

The 2012 Record Low Sea Ice Minimum and its Effect on Arctic Biodiversity



Adrià Blanco¹, Céline Gieße², Marlen Kolbe³, Karla B. Parga Martínez⁴, Kruti Upadhyay, Virryna (Yue) Wu⁵

¹*University of Barcelona, Barcelona, Spain*

²*University of Hamburg, Hamburg, Germany*

³*University of Algarve, Faro, Portugal*

⁴*Alfred Wegener Institute, Bremerhaven, Germany*

⁵*Pandit Deenday Petroleum University, Gujarat, India*

⁶*University of East Anglia, Norwich, United Kingdom*

Abstract

Rising temperatures due to global warming and Arctic amplification have caused a substantial loss of Arctic sea ice over the past decades. In September 2012, the Arctic sea ice extent reached its up to now minimum of only $3.4 \cdot 10^6$ km². This massive sea ice loss has been caused by a storm event, bringing heat and moisture from lower latitudes and shearing off a sizeable segment of the already thinned and weakened ice cover. The loss of sea ice has tremendous consequences for Arctic marine mammals, which are actively or passively dependent on the sea ice. Observations of polar bear populations show an overall declining population and changes in habitat locations. The most directly affected group of stakeholders are native Arctic communities, which are increasingly put at risk in a changing Arctic climate and ecosystem. Further groups of stakeholders affected by Arctic climate change and sea ice loss are public and nation-related entities as well as the private sector. More observations and research about ocean circulation, heat transport and atmospheric forcing like storms will allow for more accurate Arctic sea ice predictions. Moreover, a closer collaboration between stakeholders and science departments is necessary to achieve improved adaptation strategies to the changing conditions in the Arctic.

Table of Contents

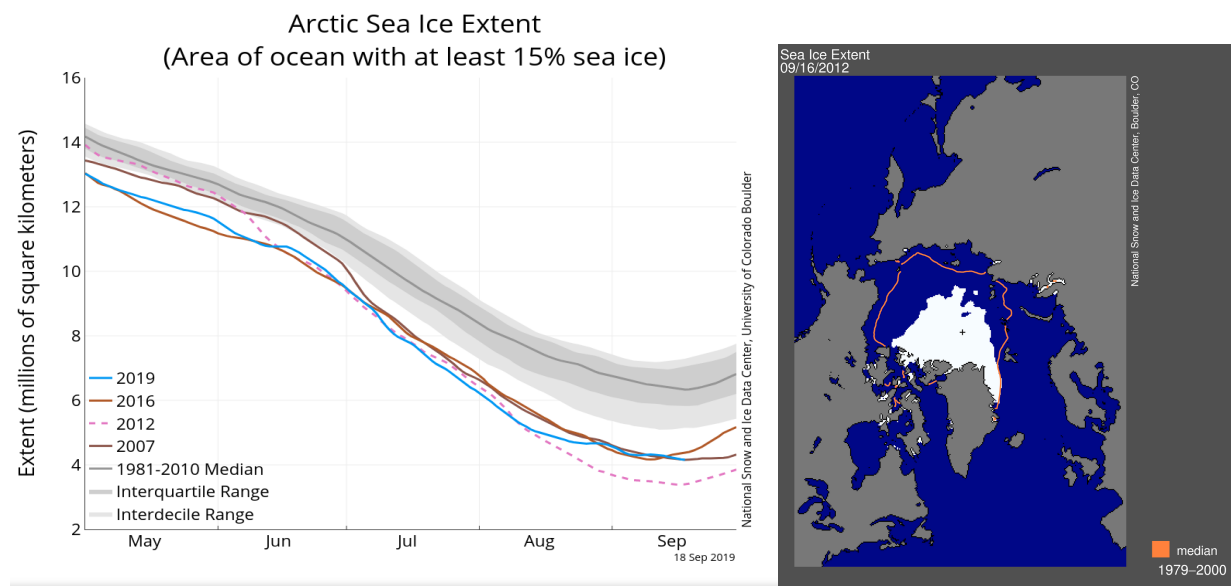
Influencing drivers on the 2012 low sea ice extent	4
Arctic Biodiversity in a declining sea ice habitat: polar bear populations at stake	7
Better Prediction of the Arctic Sea ice in the Climate Model Fehler! Textmarke nicht definiert. References	13

