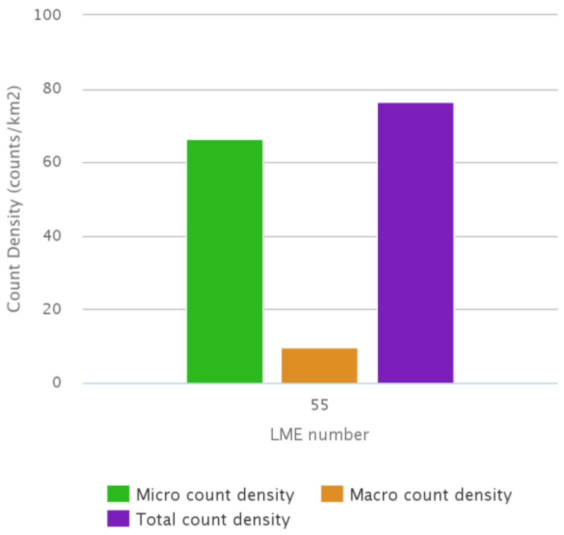
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

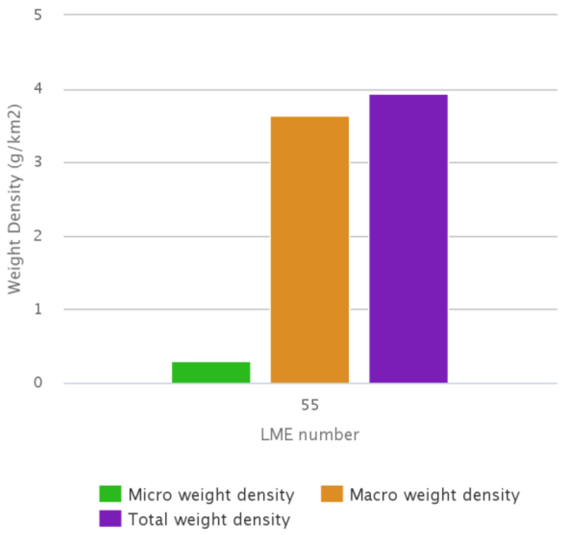
POPs

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

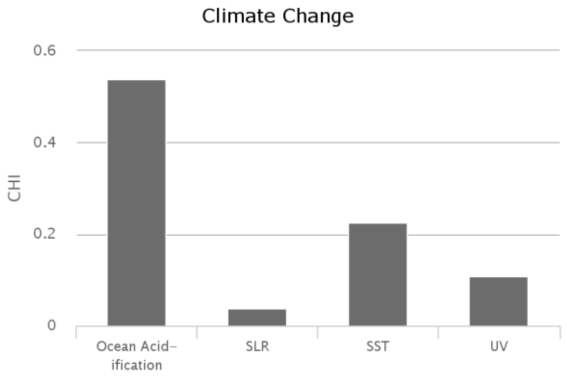
Not applicable.

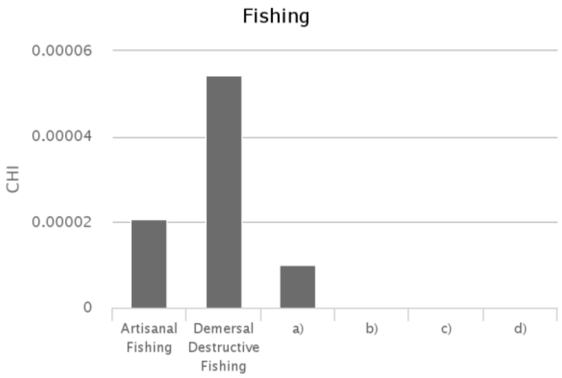
Marine Protected Area change

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.

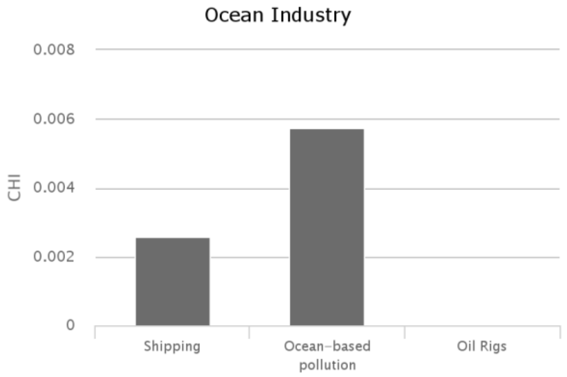
Cumulative Human Impact

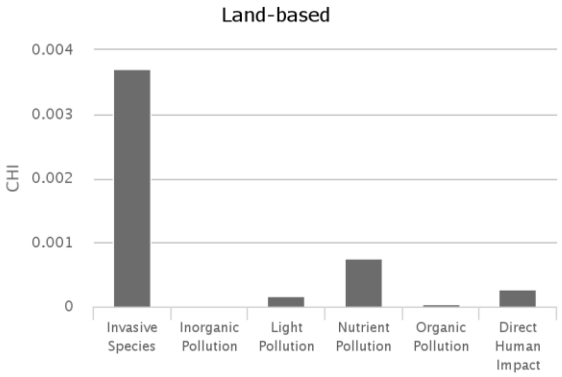
The Beaufort Sea LME experiences one of the lowest overall cumulative human impact (score 0.93; maximum LME score 5.22). It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected 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.


Climate Change


Fishing

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

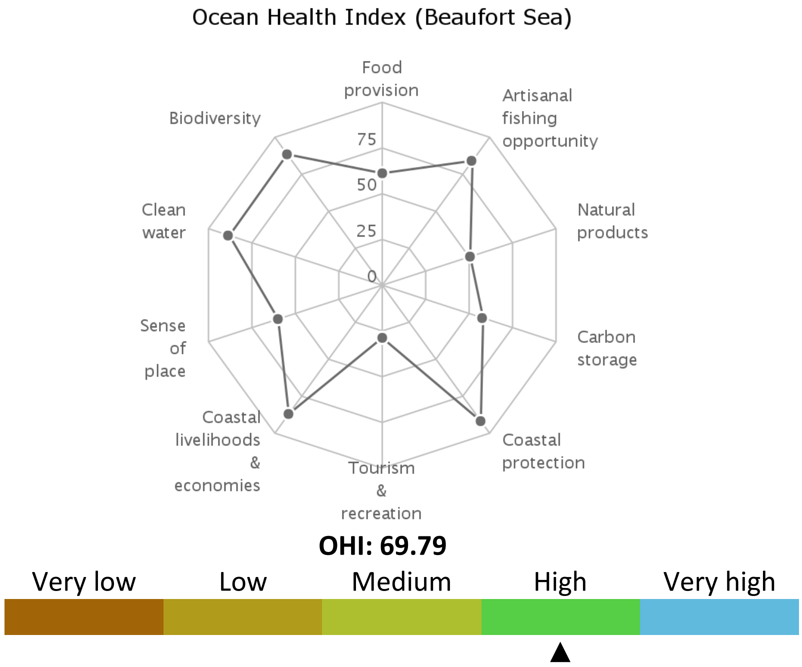

Ocean Industry


Land-based

CHI: 0.93

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).



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.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
🟩 0.4270	🟦 0.2175	🟦 0.2029	🟦 0.4133

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

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:

Engagement	Completeness	Integration
🟦 **100**	🟩 **67**	🟦 **1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 63 – Hudson Bay Complex

Bordering country: Canada.
LME Total area: 1,247,246 km^2

List of indicators

LME overall risk

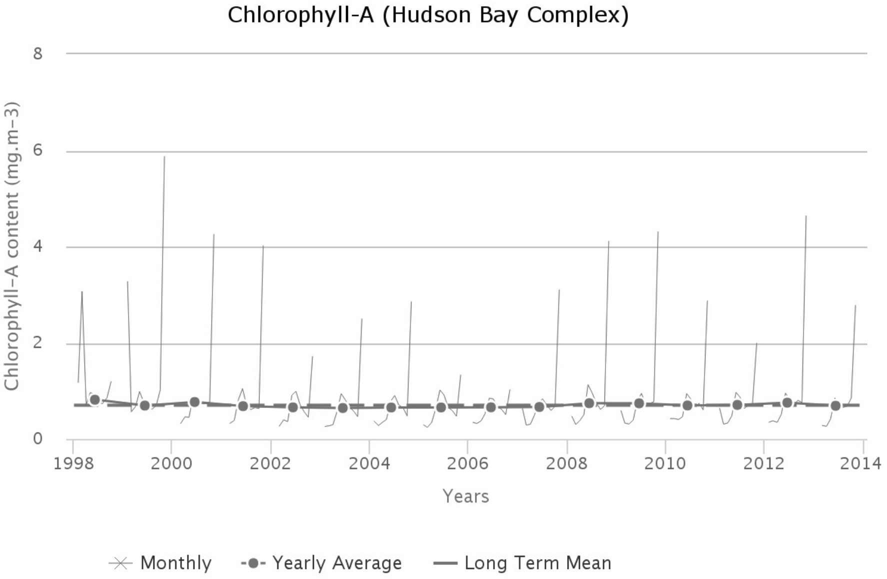
This LME falls in the cluster of LMEs that exhibit high percentages of rural coastal population, high numbers of collapsed and overexploited fish stocks, as well as high proportions of catch from bottom impacting gear.

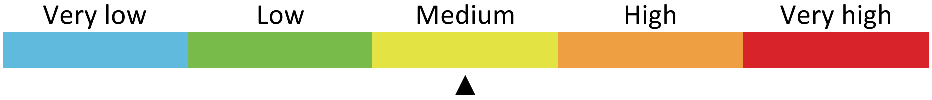
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

Productivity

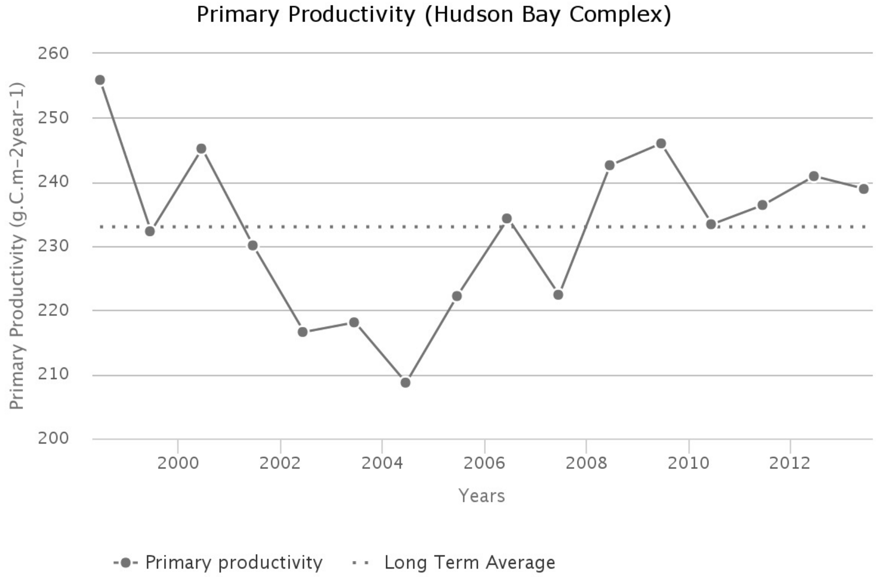
Chlorophyll-A

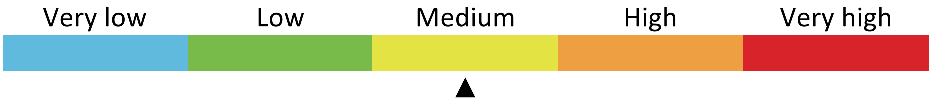
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (1.89 mg.m^{-3}) in November and a minimum (0.331 mg.m^{-3}) during March. The average CHL is 0.701 mg.m^{-3}. Maximum primary productivity (256 g.C.m^{-2}.y^{-1}) occurred during 1998 and minimum primary productivity (209 g.C.m^{-2}.y^{-1}) during 2004. There is a statistically insignificant increasing trend in Chlorophyll of 14.1 % from 2003 through 2013. The average primary productivity is 233 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





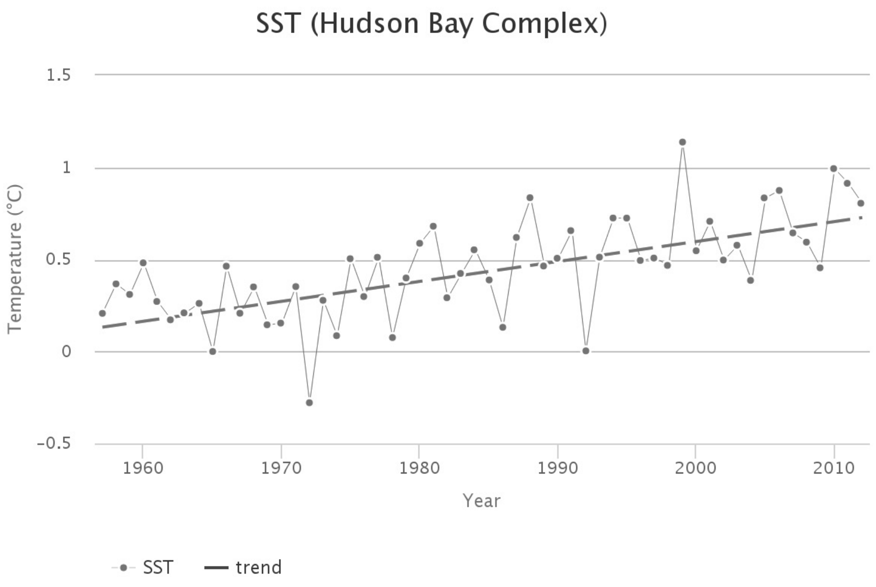
Primary productivity





Sea Surface Temperature

From 1957 to 2012, the Hudson Bay Complex LME #63 has warmed by 0.60°C, thus belonging to Category 3 (moderate warming LME). The Hudson Bay warming was steady. The all-time minimum of -0.3°C was attained in 1972, in the end of a long-term cooling epoch. The post-1972 long-term warming resulted in SST increase of >1°C over the next 20 years. The long-term 1957-2012 warming was 0.60°C. The all-time maximum of nearly 1.2°C in 1999 was an isolated event. The recent long-term decrease of river freshwater discharge into Hudson Bay caused salinization of the upper ocean (Déry et al., 2005), so that there are two modern trends – warming and salinization – that have opposite effects on water density, which decreases with rising temperature and increases with rising salinity. Circulation in Hudson Bay flushes melt water out of the Bay into Hudson Strait and eventually onto the Newfoundland Shelf (LME #9). Therefore, the continuing warming of the Hudson Bay is bound to affect the Newfoundland Shelf.

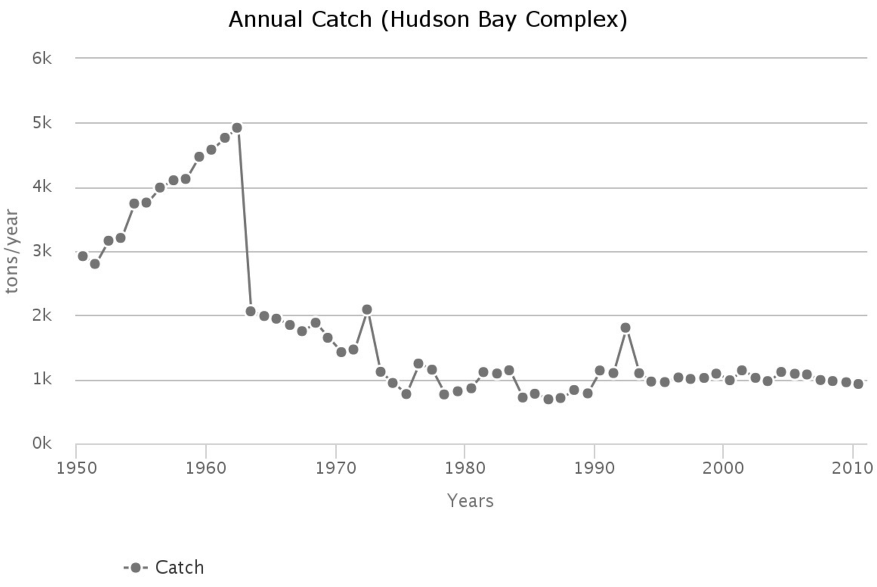


Fish and Fisheries

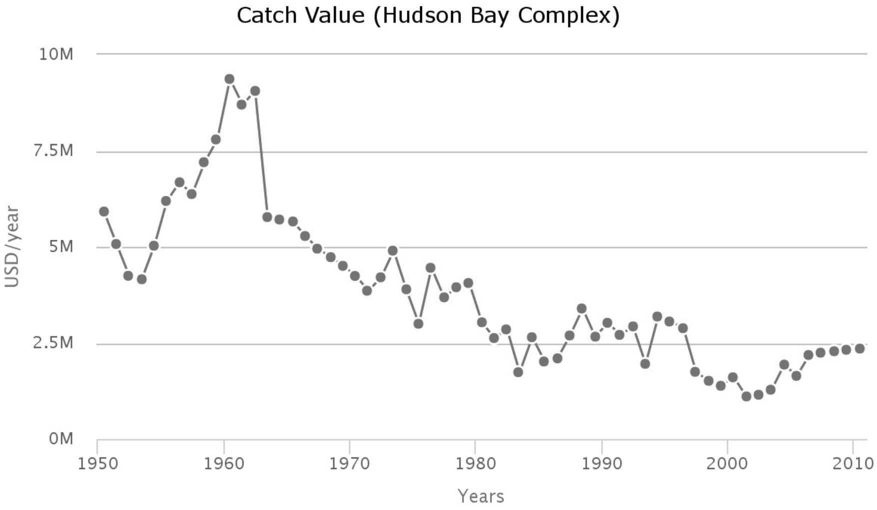
From 1957 to 2012, the Hudson Bay Complex LME #63 has warmed by 0.60°C, thus belonging to Category 3 (moderate warming LME). The Hudson Bay warming was steady. The all-time minimum of -0.3°C was attained in 1972, in the end of a long-term cooling epoch. The post-1972 long-term warming resulted in SST increase of >1°C over the next 20 years. The long-term 1957-2012 warming was 0.60°C. The all-time maximum of nearly 1.2°C in 1999 was an isolated event. The recent long-term decrease of river freshwater discharge into Hudson Bay caused salinization of the upper ocean (Déry et al., 2005), so that there are two modern trends – warming and salinization – that have opposite effects on water density, which decreases with rising temperature and increases with rising salinity. Circulation in Hudson Bay flushes melt water out of the Bay into Hudson Strait and eventually onto the Newfoundland Shelf (LME #9). Therefore, the continuing warming of the Hudson Bay is bound to affect the Newfoundland Shelf..

Annual Catch

Estimated subsistence catches in 1950 were approximately 2,920 t, and peaked in 1962 at 4,922 t before declining to approximately 1,000 t by the early 2000s. A large part of the decline over the last few decades is attributed to the fact that the snowmobile has replaced the dog sled as the major form of transportation, thus reducing the need for marine fish as dog food.

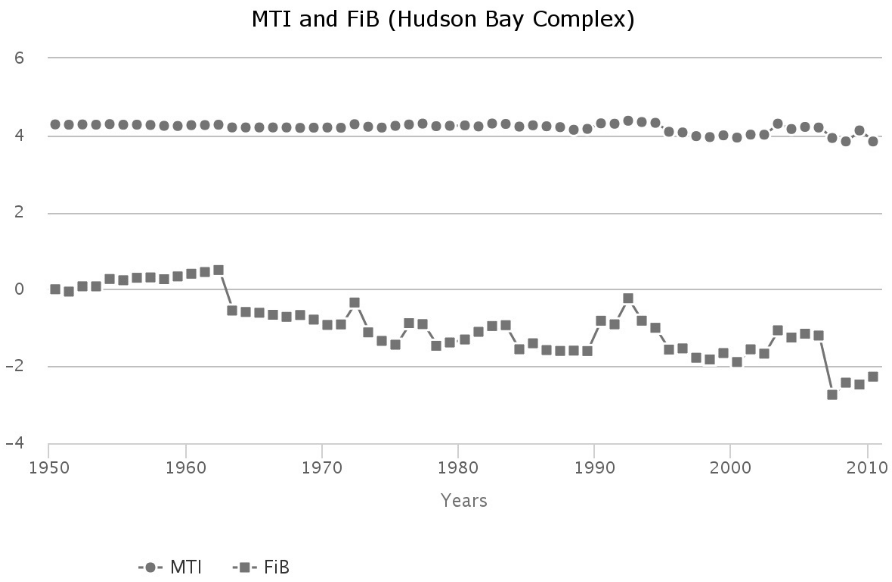


Catch value

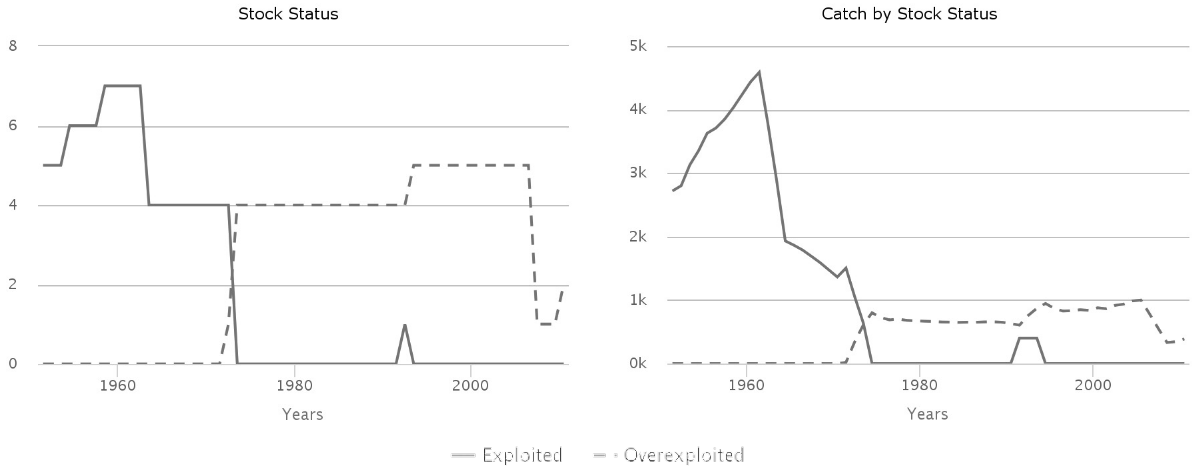


Marine Trophic Index and Fishing-in-Balance index

The catch data from this LME are too crude for ecosystem indicators such as PPR, MTI or FiB index to be computed.

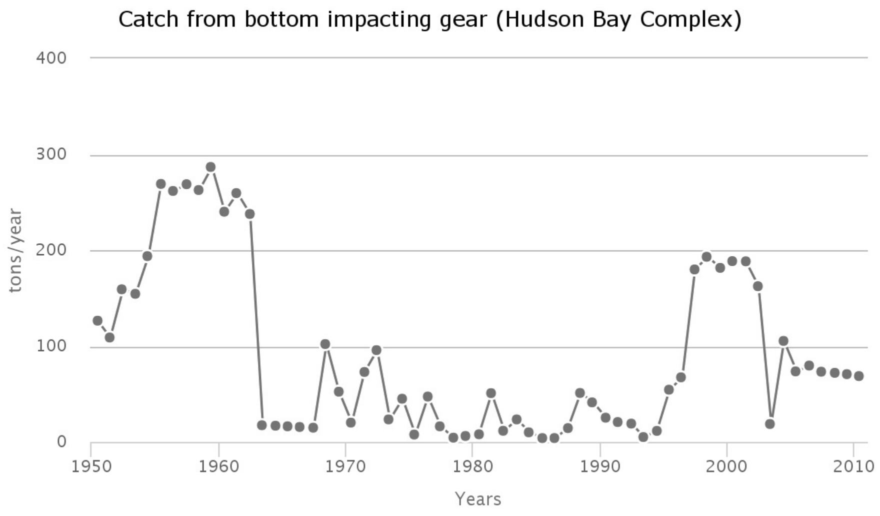


Stock status



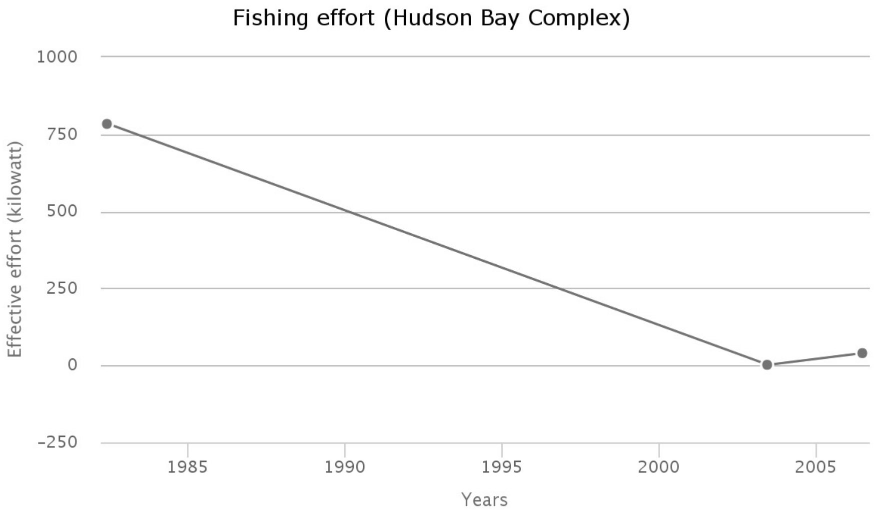
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reached its first peak at 19% in 1999. This percentage ranged between 2 and 17% in the recent decade.

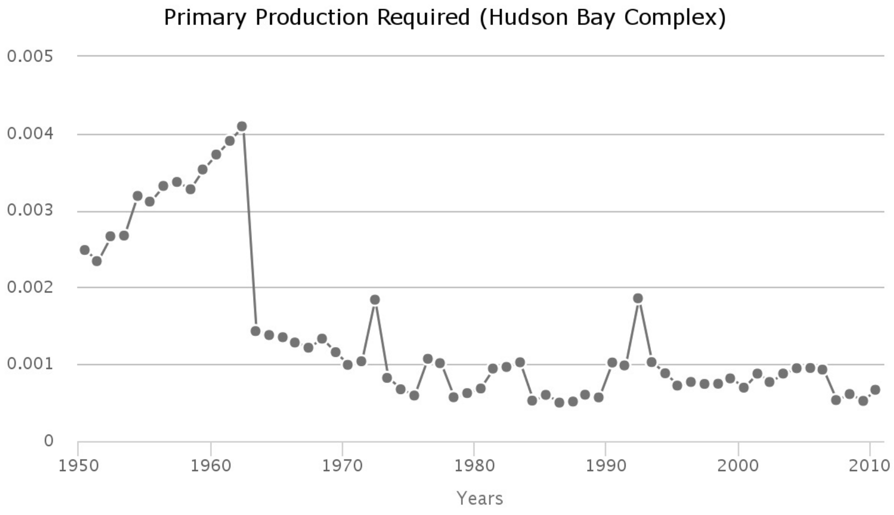


Fishing effort

The whole time series of effort data in the LME region is incomplete.



Primary Production Required



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 low (level 2 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 low (2). 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
2	3	2	2	3	2	2	3	2

Legend:

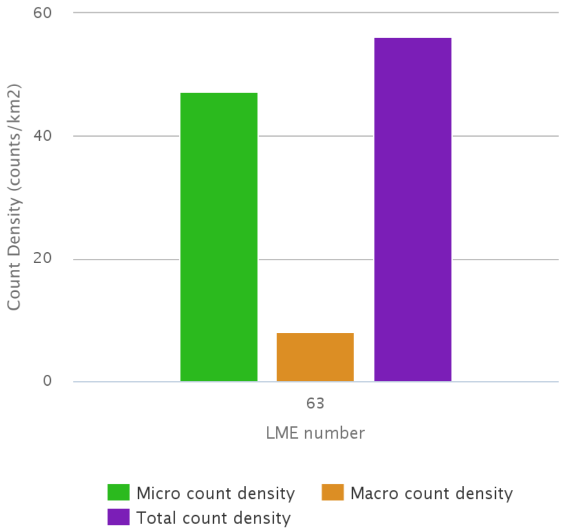
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

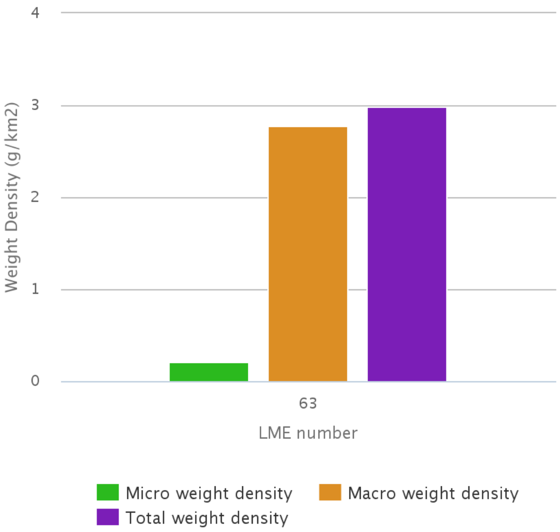
POPs

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 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

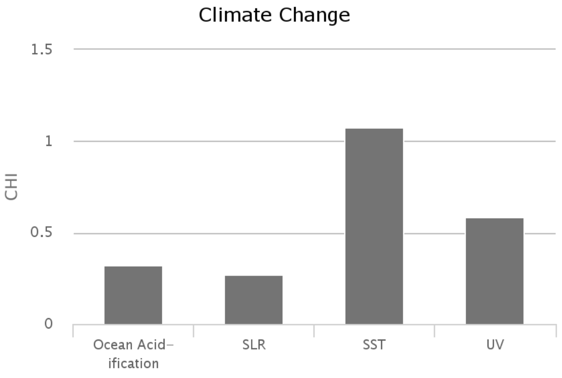
Not applicable.

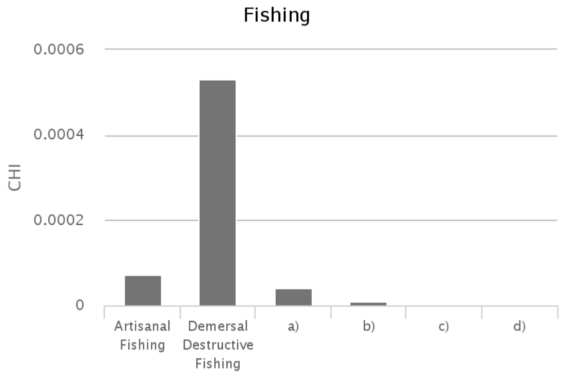
Marine Protected Area change

The Hudson Bay Complex LME experienced an increase in MPA coverage from 3,802 km^2 prior to 1983 to 8,499 km^2 by 2014. This represents an increase of 124%, within the low category of MPA change.

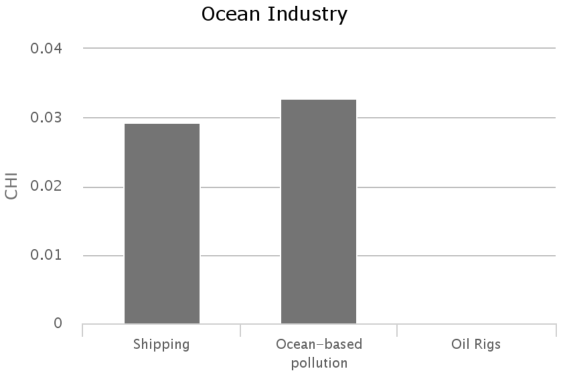
Cumulative Human Impact

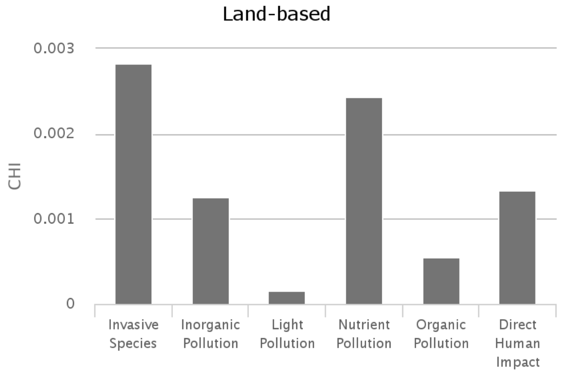
The Hudson Bay Complex LME experiences below average overall cumulative human impact (score 2.32; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most 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 (0.32; maximum in other LMEs was 1.20), UV radiation 0.58; maximum in other LMEs was 0.76), sea level rise (0.27; maximum in other LMEs was 0.71), and sea surface temperature (1.08; maximum in other LMEs was 2.16). No other stressors had high impact on this LME.