Influencing drivers on the 2012 low sea ice extent

A new record low sea ice extent of only $3.4 \cdot 10^6$ km² was reached on the 13th of September in 2012 (Parkinson and Comiso, 2013) and still remains the largest summer ice extent loss in the satellite record (Figure 1, left panel). The most affected

regions were the Chukchi Sea, the Beaufort Sea, the East Siberian Sea and the Laptev Sea (Figure 1, right panel). This section focuses on the drivers that contributed to and amplified this event.

Figure 1. Left panel: Selected time series of Arctic Sea Ice Extent during the summer period. Right panel: Sea Ice Extent on the 16th of September in 2012. Source: NSIDC.



Preconditioning

Firstly, we can generally find that the warming of the planet has led to a substantial decline of Arctic sea ice over the last decades. This is due to higher temperatures favouring the melting and thinning of the sea ice. The process of polar amplification, meaning that temperature effects are bigger at the poles compared to the rest of the hemisphere, has led to Arctic temperatures increasing almost twice as fast as the global average (e.g. Screen and Simmonds, 2010). As a result, yearly averaged Arctic sea ice extent has decreased by 4.6% per decade over the period from 1979 to 2010 (Parkinson and Comino, 2013). Perennial and multi-year ice are particularly affected, leading to a substantially stronger sea ice decline in summer compared to winter (Figure 2). The reduction in sea ice extent goes along with a substantial thinning of sea ice and the ice cover is additionally weakened by an increased formation of melt ponds due to increased rainfall in a warmer climate.

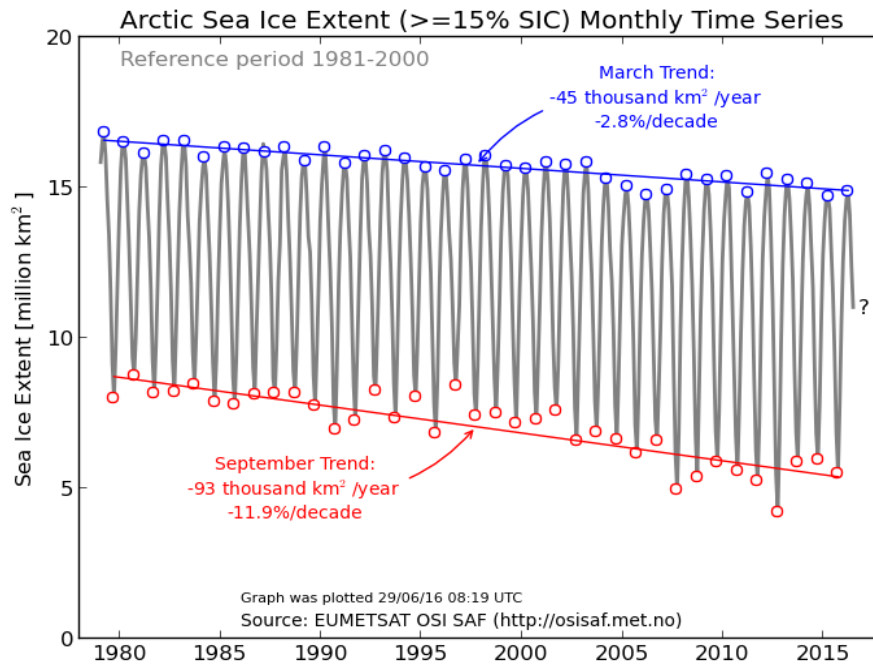


Figure 2. Time-series of the Arctic sea ice extent in March and September (blue line). Source: Polar Portal (polarportal.dk)

In 2012, the sea ice conditions were characterized by little perennial and multi-year ice, but a large expanse of seasonal ice formed in February and March. In fact, the seasonal ice extent has reached a winter maximum in March 2012 with an extent comparable to that of years in the 1990s, before the large ice decay during the summer months. As this seasonal ice cover was far more vulnerable to melting than multi-year ice, the sea ice extent decreased drastically in spring/early summer, such that the ice cover in June 2012 was comparable to that in the so far record low year of 2007. Sea surface temperatures (SST) have not been anomalously high in the year 2012 and are therefore not recognized to have played a major influence on the unusual ice retreat. According to Parkinson and Comiso, the reason for the relatively low SST in 2012 might even stem from the increased amount of cold water from the melted sea ice (Parkinson and Comiso, 2013).

The August 2012 storm

The weakening of the Arctic sea ice over the last decades left the remaining ice cover in 2012 more vulnerable to weather events such as storms than it would have been in earlier decades. This leads to the most likely biggest additional influence: In early August the tropopause polar vortex led to the creation of a major storm that entered the central Arctic from Siberia (Figure 3). It lasted for 13 days, reaching its peak intensity on the 6th of August. This storm led to a substantial sea ice decrease by bringing heat and moisture from the South and particularly by shearing off a

sizeable segment of ice as big as 0.4×10^6 km² in the Bering Strait/Chukchi Sea region. This ice segment eventually melted entirely due to wave action and surrounding water, leaving the rest of the ice sheet more vulnerable as well (Parkinson and Comiso, 2013).

Although the Arctic sea ice was already in a more vulnerable condition compared to the 2007-2011 mean, studies suggest that this storm played an important role for the low ice extent. However, even without the storm, model results suggest that the Arctic sea ice extent might have reached a new record minimum in 2012 (Zhang et al., 2013).

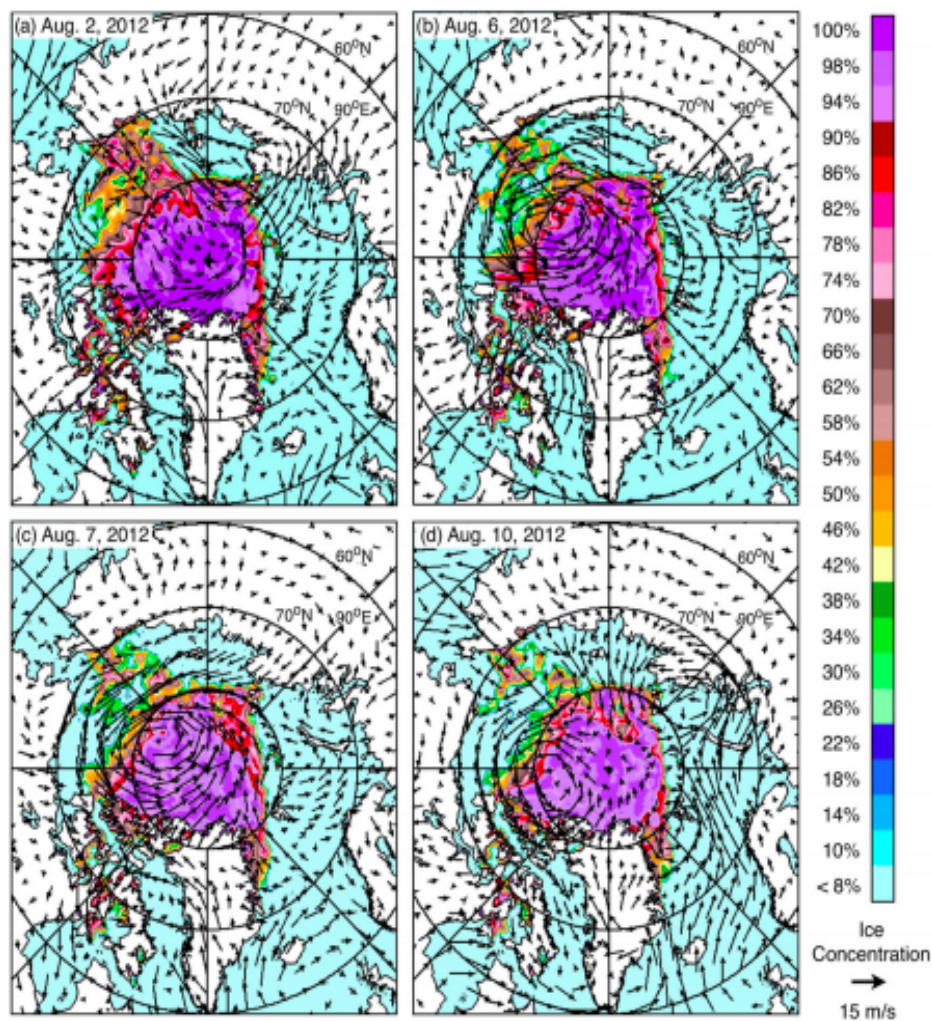


Figure 3. Maps of sea ice concentration from the SSMIS, overlain by wind vectors from NCEP, 2–10 August 2012. (Parkinson and Comiso, 2013)