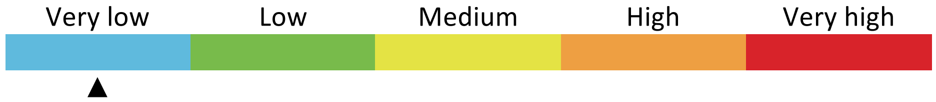


a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing



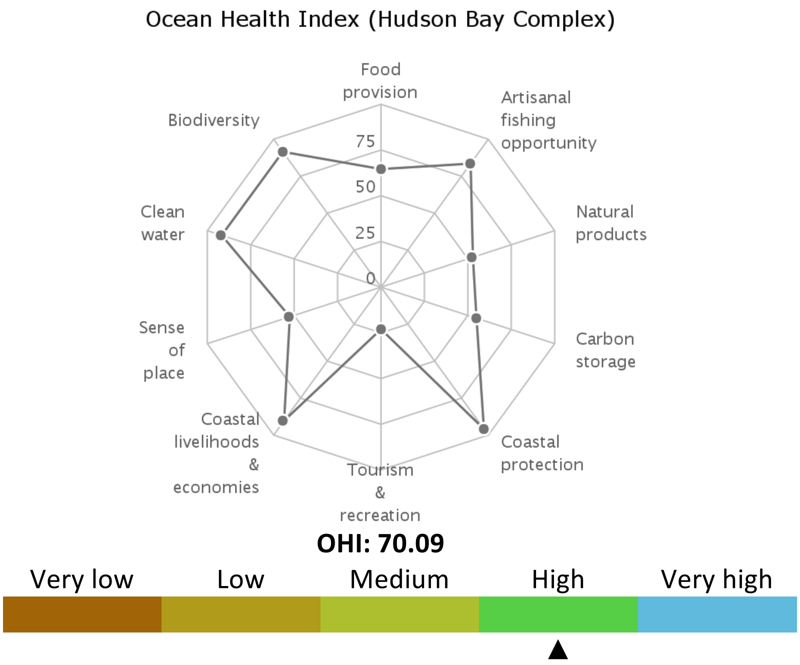


CHI: 2.32



Ocean Health Index

The Hudson Bay Complex 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 well below its optimal level of ocean health, although there are some aspects that are doing well. Its score in 2013 increased 2 points compared to the previous year, due in large part to changes in the score for clean waters. This LME scores lowest on carbon storage, tourism & recreation, and lasting special places goals and highest on mariculture, artisanal fishing opportunities, coastal protection, coastal economies, and 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).



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 938 411 km^2. A current population of 44 thousand in 2010 is projected to decrease to 21 thousand in 2100, with a density of 5 persons per 100 km^2 in 2010 decreasing to 2 per 100 km^2 by 2100. About 99% 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**
44,029	20,975	43,502	20,771

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 12% 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
5,252

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 $2.20 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 2013

$19 522 million places it in the medium-revenue category. On average, LME-based tourism income contributes 5% 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
2,202,056	9.7	19,522,395,900	5.2	0.6830

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 0.899, this LME has an HDI Gap of 0.101, 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 low-risk category (high HDI) because of reduced income levels and population values from those in a sustainable development pathway.

	HDI 2100	
HDI	SSP1	SSP3
0.8986	0.9740	0.7712

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.

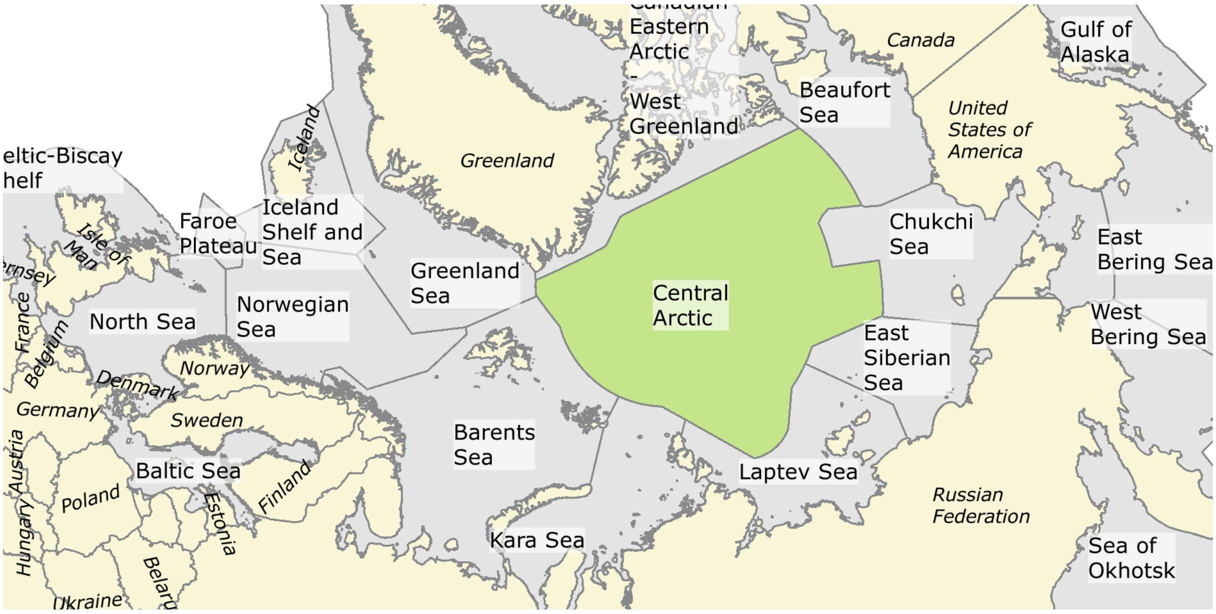
Present day climate threat index of this LME is within the very low-risk (very low threat) category. The combined contemporaneous risk due to extreme climate events, degrading LME states and the level of vulnerability of the coastal population, is very low. In a sustainable development scenario, the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

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.3509	0.2006	0.1002	0.2021

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 64 – Central Arctic



Bordering country: No country
LME Total area: 3,522,239 km^2

List of indicators

LME overall risk

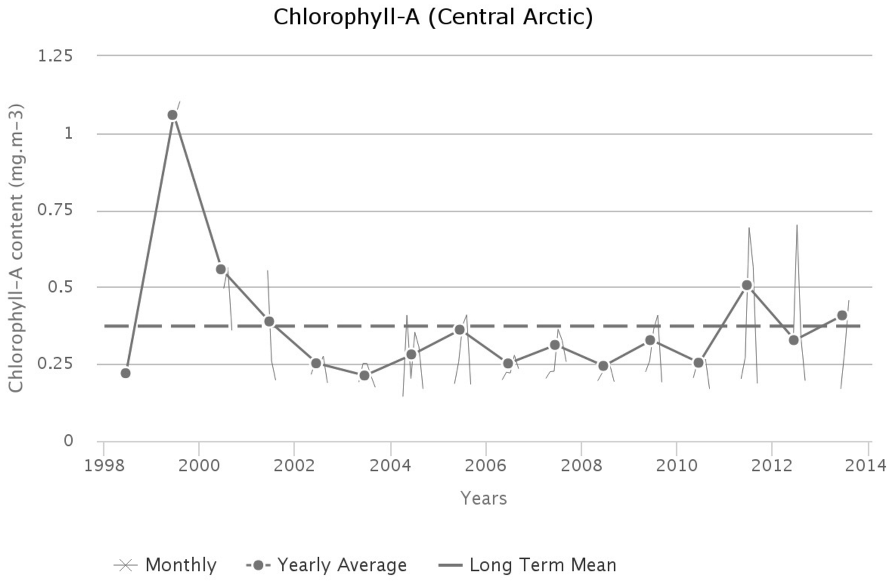
This LME falls in the cluster of LMEs that exhibit high percentages of rural coastal population, high numbers of collapsed and overexploited fish stocks, as well as high proportions of catch from bottom impacting gear.

Because this LME does not have resident citizens, it has no Human Development Index and no risk score.

Productivity

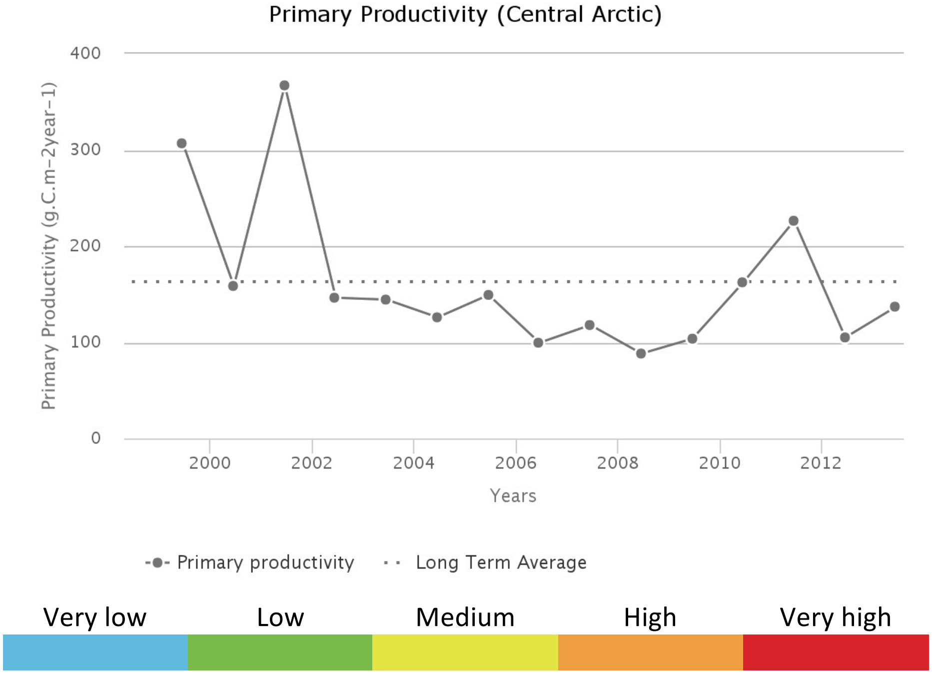
Chlorophyll-A

The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.297 mg.m^{-3}) in August and a minimum (0.169 mg.m^{-3}) during April. The average CHL is 0.373 mg.m^{-3}. Maximum primary productivity (367 g.C.m^{-2}.y^{-1}) occurred during 2001 and minimum primary productivity (88 g.C.m^{-2}.y^{-1}) during 2008. There is a statistically insignificant increasing trend in Chlorophyll of 139. % from 2003 through 2013. The average primary productivity is 163 g.C.m^{-2}.y^{-1}, which places this LME in Group 2 of 5 categories (with 1 = lowest and 5= highest).



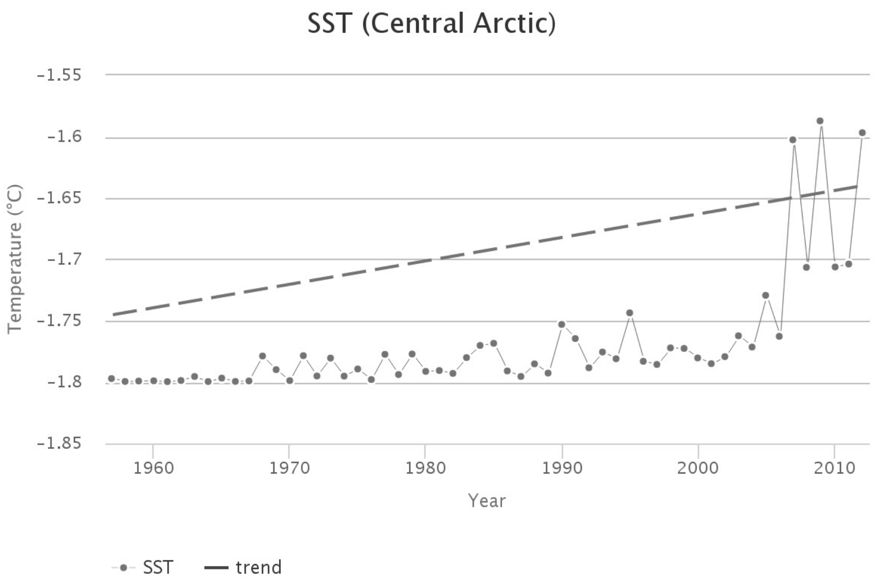
Very low	Low	Medium	High	Very high
🟦	🟩	🟨	🟧	🟥

Primary productivity



Sea Surface Temperature

From 1957 to 2012, the Central Arctic LME #64 has warmed by 0.10°C, thus belonging to Category 4 (slow warming LME). The Central Arctic is covered with ice in winter. During that time ice concentration approaches 100%. Leads between ice floes are quite rare and narrow. Wide leads or polynyas that would allow satellite measurements of SST are almost non-existent. In summer the sea ice cover retreats, so that the Central Arctic become partly ice-free. The annual mean SST analyzed in this report is thus based almost exclusively on summertime measurements. Because of this constraint, the thermal history of SST in this LME has not been covered in the previous analysis (Belkin, 2009). The extremely slow warming observed since 1957 through 2001 was followed by a relatively rapid warming, which was quite abrupt between 2006-2007. This abrupt shift was possibly related to the rapid shrinking of the Arctic sea ice cover observed in the 2000s. After the 2006-2007 shift, the Central Arctic SST remained stable between 2007 and 2012, notwithstanding the ongoing shrinking of the Arctic sea ice cover.

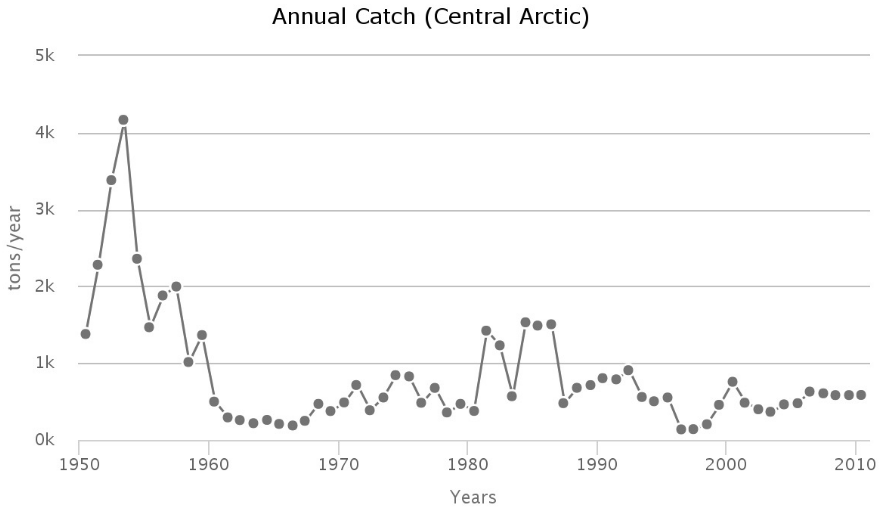


Fish and Fisheries

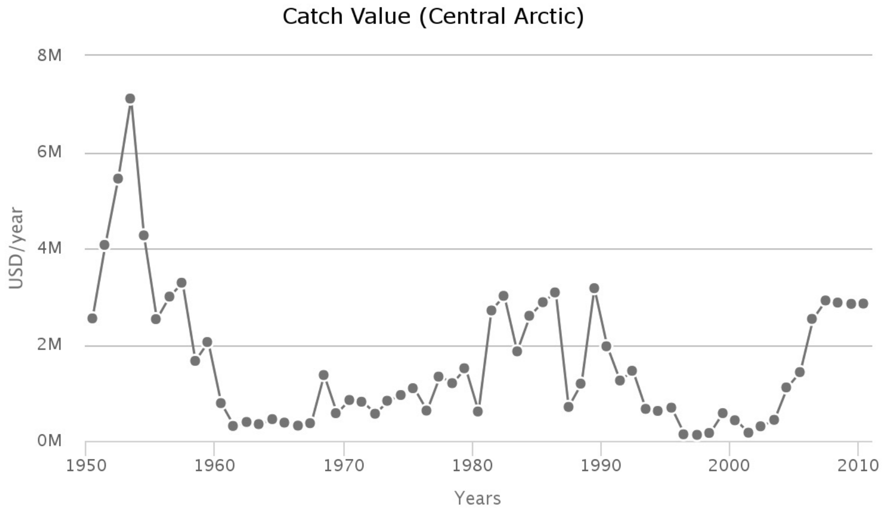
The Central Arctic LME, along with its surrounding LMEs is unique in that the melting and freezing of ice creates rich habitats close to the sunlit surface. The wide continental shelves provide large shallow areas, where freshwater from north-flowing rivers creates estuarine conditions. There is a limited number of true Arctic species of commercial importance. Arctic charr (*Salvelinus alpinus*) occurs throughout the Canadian Arctic. In the summer, many stocks of Arctic char migrate to the sea, where they have a larger resource base to exploit and thus are able to grow faster. While at sea, they feed on crustaceans and small fish. Before winter, these migrants return to the rivers and lakes. Under extreme winter conditions, they hardly feed at all.

Annual Catch

Sea mammals abound and are still exploited. However, the Central Arctic LME does include waters seasonally ice-free and regularly commercially fished, both in the Northwest Atlantic (around Greenland, including Davis Strait and Baffin Bay) and the Northeast Atlantic (waters north of Iceland and towards Svalbard). Thus, reported landings in this LME are dominated by catches taken in the Atlantic waters. From the 1950s to early 1970s, the catch was dominated by ocean perch and thereafter by capelin. The highest catch of about half a million t, consisting mainly of capelin, was obtained in 1996.

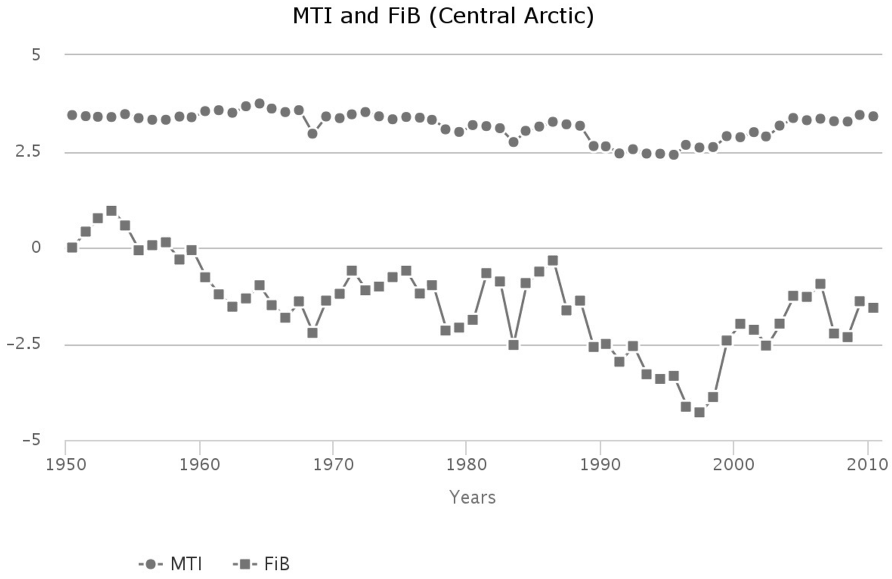


Catch value

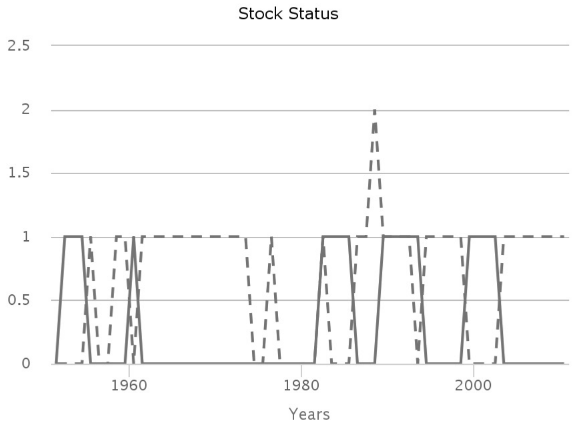


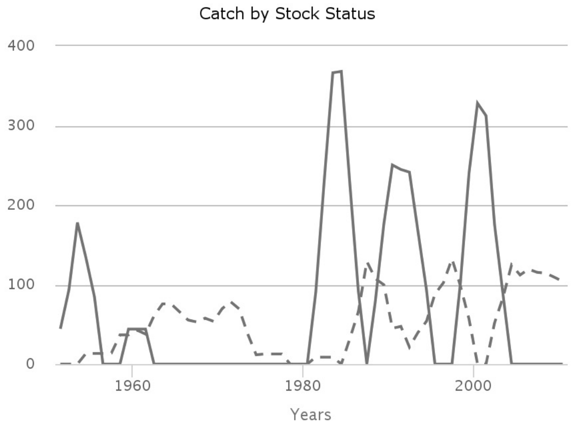
Marine Trophic Index and Fishing-in-Balance index

The catch data from this LME are too crude for ecosystem indicators such as PPR, MTI or FiB index to be computed.



Stock status

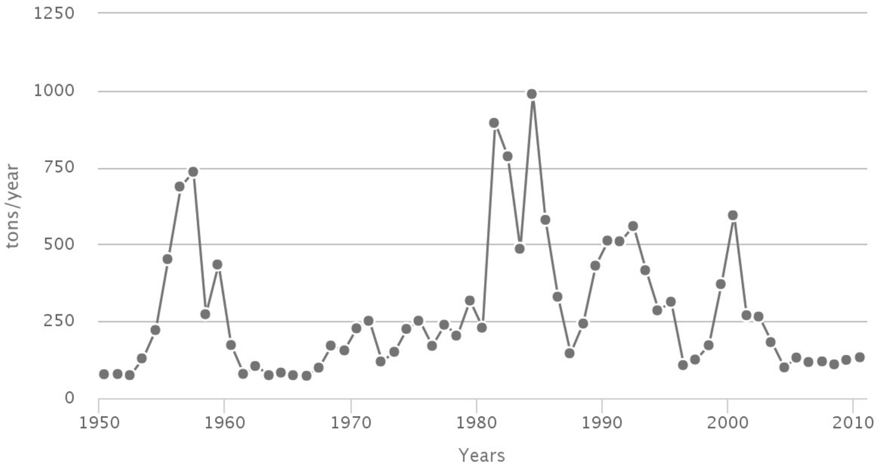




Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reached its first peak at 90% in 1996. This percentage ranged between 18 and 67% in the recent decade.

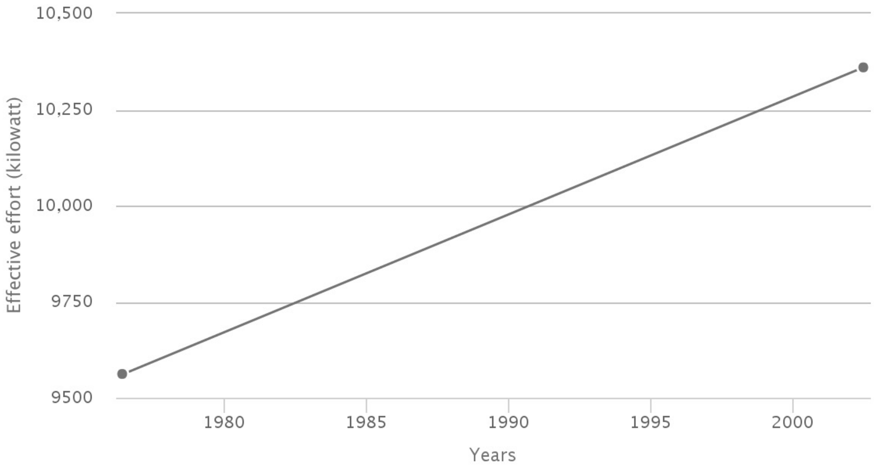
Catch from bottom impacting gear (Central Arctic)



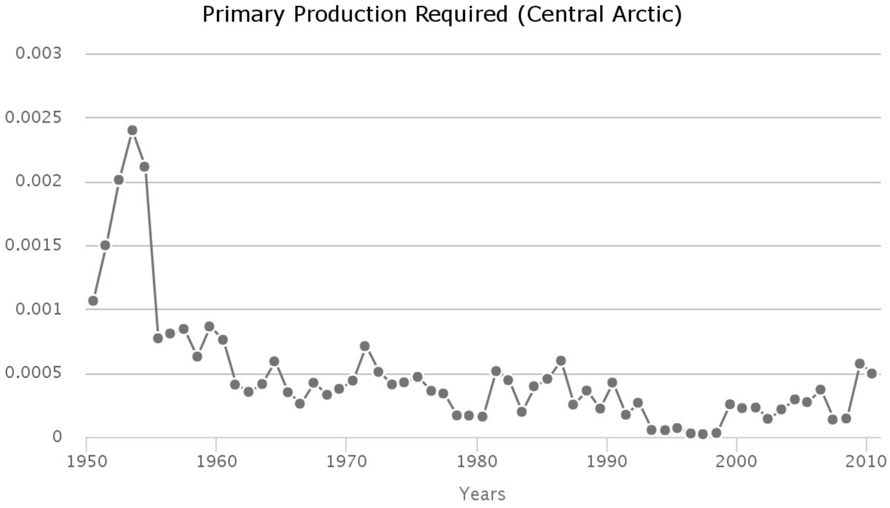
Fishing effort

The whole time series of effort data in the LME region is incomplete.

Fishing effort (Central Arctic)



Primary Production Required



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

No data for this LME.

Nutrient ratio

No data for this LME.

Merged nutrient indicator

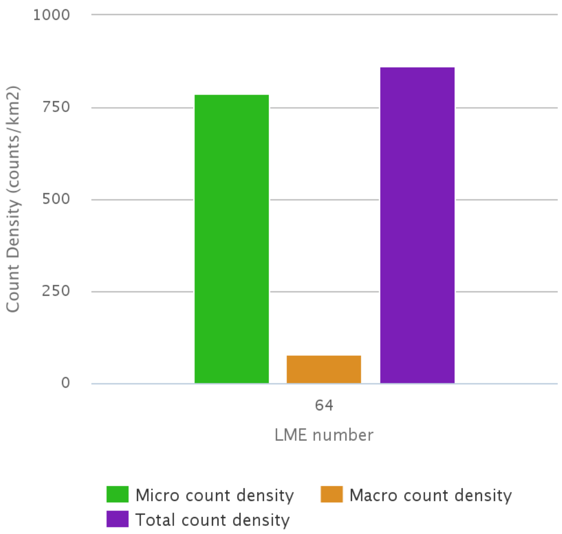
No data for this LME.

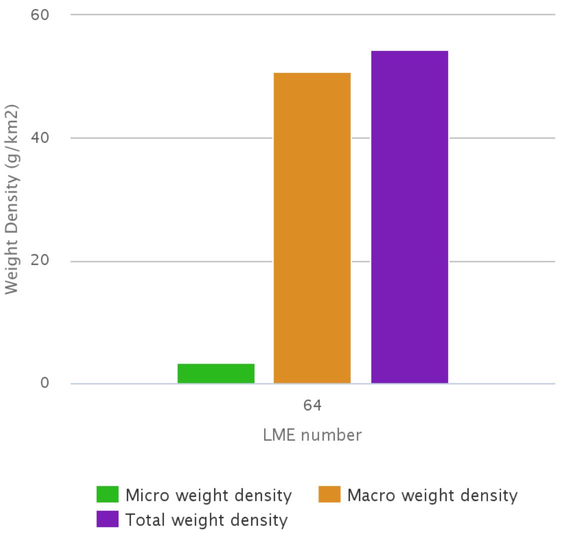
POPs

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 relatively low levels of 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 relative remoteness of this LME from significant sources of plastic. The abundance of floating plastic in this category is estimated to be on average over 40 times lower that 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

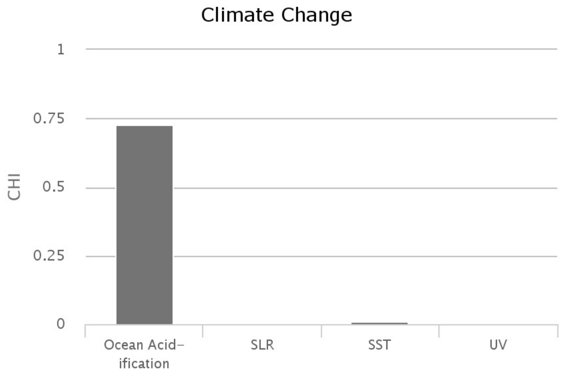
Not applicable.

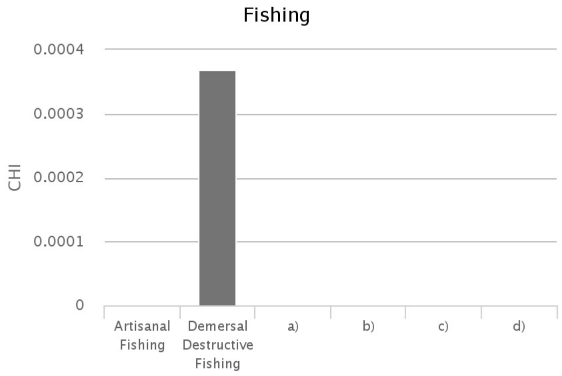
Marine Protected Area change

Not applicable.

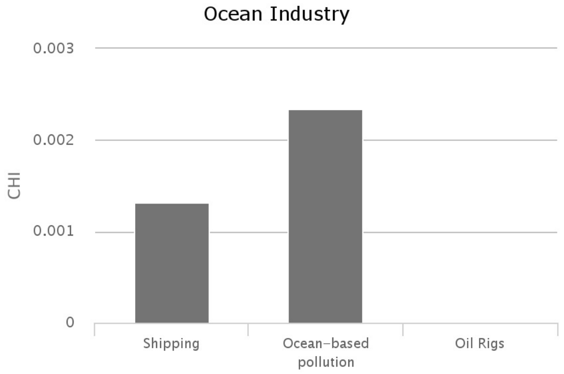
Cumulative Human Impact

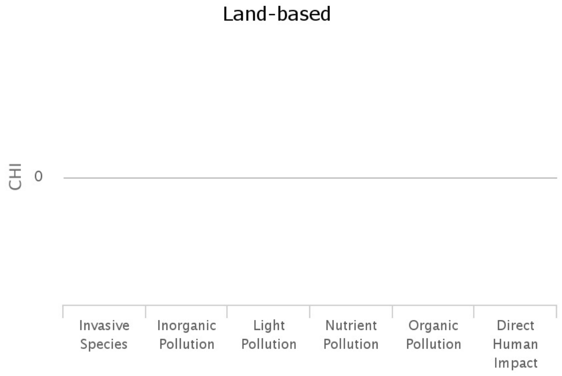
The Central Arctic LME experiences one of the lowest overall cumulative human impact (score 0.74; maximum LME score 5.22). It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, the only stressor with high average impact on the LME was ocean acidification (0.73; maximum in other LMEs was 1.20), comprising 98% of the total overall impact.

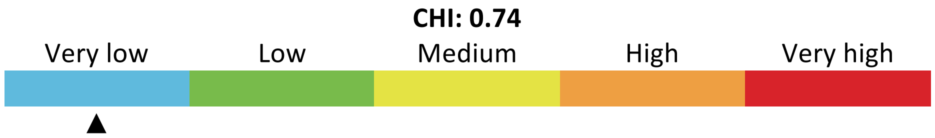




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

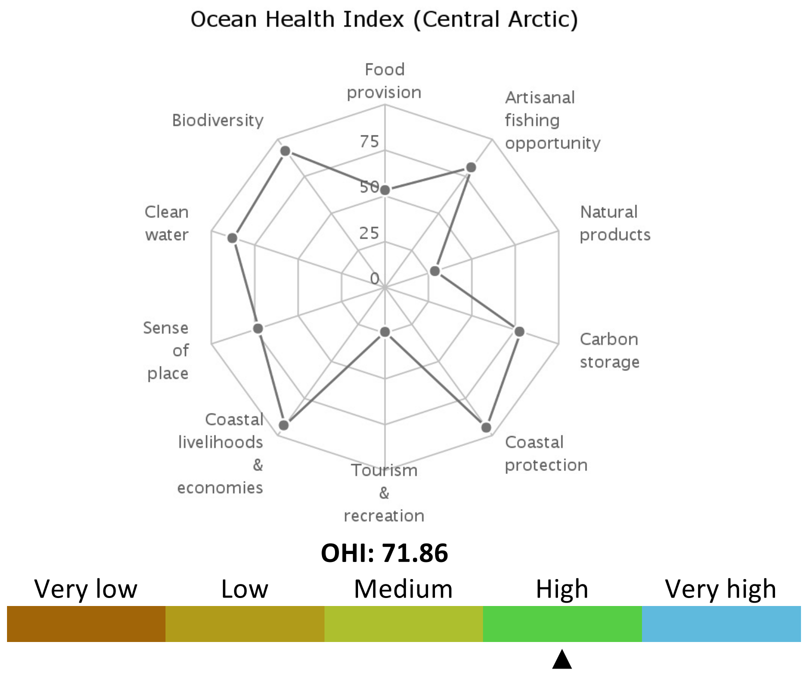






Ocean Health Index

The Central Arctic LME scores above average on the Ocean Health Index compared to other LMEs (score 74 out of 100; range for other LMEs was 57 to 82), but still relatively low. 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 1 point compared to the previous year, due in large part to changes in the score for clean waters. This LME scores lowest on food provision, natural products and tourism & recreation goals and highest on artisanal fishing opportunities, coastal protection, coastal economies, and habitat biodiversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



Socio-economics

This LME has no resident population so population-related indicators are not evaluated. However, nearby countries and distant fishing nations utilize this LME for fishing and tourism, the revenues for which are reported here.

Population

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 $2 million for the period 2001-2010. Its yearly average tourism revenue for 2004-2013 of US 2013 $17 277 million places it in the medium-revenue category.

Total population		**Rural population**	
2010	**2100**	**2010**	**2100**
No data	No data	No data	No data

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Revenues and Spatial Wealth Distribution

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
1,985,753	No data	17,277,477,680	No data	No data

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Human Development Index

Xxx.

	HDI 2100	
HDI	**SSP1**	**SSP3**

HDI	HDI 2100	
	SSP1	SSP3

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Climate-Related Threat Indices

2010		2100	
Climate Threat	Contemporary Threat	SSP1	SSP3
No data	No data	No data	No data

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

None of the three transboundary fisheries arrangements (NEAFC, ICCAT and NASCO) appear to be integrated while the three arrangements for pollution and biodiversity (NAMMCO, ACPB and OSPAR) appear to have the Arctic Council as an integrating arrangement for one set of issues and OSPAR for a similar set of issues. However, the Arctic Council is not a binding arrangement so its implementation is voluntary and country dependent. It does appear to have the potential to develop into an informal overall policy coordinating organization, although as mentioned, its policy coordination role with respect to fisheries is weak. Consequently,, this LME has been assigned an overall integration score of 1.0 due to the presence of the Arctic Council.