Arctic Biodiversity in a declining sea ice habitat: polar bear populations at stake

The 2012 NOAA Arctic Report Card found evidence of the changes in multiple indicators that affect the Arctic environmental system as a result of the persistent warming trend for the last 30 years. The main source of change is sea ice cover, snow cover, glaciers and Greenland ice sheet. These changes affect the foundation of the food web working their way up to higher-trophic Arctic species (Moore, S; Gill, 2012). In general, Arctic fauna is either dependent on sea ice or partially affected by its presence. Marine mammals are actively or passively using sea ice for hunting, mating, resting, whelping, rearing offspring or avoiding predators (Moore and Huntington, 2008). However, given the elusive nature of many species and their large ranges, it is difficult to assess their populations' status and trends. There are 35 species of marine mammals that inhabit or seasonally use Arctic waters, seven of them are endemic and dependent on or highly associated with sea ice: narwhal, beluga, bowhead whale, ringed seal, bearded seal, walrus and polar bear (CAFF, 2013).

Polar bears are distributed throughout ice-covered Arctic regions and their global population (20,000 to 25,000 individuals) is divided into 19 sub-populations (Stern and Laidre, 2016). The largest sub-populations are in Davis Strait, the Barents Sea and Foxe Basin with more than 2,000 individuals each (Aars et al., 2009; Obbard, Martyn; Thiemann, G.W.; Peacock, E.; DeBruyn, 2010; Peacock et al., 2013, respectively). The trend in 2013 pointed at seven declining sub-populations, four stable and one increasing, lacking data for the remaining seven sub-populations. However, the most recent Conservation of Arctic Flora and Fauna (CAFF) Report from 2017 states one declining sub-population, five stable, one increasing and 12 unknown, which means that five sub-populations became unassessable since 2013 (Table 1).

This ice-obligate species is predicted to decrease fitness with declining sea ice in the Arctic as they require ice as a platform for resting, breeding and/or hunting (Moore and Huntington, 2008). Shifts in their summer and fall distributions have been already demonstrated (Fischbach et al., 2007; Schliebe et al., 2008). In fact, their declining numbers hold a statistical relationship with sea ice duration (Regehr et al., 2016). Adverse effects include decline in body condition, abundance, survival and recruitment, and loss of critical habitat (Huntington et al., 2016), which forces them to find new locations for denning in response to changing ice conditions (Fischbach et al., 2007) and to increase swimming activity (Pagano et al., 2012). Moreover, early retreat or break up of sea ice causes polar bears to arrive on land earlier moving to new areas (Schliebe et al., 2008). The situation worsens as their main prey, bearded and ringed seals, are also ice-obligate species all year round for

rearing pups and moulting, whose sea ice loss effects cascade to polar bears (Macias-Fauria and Post, 2018). As a result, polar bears have been reported to increase predation on ground-nesting seabird colonies (Hamilton et al., 2017) and to become familiar with human settlements.