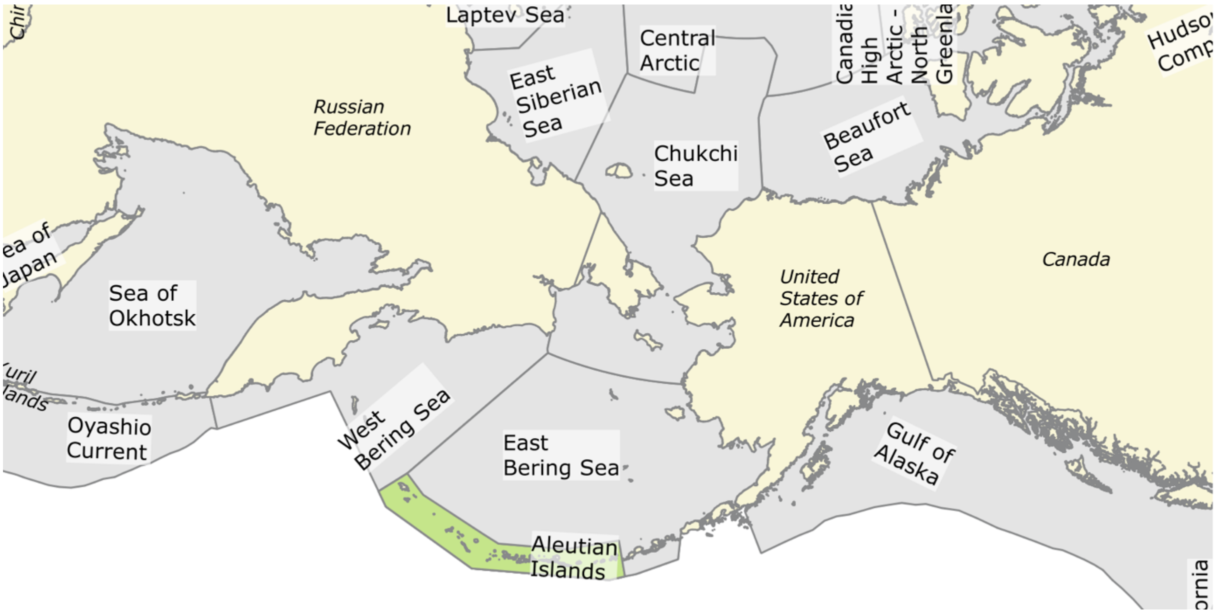
The overall scores for ranking of risk were:

Engagement	Completeness	Integration
72	73	1

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

LME 65 – Aleutian Islands



Bordering countries: United States of America.
LME Total area: 220,000 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.

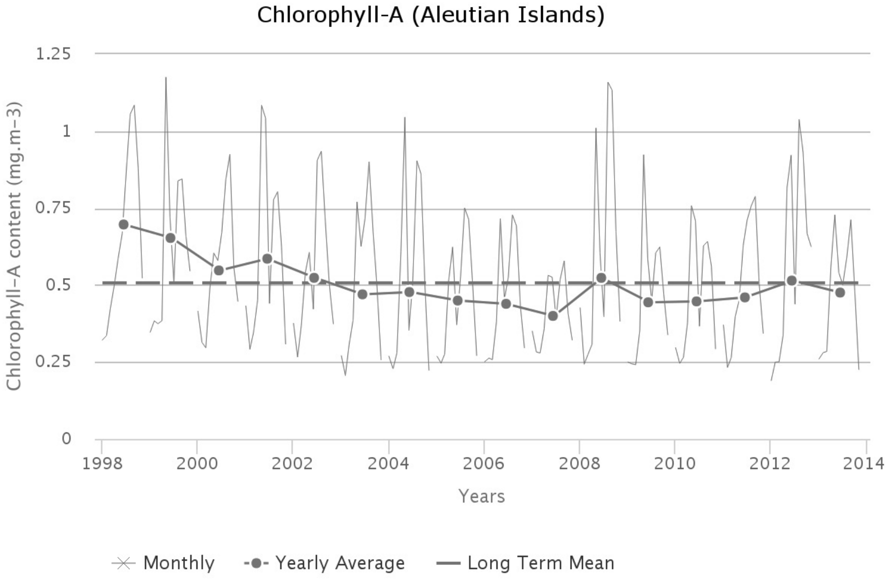
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is very low..

Very low	Low	Medium	High	Very high
▲				

Productivity

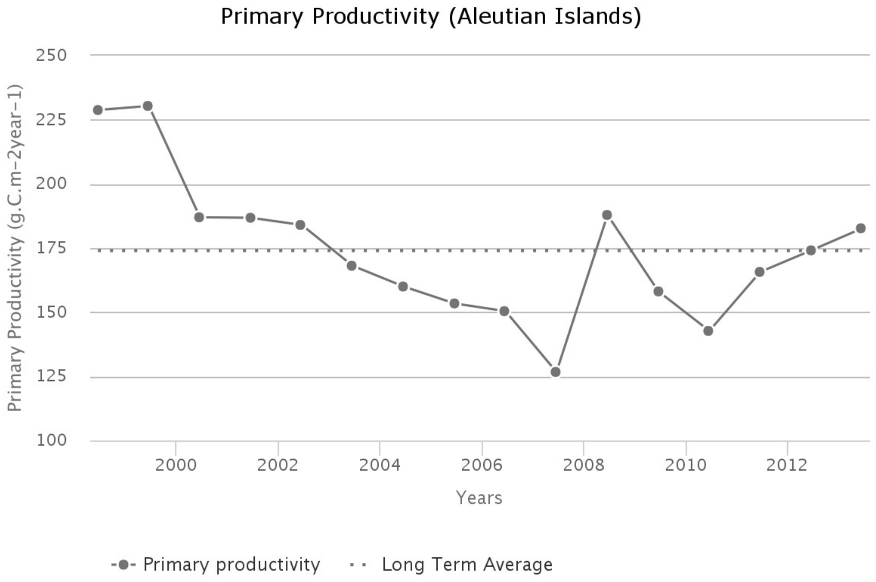
Chlorophyll-A

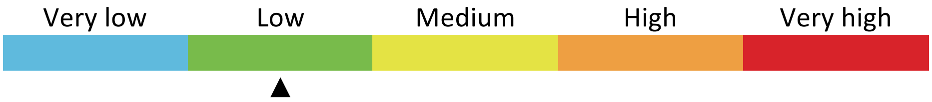
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.800 mg.m^{-3}) in August and a minimum (0.259 mg.m^{-3}) during February. The average CHL is 0.507 mg.m^{-3}. Maximum primary productivity (230 g.C.m^{-2}.y^{-1}) occurred during 1999 and minimum primary productivity (127 g.C.m^{-2}.y^{-1}) during 2007. There is a statistically insignificant decreasing trend in Chlorophyll of -6.22 % from 2003 through 2013. The average primary productivity is 174 g.C.m^{-2}.y^{-1}, which places this LME in Group 2 of 5 categories (with 1 = lowest and 5= highest).



Very low	Low	Medium	High	Very high
	▲			

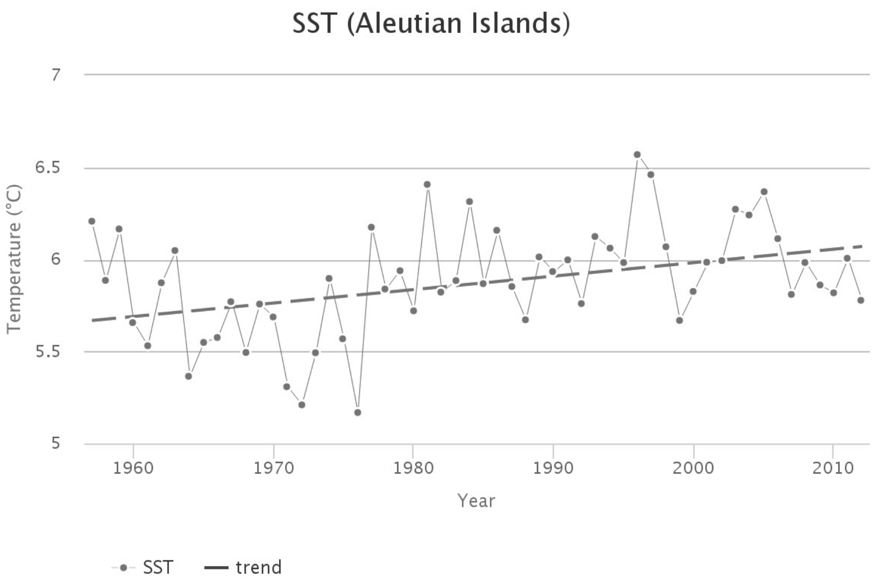
Primary productivity





Sea Surface Temperature

From 1957 to 2012, the Aleutian Islands LME #65 has warmed by 0.40°C, thus being on a threshold between Categories 3 and 4 (moderate-to-slow warming LME). This newly-defined LME extends along the Aleutian Island chain, spanning both sides. It is affected by the Alaskan Stream on the Pacific side. It is also affected by the circulation within the Bering Sea. As a result, this LME is affected by currents of the subarctic North Pacific and, to a lesser extent, by water masses coming out of the Arctic Ocean through the Bering Sea past the Chukchi Peninsula (Chukotka). Two epochs can be identified separated by a step-like regime shift in 1976-1977. During the first, cooling epoch SST decreased from 6.2°C in 1957 down to <5.2°C. The regime shift of 1976-1977 manifested by an abrupt increase of SST from 5.2°C in 1976 to 6.2°C in 1977. The second, stable epoch commenced right after the regime shift of 1976-1977. This epoch has continued through 2012. During this stable preriod a warm peak of 6.6°C in 1996 stands out.

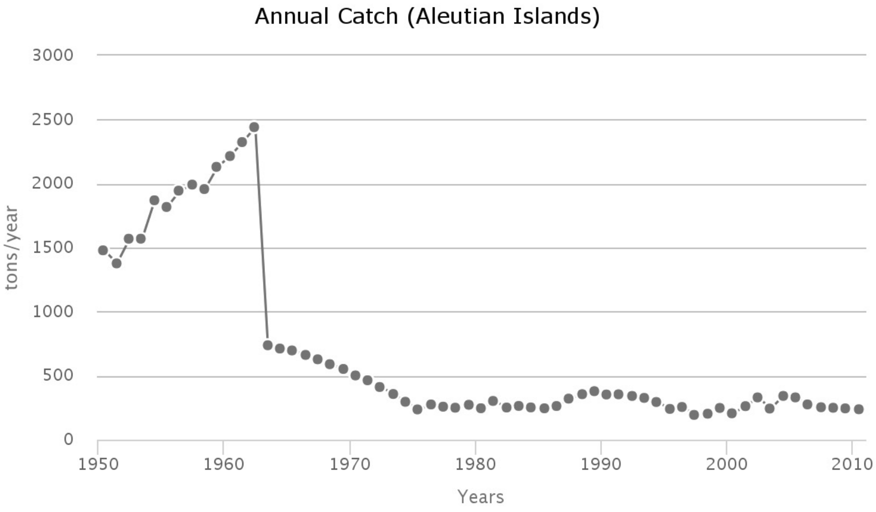


Fish and Fisheries

The Aleutian Islands LME supports around 37 species and the major targeted species is Arctic char (*Salvelinus alpinus alpinus*).

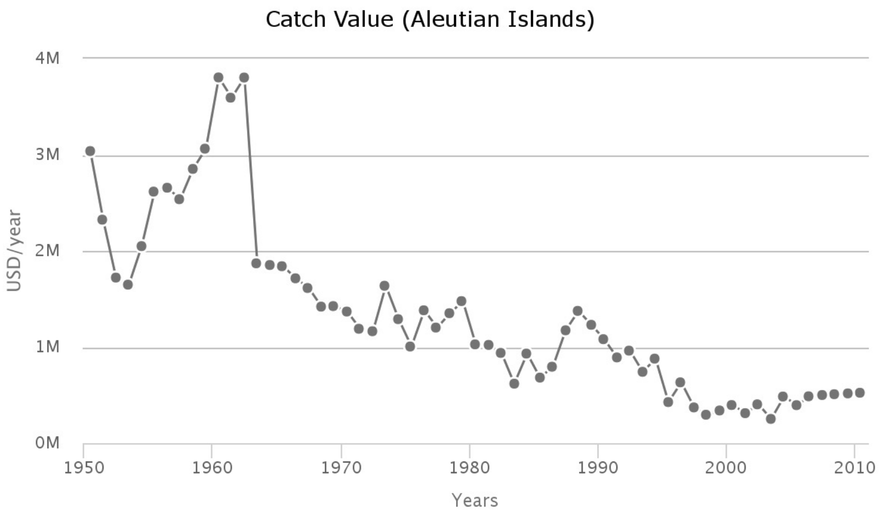
Annual Catch

Total reported landings rose steadily to a historic high of 0.3 million t in 1987, followed by a decline to around 0.15 million t in the recent years..



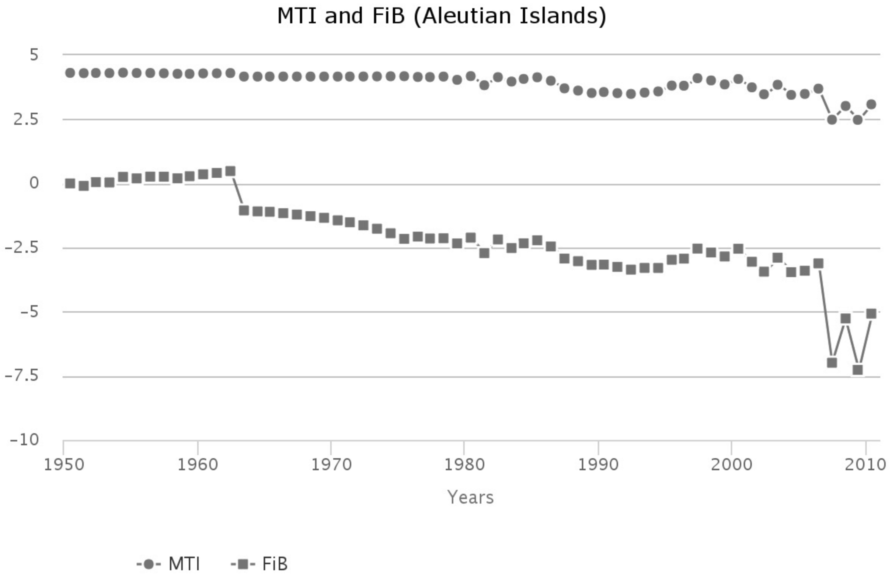
Catch value

The value of the landings reached its peak at 0.3 billion US$ (in 2005 US$) in 1979.



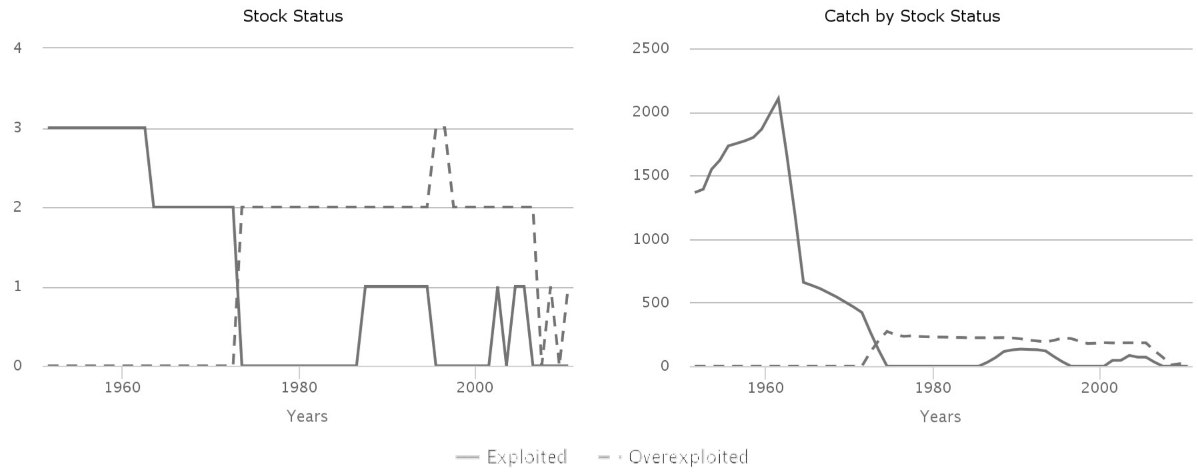
Marine Trophic Index and Fishing-in-Balance index

The MTI fluctuated around 4 from 1950 to the 2000s and then started to decline in the early 2000s. The FiB index kept decreasing from 1950 to 2010, which shows that there is no spatial expansion of fisheries in this region.