Estimate from 2013 <i>Source CAFF, 2013</i>				Current estimate from 2017 <i>Source CAFF, 2017</i>		
Sub-population	Abundance	Year	Trend	Abundance	Year	Trend
Arctic Basin	Unknown	-	Unknown	Unknown	-	Unknown
Baffin Bay	1,546	2004	Declining	2,826	2013	Unknown
Barents Sea	2,650	2004	Unknown	2,644	2004	Unknown
Chukchi Sea	Unknown	-	Declining	Unknown	-	Unknown
Davis Strait	2,158	2007	Stable	2,158	2007	Stable
E Greenland	Unknown	-	Unknown	Unknown	-	Unknown
Foxe Basin	2,578	2007	Unknown	2,580	2010	Stable
Gulf of Boothia	1,592	2000	Stable	1,592	2000	Unknown
Kane Basin	164	1998	Declining	357	2014	Increasing
Kara Sea	Unknown	-	Unknown	Unknown	-	Unknown
Lancaster Sound	2,541	1998	Declining	2,541	1997	Unknown
Laptev Sea	Unknown	1993	Unknown	Unknown	1993	Unknown
M'Clintock Channel	284	2000	Increasing	284	2000	Unknown
Northern Beaufort Sea	1,202	2006	Stable	980	2006	Stable
Norwegian Bay	190	1998	Declining	203	1997	Unknown
Southern Beaufort Sea	1,526	2006	Declining	907	2010	Declining
Southern Hudson Bay	900 – 1,000	2005	Stable	951	2012	Stable
Western Hudson Bay	935	2004	Declining	1,030	2011	Stable
Viscount Melville	215	1992	Unknown	161	1992	Unknown

Table 1. Abundance estimate of polar bears sub-populations, the year of the estimate and the trend in 2013 and 2017. Red means changes in the status.

Better Prediction of the Arctic Sea ice in the Climate Model

In long-term climate projections, the latest state-of-art global climate models (well-known like CMIP5 and just released CMIP6) do show the sea ice decline with increasing anthropogenic greenhouse forcing. However, challenges still remain in (a) a wide spread in hindcast among models; (b) the conservative simulated sea ice decline compared to observations [Stroeve et al., 2012], which can be attributed to low sea ice sensitivity [Ding et al., 2019]; and (c) low predictability in sea ice thickness and sea ice volume due to a lack of observation to date [Tietsche et al., 2014]. Generally, models show good predictability in the central Arctic, which holds most of the multi-year sea ice persistence, while in the peripheral seas, predictions of winter sea ice are more reliable than the other seasons in terms of sea ice concentration and thickness. These large uncertainties lie particularly in unpredictable sea ice edge location [Cruz-García et al., 2019], which is strongly associated with ocean circulation and heat content underneath. Extra surface heat fluxes and ocean heat transport from lower latitudes are dominant factors for sea ice loss. The atmospheric dynamics, in particular the relative location of the high/low pressure system is crucial for the overall ice conditions.

For short-term seasonal forecast, summer sea ice has always been a top concern in advancing predictive capability in the North pole region. Our case study of the 2012 sea ice minima event has indicated that Arctic ice conditions are becoming more vulnerable to storms, implying that polar cyclones should be more carefully monitored and treated as an important influence on sea ice extent. The linkage between JJA (June-July-August) atmospheric circulation patterns and September sea ice has been established, showing that a strong barotropic circulation change in the Arctic may act as an important factor in determining sea ice internal variability in the summertime [Ding et al., 2019]. Using sea ice loss patterns caused by external forcing and sea ice internal variability, Ding et al., [2019] successfully reconstructed the sea ice decline being more reconcile to observations. This provides a possibility for better predictions of summer sea ice by large ensemble experiments in the future. In spite of this correction for climate models, the technical improvements are still urgent for scientists. For future science, more observations are required to help the model corrections. Our case study concludes that model improvements are needed with respect to the high ice sensitivity in response to warming climate, more accurate ocean circulation and its heat content to provide advective and thermodynamics sea ice processes, and atmospheric forcing pattern in middle summer to maximise the predictability of Arctic summer sea ice minima.

Better sea ice predictions are not only scientifically valuable, but also stakeholders could potentially benefit in various aspects (next section). Therefore, we recommend

a stronger collaboration between stakeholders and science departments, from which both sides would profit.