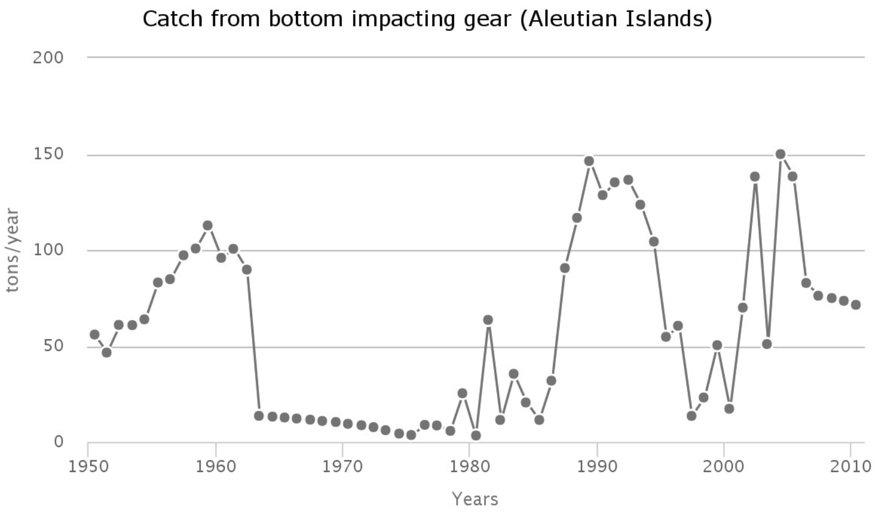
Stock status

The Stock-Catch Status Plots indicate that about 45% of the commercially exploited stocks have collapsed and are over-exploited. The majority of the reported landings is still supplied by over-exploited stocks (i.e., 60% of the total catch).



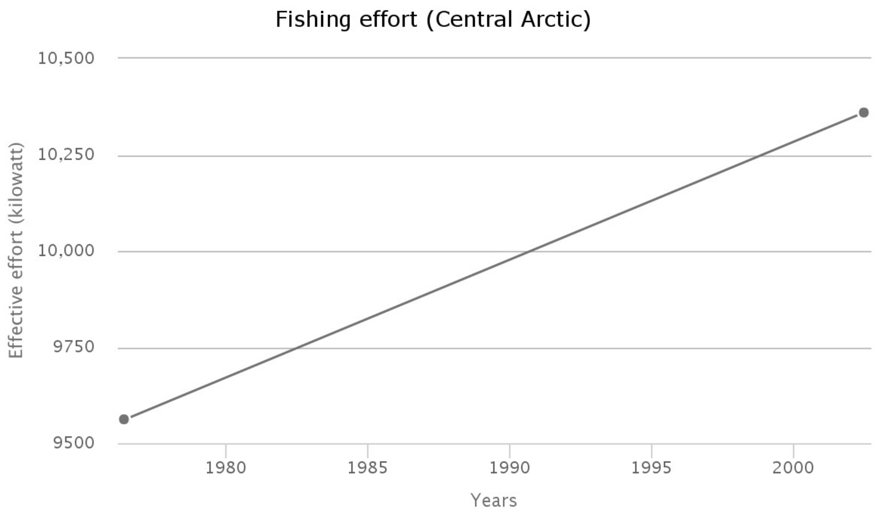
Catch from bottom impacting gear

The percentage of catch from the bottom gear type to the total catch reaches its first maximum at 16% in 1965 and then this percentage dropped to 5 % in 1983. It fluctuated between 7 to 14% in the last 20 years.



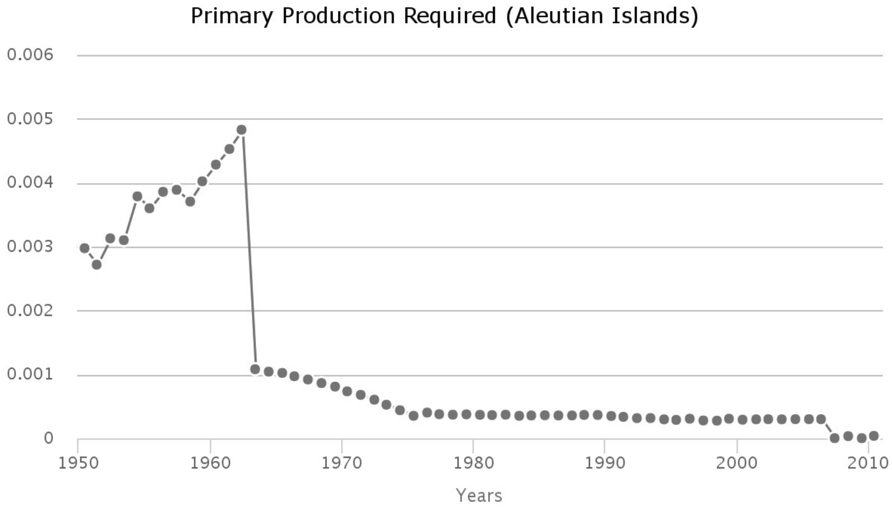
Fishing effort

The total effective effort fluctuated between 3 and 5 million kW from 1950 to 1980 and started to increase since the 1980s. It keeps increasing continuously in the last few decades and reaches its maximum in 2001 at 12 million kW.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in this LME is less than 1% in these 60 years.



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

No data for this LME.

Nutrient ratio

No data for this LE.

Merged nutrient indicator

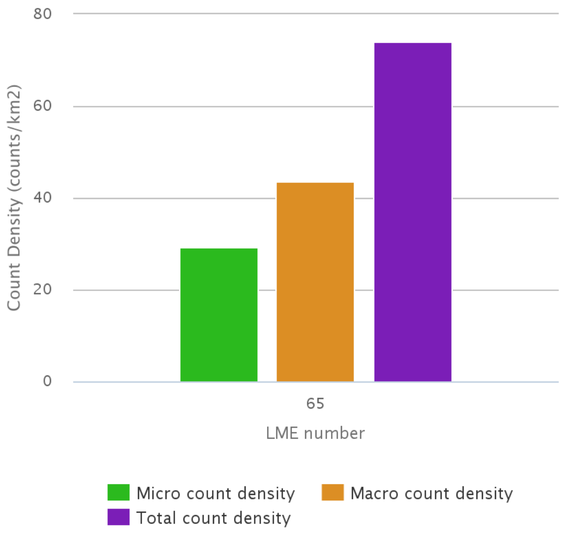
No data for this LME.

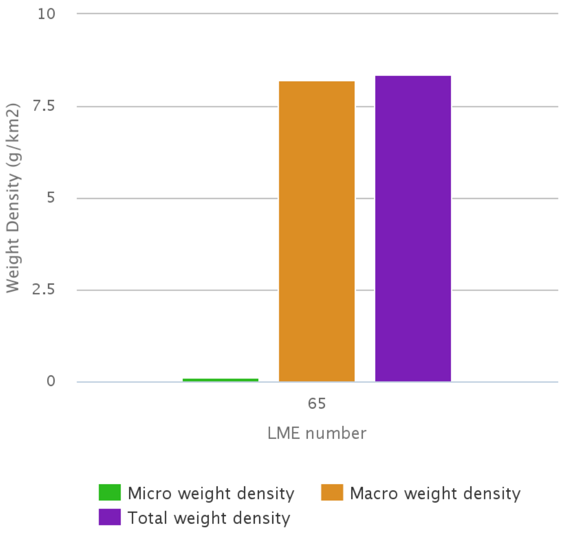
POPs

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

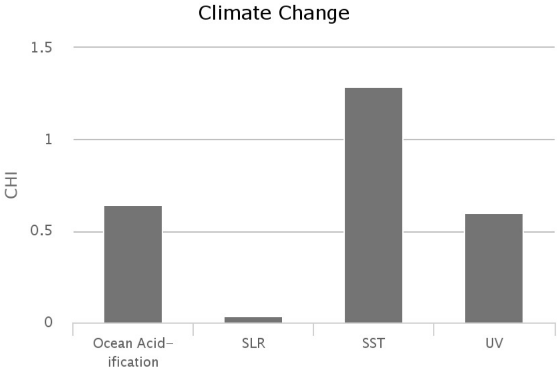
Not applicable.

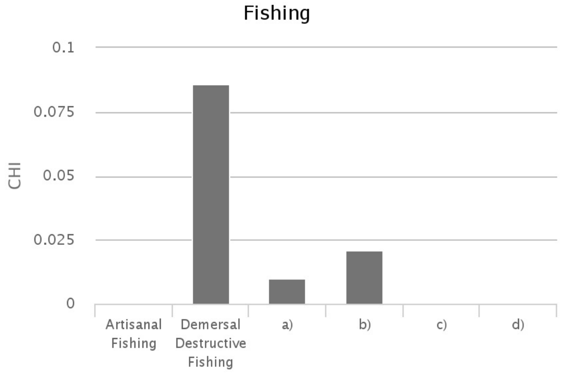
Marine Protected Area change

The Aleutian Islands LME experienced an increase in MPA coverage from 1,313 km^2 prior to 1983 to 3,670 km^2 by 2014. This represents an increase of 180%, within the low category of MPA change..

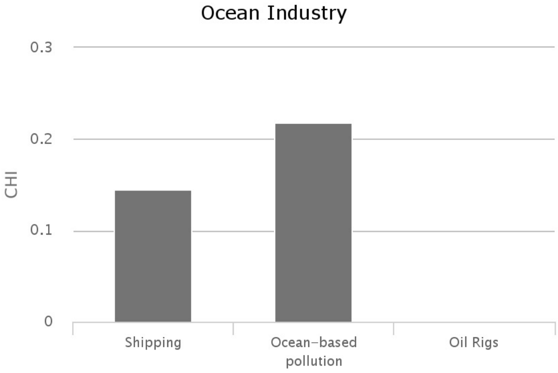
Cumulative Human Impact

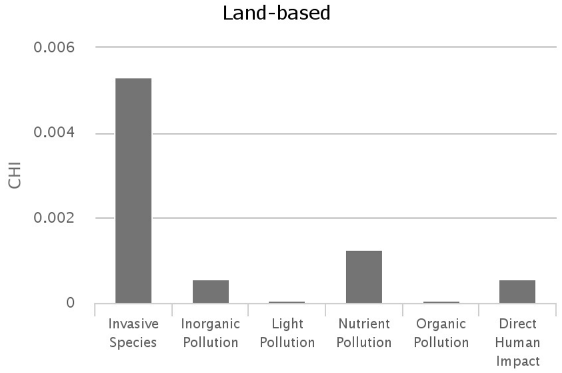
The Aleutian Islands LME experiences average overall cumulative human impact (score 3.05; maximum LME score 5.22), but which is still well above the LME with the least cumulative impact. It falls in risk category 2 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, three connected to climate change have the highest average impact on the LME: ocean acidification (0.64; maximum in other LMEs was 1.20), UV radiation (0.60; maximum in other LMEs was 0.76), and sea surface temperature (1.29; maximum in other LMEs was 2.16). Other key stressors include commercial shipping, ocean based pollution, and demersal destructive commercial fishing.

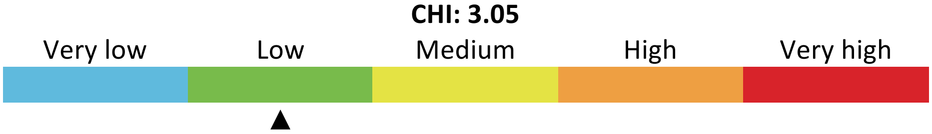




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

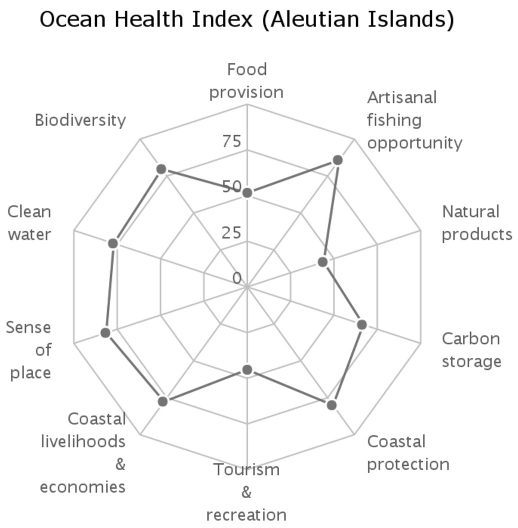


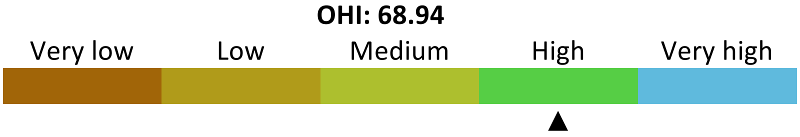




Ocean Health Index

The Aleutian Islands LME scores above average on the Ocean Health Index compared to other LMEs (score 72 out of 100; range for other LMEs was 57 to 82), but still relatively low. 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 9 points compared to the previous year, due in large part to changes in the score for clean waters. This LME scores lowest on food provision, coastal livelihoods and tourism & recreation goals and highest on artisanal fishing opportunities, coastal economies, and lasting special places goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).





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 460 km^2. A current population of 287 in 2010 is projected to increase to 4 466 in 2100, with a density of 6 persons per 10 km^2 in 2010 increasing to 97 per 10 km^2 by 2100. About 100% of coastal population lives in rural areas, and is projected to remain the same in 2100..

Total population		Rural population	
2010	2100	2010	2100
287	4,466	287	4,466

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

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).

Coastal poor
49

Revenues and Spatial Wealth Distribution

Fishing and tourism depend on ecosystem services provided by LMEs. This LME ranks in the low revenue category in fishing revenues based on yearly average total ex-vessel price of US 2013 $200 million for the period 2001-2010. Fish protein accounts for 7% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013 $36 million places it in the very 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 category with very low risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
199,506,838	7.4	36,286,225	8.4	🟦 0.6022

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, this LME HDI belongs to the very high HDI and very low risk category. Based on an HDI of 0.909, this LME has an HDI Gap of 0.091, 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 maintain its position in the very low risk category (highest HDI) in 2100 under a sustainable development pathway or scenario. Under a fragmented world scenario, this LME is projected to slip to the high-risk category (low HDI) because of reduced income level and bigger population size compared to those estimated in a sustainable development scenario.

	HDI 2100	
HDI	**SSP1**	**SSP3**
0.9094	0.9662	0.6971

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 to this LME is within the very low risk (very 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. Regardless of development pathway, this LME is projected to belong to the very low risk category that is least threatened by sea level rise in 2100.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.2736	0.1927	0.1907	0.3902

Legend:

🟦	Very low	🟩	Low	🟨	Medium	🟧	High	🟥	Very high

LME 66 – Canadian High Arctic / North Greenland

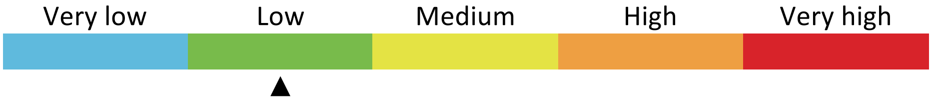
Bordering countries: Greenland, Canda.
LME Total area: 600,000 km^2

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.

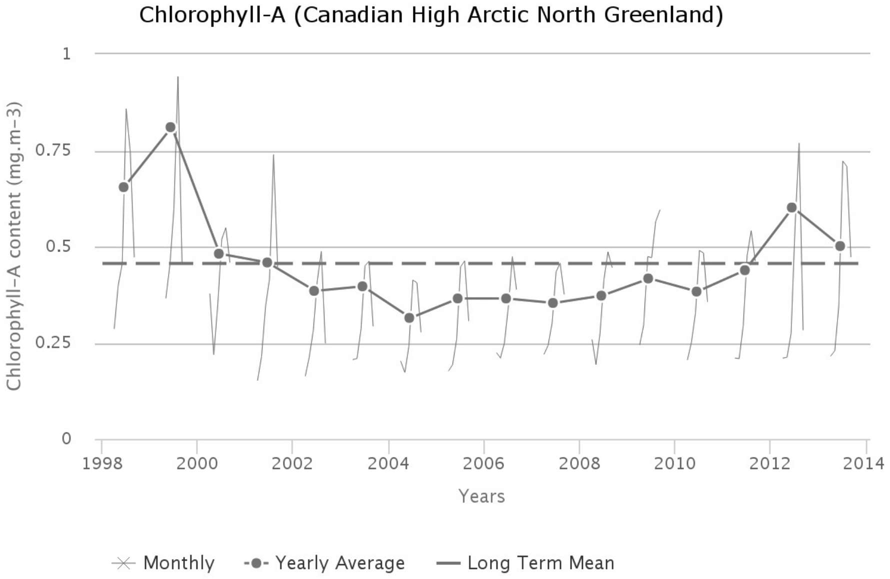
Based on a combined measure of the Human Development Index and the averaged indicators for fish & fisheries and pollution & ecosystem health modules, the overall risk factor is low.

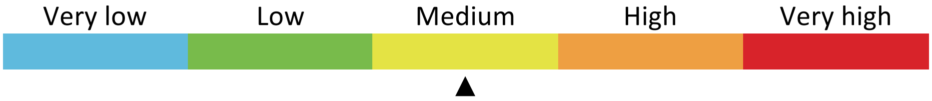


Productivity

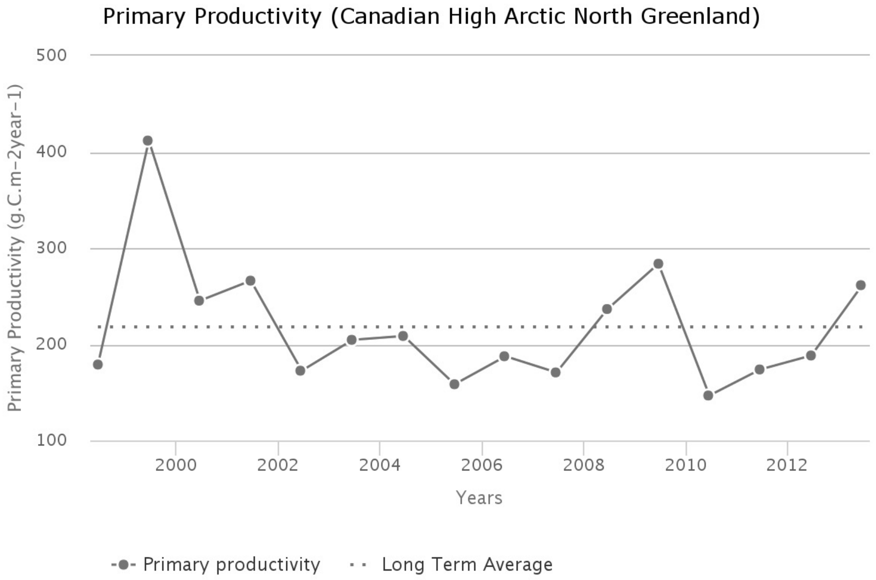
Chlorophyll-A

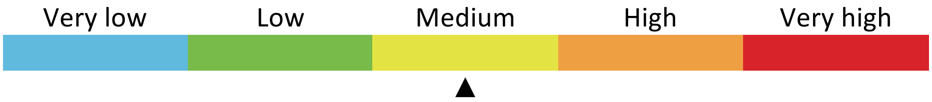
The annual Chlorophyll a concentration (CHL) cycle has a maximum peak (0.414 mg.m^{-3}) in August and a minimum (0.205 mg.m^{-3}) during May. The average CHL is 0.456 mg.m^{-3}. Maximum primary productivity (412 g.C.m^{-2}.y^{-1}) occurred during 1999 and minimum primary productivity (147 g.C.m^{-2}.y^{-1}) during 2010. There is a statistically insignificant increasing trend in Chlorophyll of 17.8 % from 2003 through 2013. The average primary productivity is 218 g.C.m^{-2}.y^{-1}, which places this LME in Group 3 of 5 categories (with 1 = lowest and 5= highest).





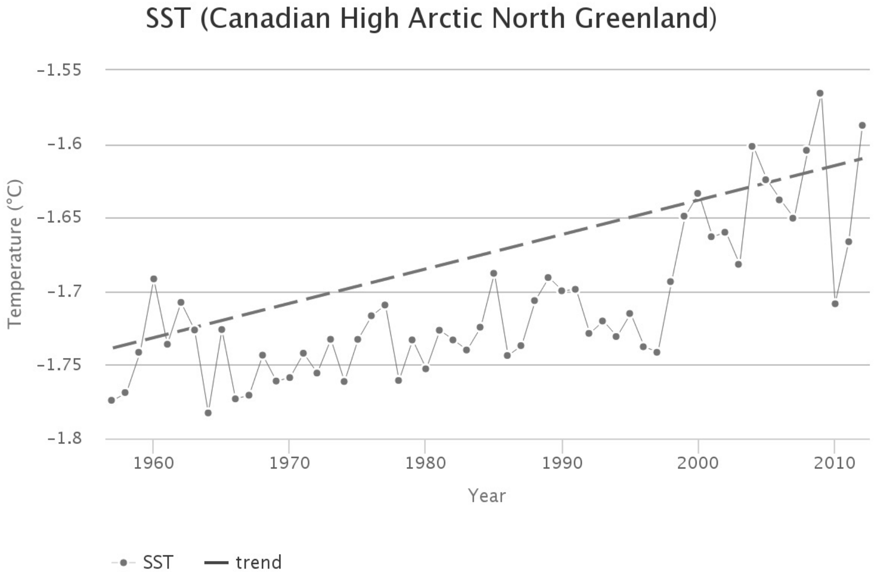
Primary productivity





Sea Surface Temperature

From 1957 to 2012, the Canadian High Arctic-North Greenland LME #66 has warmed by 0.13°C, thus belonging to Category 4 (slow warming LME). This LME is covered with sea ice in winter. In summer, some straits become ice-free, especially in the 2000s-2010s. Still, SST measurements in this region should be treated with caution. Between 1957-2012, SST warming was extremely slow until 1997, when SST abruptly increased between 1997-1998 and remained relatively high through 2012. Qualitively, this pattern is similar to that in the Central Arctic (LME #64). The main – and significant – difference is the timing of regime shift. In the Central Arctic, it occurred between 2006-2007, nine years after the above-mentioned regime shift in the Canadian High Arctic-North Greenland LME. Clearly, these regime shifts are not related to one another.

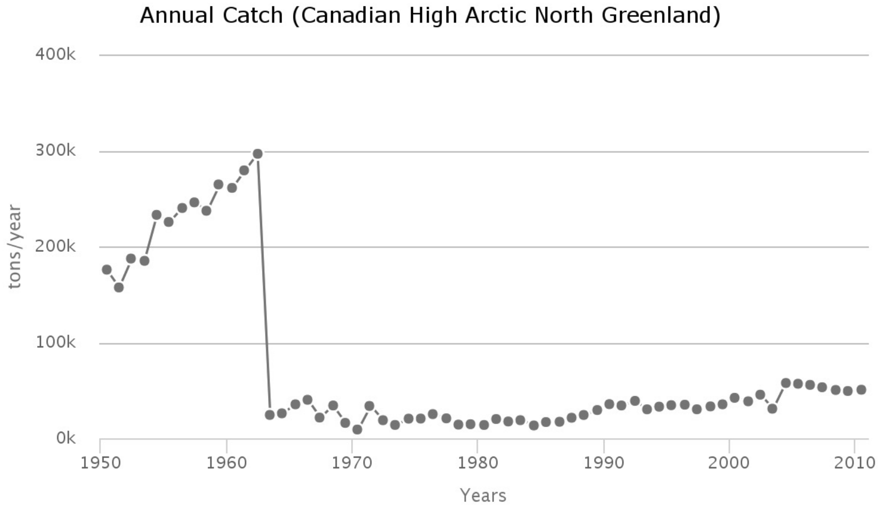


Fish and Fisheries

The Canadian High Arctic LME supports around 70 species and the major targeted species is Atlantic cod (*Gadus morhua*).

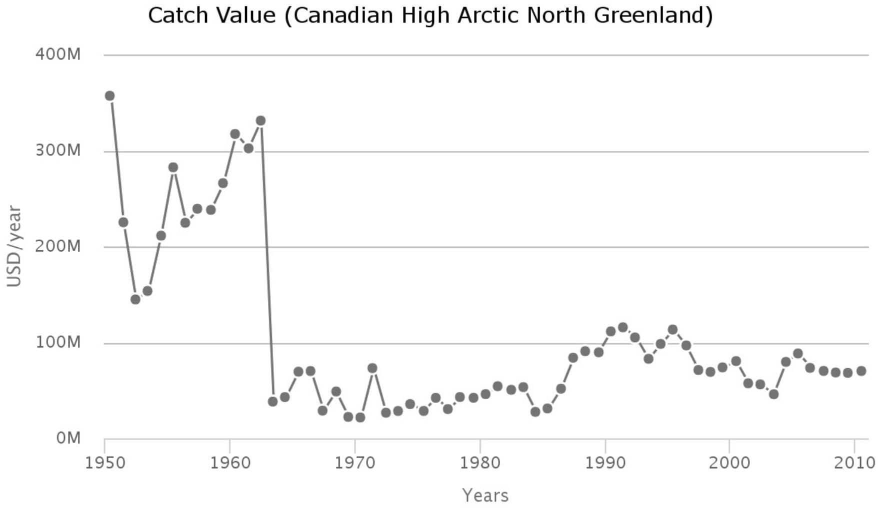
Annual Catch

Total reported landings reached a historic high of 2,100 t in 1962, followed by a sharp decline to around 640t in 1963. The total landings kept declining and fluctuated around 240 t in the recent few decades.



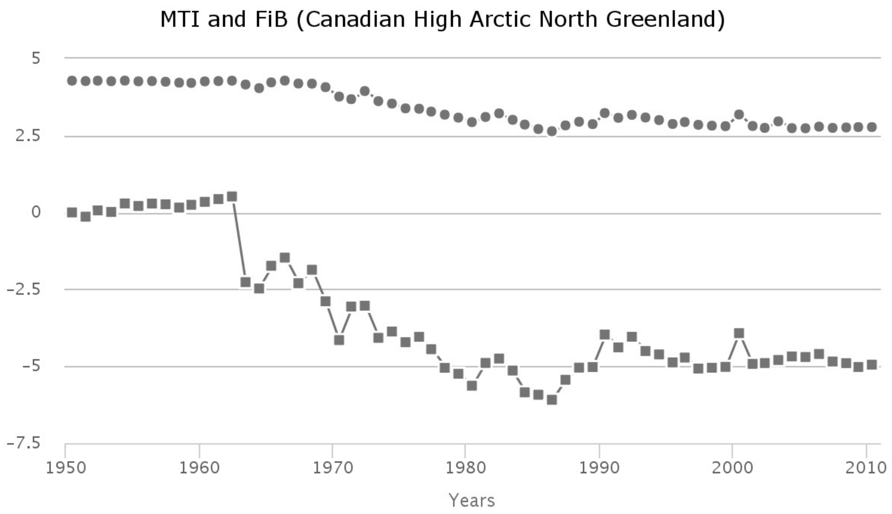
Catch value

The value of the landings reached its peak at 3 million US$ (in 2005 US$) in 1960.



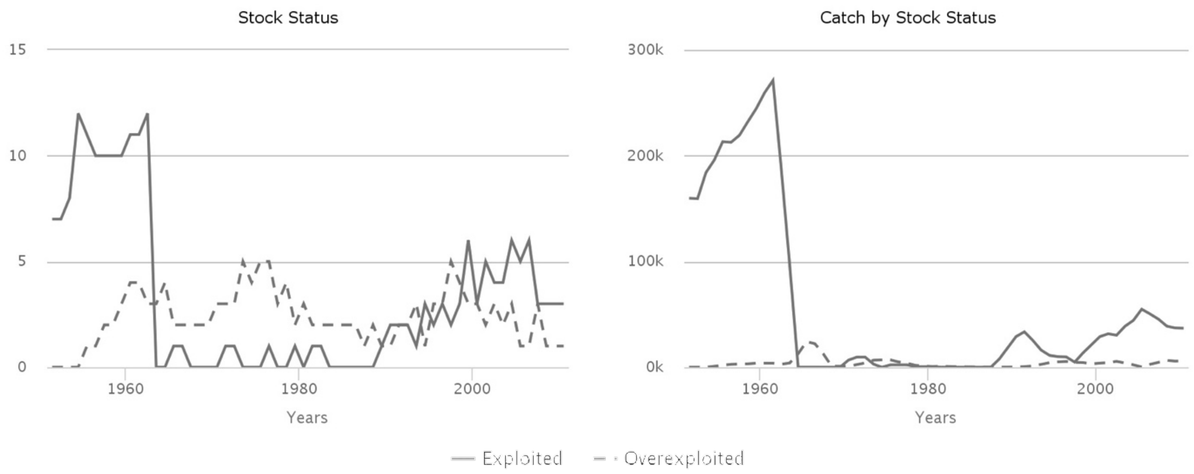
Marine Trophic Index and Fishing-in-Balance index

The MTI fluctuated around 4 from 1950 to late 1960s and then declined steadily to around 3 in the early 1980s. The FiB index keeps decreasing from 1950 to 2010, showing that there is no spatial expansion of fisheries in this region.



Stock status

As the catch data does not include most of the subsistence and artisanal catches in this LME, the stock status plots cannot realistically reflect the status of stocks in this region.

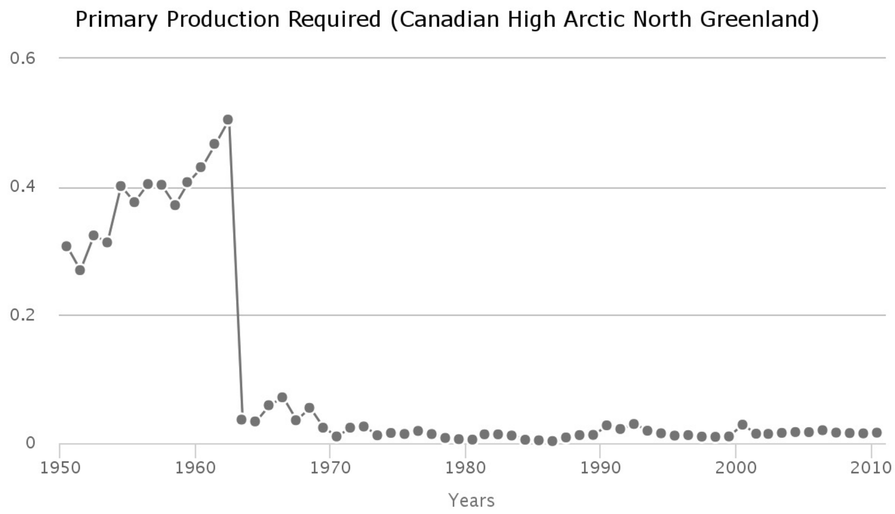


Catch from bottom impacting gear

Both the indicators of catch from bottom impacting gear type and fishing effort do not reflect the situation in this LME because of insufficient data.

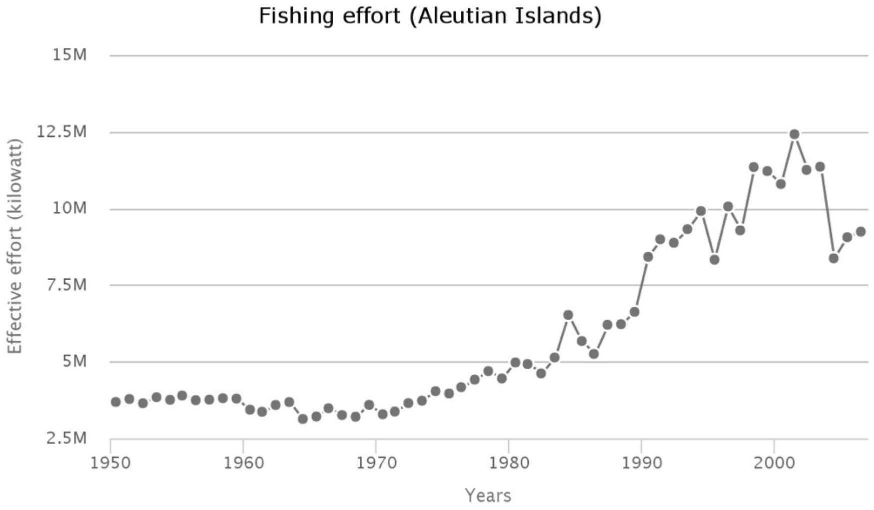
The percentage of catch from the bottom gear type to the total catch was lower than 5% before 1977. It then reached its first peak at 40% in 1991. After that, this percentage dropped to around 7% in 1996. It ranged between 20 and 42% in the recent decade.

Given the very low quality of the underlying catch data and insufficient data information, both the indicators of catch from impacting gear type and fishing effort are likely to be very unreliable..



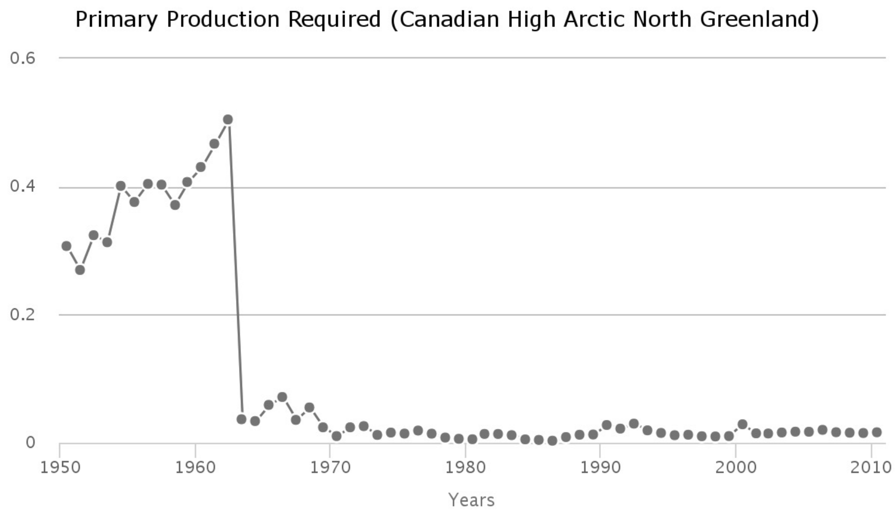
Fishing effort

The whole time series of effort data in the LME region is incomplete and only one year of effective effort data in this LME is available (i.e., about 3000 kW in 2002). Given the very low quality of the underlying catch data and insufficient data information, both the indicators of catch from impacting gear type and fishing effort are likely to be very unreliable.