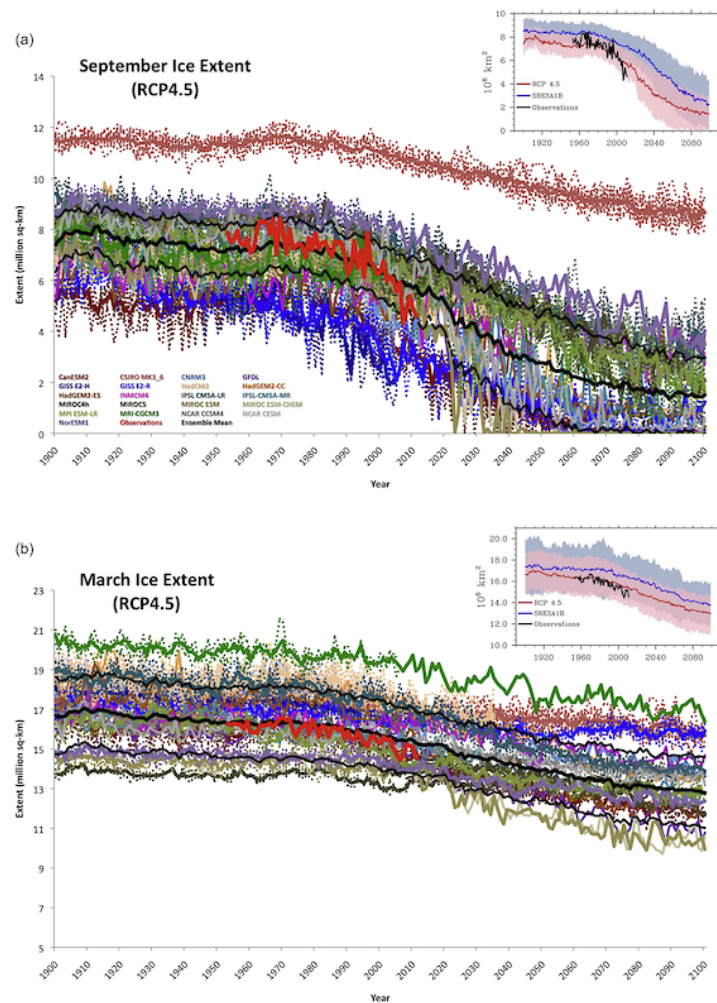


Figure 6. Time-series of modeled (colored lines) and observed (solid red line) (a) September and (b) March sea ice extent from 1900 to 2100. All 56 individual ensemble members from 20 CMIP5 models are included as dotted colored lines, with their individual model ensemble means in solid color lines. The multi-model ensemble mean is based on 38 ensemble members from 17 CMIP5 models (shown in black), with ± 1 standard deviation shown as dotted black lines. Figures 2a and 2b insets are based on the multi-model ensemble mean from CMIP5 and CMIP3, ± 1 standard deviation (Stroeve et al., 2012).

Polar stakeholders affected by climate change

Climate change is leading many changes in the Arctic. From a natural impact threatening wildlife to sociopolitical issues where a wide range of stakeholders might be involved. A better prediction of the sea ice extent must optimize and ease their activity (R. Newton et al., 2016) collaborating positively with the environment.

Those stakeholders might be classified in different categories based on their direct relation and purposes at the Arctic. As a first approach, (a) native arctic communities are those who might be more vulnerable during a transitional phase linked to climate change. With a traditional lifestyle and generational habits, a reduction in the sea ice extent might decrease their principal sources of income. Both native and major population agglomerations might also be directly threatened by extreme weather events propitiated by a changing climate. (b) Public sector and nation-related stakeholders are also considered as one of the biggest affected groups under a progressive ice-loss scenario. Even though, this category is quite widespread and there are plenty of contributors as the military, natural resources exploiters, etc., but also nations are into finance scientific expeditions and send bigger amount of field researchers to the Arctic. Non-profit organizations could also be classified in this same category. This is especially relevant for the Arctic coastal states such as Norway, Denmark, Canada, United States, Russian Federation and Iceland and for the non-coastal states of Sweden and Finland (Paul Berkman, 2012). c) Private sector might not be the more negatively affected but the more interested in taking advantage of new opportunities in the Arctic regions. A sea ice extent reduction might allow private companies to easily access and exploit new areas. For example, as shown in Figure 4, an increasing number of shipping trading routes have recently been established through the Arctic Ocean due to a lack in the sea ice coverage. The energy and tourism sectors are also considerably developing in these areas.