Primary Production Required

The primary production required (PPR) to sustain the reported landings in this reached its maximum at 60% in 1962 and then declined to less than 5% in the following year. The PPR then ranges between 0.5 to 2% in the recent few decades.



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 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 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	4	1	1	4	1	1	4	1

Legend:

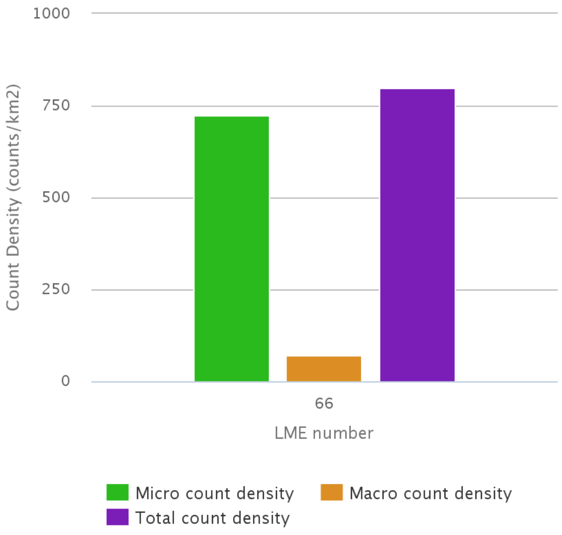
🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

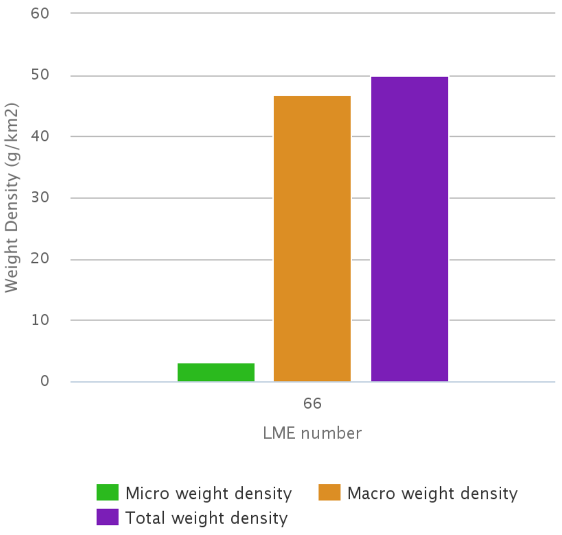
POPs

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 relatively low levels of 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 relative remoteness of this LME from significant sources of plastic. The abundance of floating plastic in this category is estimated to be on average over 40 times lower that 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

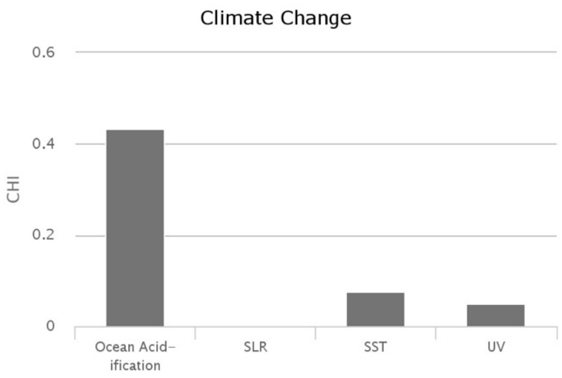
Not applicable.

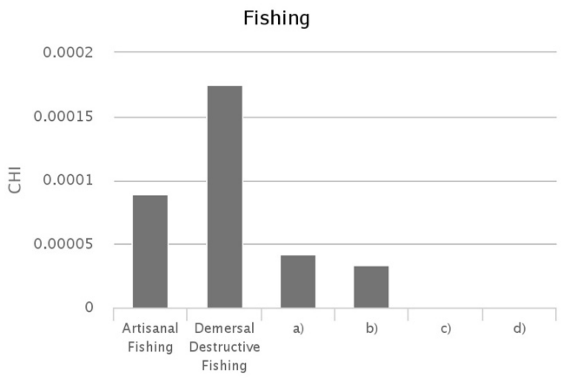
Marine Protected Area change

The Canadian High Arctic - North Greenland LME experienced an increase in MPA coverage from 37,888 km^2 prior to 1983 to 40,655 km^2 by 2014. This represents an increase of 7%, within the lowest category of MPA change.

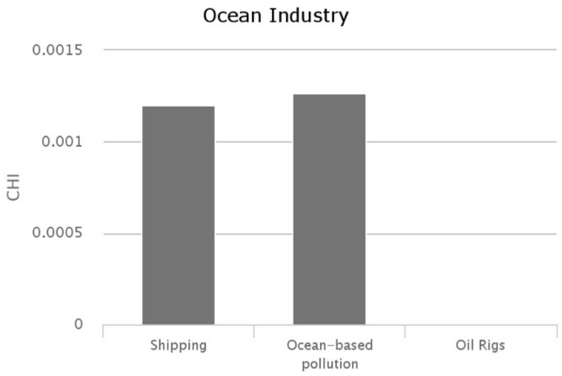
Cumulative Human Impact

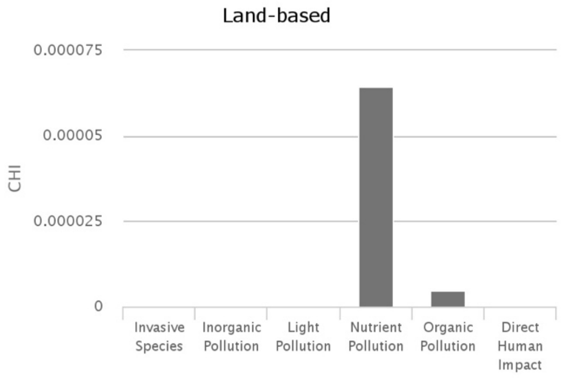
The Canadian High Arctic – North Greenland LME experiences one of the lowest overall cumulative human impact (score 0.56; maximum LME score 5.22). It falls in risk category 1 of the five risk categories (1 = lowest risk; 5 = highest risk). This LME is most vulnerable to climate change. Of the 19 individual stressors, ocean acidification has the highest average impact on the LME (score 0.43; maximum in other LMEs was 1.20). Other key stressors include UV radiation and sea surface temperature.

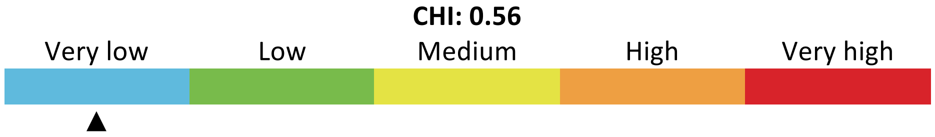




a) Demersal Non-destructive High Bycatch Fishing
c) Pelagic High Bycatch Fishing
b) Demersal Non-destructive Low Bycatch Fishing
d) Pelagic Low Bycatch Fishing

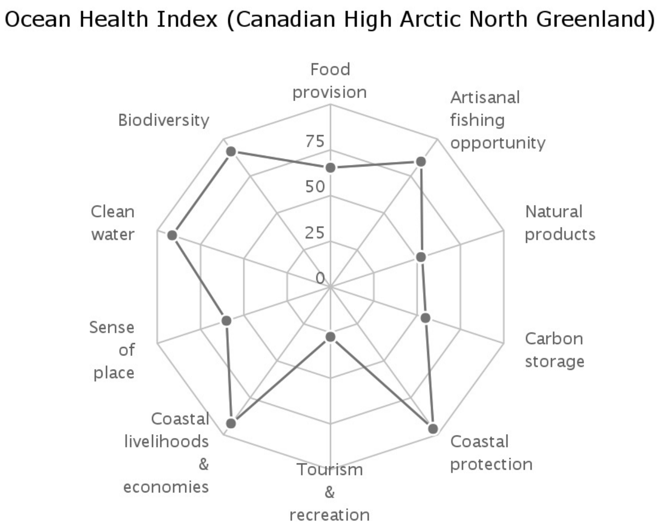






Ocean Health Index

The Canadian High Arctic – North Greenland LME scores above average on the Ocean Health Index compared to other LMEs (score 74 out of 100; range for other LMEs was 57 to 82), but still relatively low. 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 2 points compared to the previous year, due in large part to changes in the score for clean waters. This LME scores lowest on natural products, carbon storage, tourism & recreation and lasting special places goals and highest on mariculture, artisanal fishing opportunities, coastal protection, coastal economies, and biodiversity goals. It falls in risk category 2 of the five risk categories, which is a moderate level of risk (1 = lowest risk; 5 = highest risk).



OHI: 72.96

Very low	Low	Medium	High	Very high
				▲

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 442 031 km^2. A current population of 289 in 2010 is projected to decrease to 138 in 2100, with a density of 65 persons per 100 000 km^2 in 2010 decreasing to 31 per 100 000 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**
289	138	289	138

Legend: 🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Coastal poor

The indigent population makes up 12% of the LME's coastal dwellers. This LME places in the very low-risk category based on percentage and in the very low-risk category using absolute number of coastal poor (present day estimate).

Coastal poor
34

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 $0.45 million for the period 2001-2010. Fish protein accounts for 11% of the total animal protein consumption of the coastal population. Its yearly average tourism revenue for 2004-2013 of US 2013

$216 million places it in the very low-revenue category. On average, LME-based tourism income contributes 4% 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 high risk.

Fisheries Annual Landed Value	**% Fish Protein Contribution**	**Tourism Annual Revenues**	**% Tourism Contribution to GDP**	**NLDI**
454,337	10.8	216,011,710	4.3	🟧 0.8213

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 0.899, this LME has an HDI Gap of 0.101, 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 low-risk category (high HDI) because of reduced income levels and population values from those in a sustainable development pathway.

	HDI 2100	
HDI	**SSP1**	**SSP3**
🟦 0.8986	🟦 0.9740	🟩 0.7712

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 very low-risk (very 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 remains the same even under a fragmented world development pathway.

2010		**2100**	
Climate Threat	**Contemporary Threat**	**SSP1**	**SSP3**
0.2258	0.1455	0.1249	0.2579

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high

Governance

Governance architecture

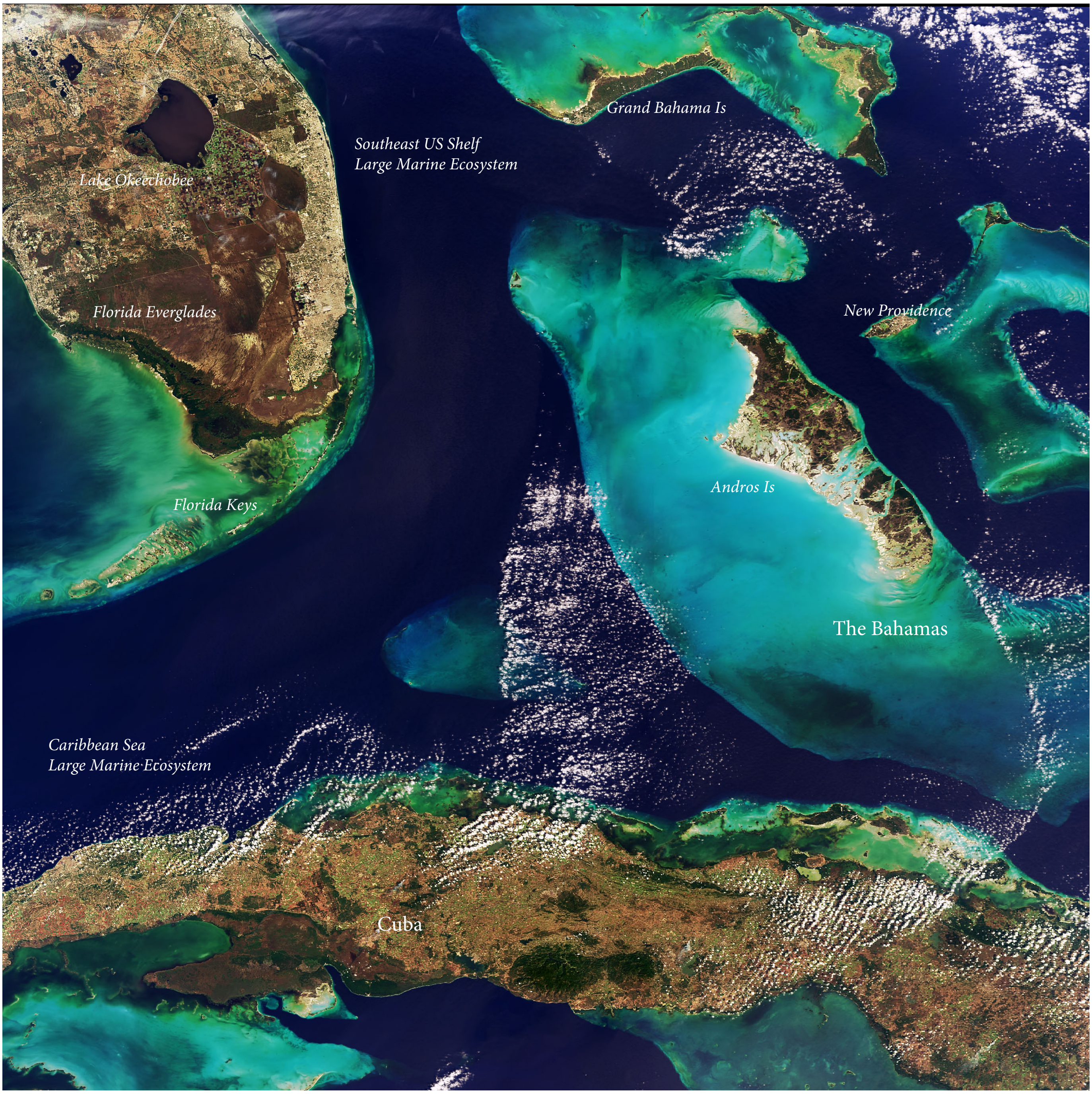
None of the transboundary fisheries arrangements (NEAFC, ICCAT, NAMMCO and NASCO) appear to be integrated while the three arrangements for pollution and biodiversity appear to have the Arctic Council as an integrating arrangement for one set of issues and the OSPAR Convention for a second set of similar issues relating to pollution and biodiversity. Additionally, the specific biodiversity arrangements for marine mammals and polar bears do not appear to have any formal linkages. The Arctic Council is not a binding arrangement so its implementation is voluntary and country dependent. It does appear to have the potential to develop into an informal overall policy coordinating organization, although as mentioned, its policy coordination role with respect to fisheries is weak. Consequently, 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:

Engagement	Completeness	Integration
75	**77**	**1**

Legend:

🟦 Very low 🟩 Low 🟨 Medium 🟧 High 🟥 Very high



Grand Bahama Is
Southeast US Shelf
Large Marine Ecosystem
Lake Okeechobee
Florida Everglades
New Providence
Florida Keys
Andros Is
The Bahamas
Caribbean Sea
Large Marine Ecosystem
Cuba

ESA

UNEP-DHI PARTNERSHIP
Centre on Water and Environment

UNEP

DHI

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

International
Hydrological
Programme

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental
Oceanographic
Commission

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The water systems of the world – aquifers, lakes, rivers, large marine ecosystems, and open ocean- sustain the biosphere and underpin the socioeconomic wellbeing of the world's population. Many of these systems are shared by two or more nations. These transboundary waters, stretching over 71% of the planet's surface, in addition to the subsurface aquifers, comprise humanity's water heritage.

Recognizing the value of transboundary water systems and the reality that many of them continue to be degraded and managed in fragmented ways, the Global Environment Facility Transboundary Waters Assessment Programme (GEF TWAP) was developed. The Programme aims to provide a baseline assessment to identify and evaluate changes in these water systems caused by human activities and natural processes, and the consequences these may have on dependent human populations. The institutional partnerships forged in this assessment are envisioned to seed future transboundary assessments as well.

The final results of the GEF TWAP are presented in the following six volumes:
Volume 1 – ***Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends***
Volume 2 – ***Transboundary Lakes and Reservoirs: Status and Trends***
Volume 3 – ***Transboundary River Basins: Status and Trends***
Volume 4 – ***Large Marine Ecosystems: Status and Trends***
Volume 5 – ***The Open Ocean: Status and Trends***
Volume 6 – ***Transboundary Water Systems: Crosscutting Status and Trends***

A *Summary* for Policy Makers accompanies each volume. All TWAP publications are available for download at http://www.geftwap.org

This annex – Transboundary waters: A Global Compendium. Water System Information Sheets: Northern America. Volume 6 - Annex A -- is one of 12 annexes to the Crosscutting Analysis discussed in Volume 6. The global compendium organized into 14 TWAP regions, compiles information sheets on 765 international water systems including the baseline values of quantitative indicators that were used to establish contemporary and relative risk levels at system and regional scales. Over the long term, it is envisioned that these baseline information sheets will continue to be updated by future assessments at multiple spatial and temporal scales to better track the changing states of transboundary waters that are essential in sustaining human wellbeing and ecosystem health.

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