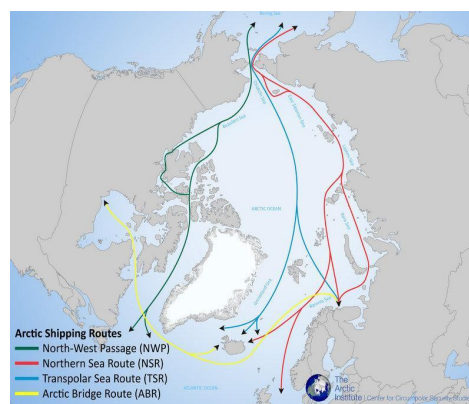


Figure 4. New shipping routes under free-ice scenarios (The Arctic Institute)

The relation of these different groups of stakeholders with the record low sea ice minima of 2012 is then of great interest. It allows stakeholders to understand how a more likely ice-free scenario would affect the different categories and how a better prediction would ease their activity and reduce their impact on the environment. However, as agreed by international communities since 1958, the high seas are “open to all nations” and “no State may validly purport to subject any part of them to its sovereignty” (Paul A. Berkman, 2009). So, the centre of the Arctic Ocean would always be an international space, representing a region of common interests in contrast to national interests.

For these reasons and in order to achieve a sustainable development in these regions, a balance between stakeholders and interests must be guaranteed. Environmental protection, economic prosperity and social equity are among the key drivers to sustain this equilibrium (Paul Berkman, 2012). Building common interests and understanding the risks of the stakeholders in a changing environment, might be the essential ingredients to respond to a more challenging Arctic panorama. Furthermore, building stronger relations between categories of stakeholders in the Arctic could also contribute to a more sustainable development.

References

- Aars, J., Marques, T. A., Buckland, S. T., Andersen, M., Belikov, S., Boltunov, A., et al. (2009). Estimating the Barents Sea polar bear subpopulation size. *Mar. Mammal Sci.* 25, 35–52. doi:10.1111/j.1748-7692.2008.00228.x.
- Berkman, P. (2012). Geopolitics of Arctic Sea-Ice Minima. *The Brown Journal of World Affairs*, 19(1), 145-153. Retrieved from <http://www.jstor.org/stable/24590934>
- CAFF (2013). Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity. Akureyri.
- CAFF (2017). State of the Arctic Marine Biodiversity Report. Conservation of Arctic Flora and Fauna International Secretariat, Akureyri, Iceland. 978-9935-431-63-9
- Cruz-García, R., V. Guemas, M. Chevallier, and F. Massonne (2019), An assessment of regional sea ice predictability in the Arctic ocean, *Clim. Dyn.*, 53: 427, <https://doi.org/10.1007/s00382-018-4592-6>.
- Ding, Q. H. et al. Influence of the recent high-latitude atmospheric circulation change on summertime Arctic sea ice. *Nat. Clim. Change* 7, 289–295 (2017).
- Ding, Q., A. Schweiger, M. L’Heureux, E. J. Steig, D. S. Battisti, N. C. Johnson, E. Blanchard-Wrigglesworth, S. Po-Chedley, Q. Zhang, K. Harnos, M. Bushuk, B. Markle, and I. Baxter (2019), Fingerprints of internal drivers of Arctic sea ice loss in observations and model simulations, *Nature Geosci.*, 12, 28–33, doi:10.1038/s41561-018-0256-8.
- Fischbach, A. S., Amstrup, S. C., and Douglas, D. C. (2007). Landward and eastward shift of Alaskan polar bear denning associated with recent sea ice changes. *Polar Biol.* 30, 1395–1405. doi:10.1007/s00300-007-0300-4.
- Hamilton, C. D., Kovacs, K. M., Ims, R. A., Aars, J., and Lydersen, C. (2017). An Arctic predator-prey system in flux: climate change impacts on coastal space use by polar bears and ringed seals. *J. Anim. Ecol.* 86, 1054–1064. doi:10.1111/1365-2656.12685.
- Huntington, H. P., Quakenbush, L. T., and Nelson, M. (2016). Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. *Biol. Lett.* 12, 20160198. doi:10.1098/rsbl.2016.0198.
- Macias-Fauria, M., and Post, E. (2018). Effects of sea ice on Arctic biota: an emerging crisis discipline. *Biol. Lett.* 14, 20170702. doi:10.1098/rsbl.2017.0702.
- Moore, S; Gill, M. (2012). “Marine Ecosystems Summary,” in Arctic Report Card 2012.

Moore, S. E., and Huntington, H. P. (2008). Arctic Marine Mammals and Climate Change: Impacts and Resilience. *Ecol. Appl.* 18, S157–S165. doi:10.1890/06-0571.1.

Newton, R., Pfirman, S., Schlosser, P., Tremblay, B., Murray, M., and Pomerance, R. (2016), White Arctic vs. Blue Arctic: A case study of diverging stakeholder responses to environmental change, *Earth's Future*, 4, 396–405, doi:10.1002/2016EF000356.

Obbard, M.; Thiemann, G.W.; Peacock, E.; DeBruyn, T. D. (2010). Polar bears: proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, Copenhagen, Denmark, 29 June - 3 July 2009. Gland Available at: <https://www.iucn.org/es/node/23886>.

On the 2012 record low Arctic sea ice cover: Combined impact of preconditioning and an August storm. Claire L. Parkinson and Josefino C. Comiso. 2013.

Pagano, A. M., Durner, G. M., Amstrup, S. C., Simac, K. S., and York, G. S. (2012). Long-distance swimming by polar bears (*Ursus maritimus*) of the southern Beaufort Sea during years of extensive open water. *Can. J. Zool.* 90, 663–676. doi:10.1139/z2012-033.

Parkinson, C. L., and J. C. Comiso (2013). On the 2012 record low Arctic sea ice cover Combined impact of preconditioning and an August storm, *Geophys. Res. Lett.*, 40: 1356–1361, doi:10.1002/grl.50349.

Peacock, E., Taylor, M. K., Laake, J., and Stirling, I. (2013). Population ecology of polar bears in Davis Strait, Canada and Greenland. *J. Wildl. Manage.* 77, 463–476. doi:10.1002/jwmg.489.

Regehr, E. V., Laidre, K. L., Akçakaya, H. R., Amstrup, S. C., Atwood, T. C., Lunn, N. J., et al. (2016). Conservation status of polar bears (*Ursus maritimus*) in relation to projected sea-ice declines. *Biol. Lett.* 12, 20160556. doi:10.1098/rsbl.2016.0556.

Schliebe, S., Rode, K. D., Gleason, J. S., Wilder, J., Proffitt, K., Evans, T. J., et al. (2008). Effects of sea ice extent and food availability on spatial and temporal distribution of polar bears during the fall open-water period in the Southern Beaufort Sea. *Polar Biol.* 31, 999–1010. doi:10.1007/s00300-008-0439-7.

Screen, J. A., & Simmonds, I. (2010). The central role of diminishing sea ice in recent Arctic temperature amplification. *Nature*, 464(7293), 1334.

Simmonds, I., & Rudeva, I. (2012). The great Arctic cyclone of August 2012. *Geophysical research letters*, 39(23).

Smith, L.C., and Stephenson, S. R. (2013), New Trans-Arctic shipping routes navigable by midcentury, *Proceedings of the National Academy of Sciences*, 110 (13) E1191-E1195; DOI: 10.1073/pnas.1214212110

Stern, H. L., and Laidre, K. L. (2016). Sea-ice indicators of polar bear habitat. *Cryosph.* 10, 2027–2041. doi:10.5194/tc-10-2027-2016.

Stroeve, J. C., V. Kattsov, A. Barrett, M. Serreze, T. Pavlova, M. Holland, and W. N. Meier (2012), Trends in Arctic sea ice extent from CMIP5, CMIP3 and observations, *Geophys. Res. Lett.*, 39, L16502, doi:10.1029/2012GL052676.

Tietsche, S., J. J. Day, V. Guemas, W. J. Hurlin, S. P. E. Keeley, D. Matei, R. Msadek, M. Collins, and E. Hawkins (2014), Seasonal to interannual Arctic sea ice predictability in current global climate models, *Geophys. Res. Lett.*, 41, 1035-1043, doi:10.1002/2013GL058755.

Zhang, J., Ron Lindsay, Axel Schweiger, and Michael Steele. 2013. The impact of an intense summer cyclone on 2012 Arctic sea ice retreat.