XI-33 Kara Sea: LME #58

S. Heileman and I. Belkin

The Kara Sea LME is a high-latitude Arctic system located off northern Russia. This shallow LME has an area of 800,000 km^2, of which 2.7% is protected (Sea Around Us 2007) and is seasonally ice-covered. According to the Atlas of the Oceans (USSR Navy, 1980), the Kara Sea has an average depth of 111 m, and a water catchment area of 6,589,000 km^2. Warm ocean currents flowing into this LME from the North Atlantic Ocean result in mostly ice-free conditions from May to October. Large rivers, of which the total catchment area of 6.6 x 10^6 km^2 is equal to almost half the Russian territory, flow into this LME discharging over 1200 km^3 annually. These include (discharge in km^3/yr) the Yenisei (610), Ob' (395), Pyasina (82), Taz (45) and Taimyra (38) Rivers, of which the first two are among the largest rivers of the Arctic. Freshwater and nutrient input from these rivers, and water exchange with the Arctic Ocean, characterise this LME. Together with the Laptev Sea LME, the Kara Sea LME plays a significant role in the ice and water mass transport system of the Arctic (UNEP 2005).

I. Productivity

The Kara Sea LME is a Class I, high productivity ecosystem (>300 $gCm^{-2}yr^{-1}$). In situ productivity data are sparse, patchy and extremely heterogeneous depending on location and season (Vetrov and Romankevich 2004). The maximum primary production (PP) of 200 $mgCm^{-2}d^{-1}$ is observed in the Baidaratskaya Bay (west of the Yamal Peninsula). The average PP from in situ data is 43 $mgCm^{-2}d^{-1}$ ((Vetrov and Romankevich 2004). The availability of light and nutrients has been restricted by seasonal ice cover during part of the year, limiting production to a brief period after the ice melts in the summer months. Zooplankton production is relatively low and the distribution and species composition are influenced by the proximity of the Atlantic Ocean. According to the most complete study by Lukianova (2005), benthos biomass reaches 300 g/m^{-2} in the southern Kara Sea. The sea's total biomass amounts to 41 million tons, while total annual production is between 1.4 and 2.0 million tons of carbon (Vetrov and Romankevich 2004). Generally, the coastal zone and gulfs feature high benthos biomass and highest biodiversity – nearly 400 taxa of various systematic groups. Polychaets (33%), crustaceans (30%) and molluscs (21%) dominate among all identified species (Matishov, G.G., Dzhenyuk, Sherman, K. 2006. Large Marine Ecosystems of the Shelf Seas of Russian Arctic. Paper presented at the PAME Meeting).

Numerous species of marine mammals inhabit this LME. The most abundant species are: Atlantic walrus (*Odobenus rosmarus rosmarus*), ringed seal (*Phoca hispida*), common seal (*Phoca vitulina vitulina*), Greenland seal (*Hisriophoca geonlandica oceanica*), crested seal (*Cystophora cristata*), killer whale, narwhal, and belukha whale (*Delphinapterus leucas*). Fish fauna is not well studied partly because of the lack of commercial fishery, except for the fishery for anadromous and semi-anadromous fish species in the estuaries of Siberian rivers, e.g. Yenisei, Ob', Pyasina, Taz, and Taimyra. Among 60 fish species found in the Russian Arctic Seas, a few species are considered commercial, namely Arctic cisco, European cisco, muksun (*Coregonus muksun*), Atlantic whitefish (*Coregonus huntsmani*; Russian "sig", a white fish of the salmon family), Arctic char, navaga (*Eleginus nawaga*) and sheefish (*Stenodus leucichthys*),

Oceanic fronts (after Belkin et al. (2009): The Ob' and Yenisey River discharges to the Kara Sea form a giant single freshwater plume, since both estuaries are close to each other (Figure XI-33.1). This plume spreads across the entire LME, up to Novaya Zemlya. The distribution of this plume is largely determined by the wind field that is ultimately governed by a large-scale atmospheric pressure pattern.

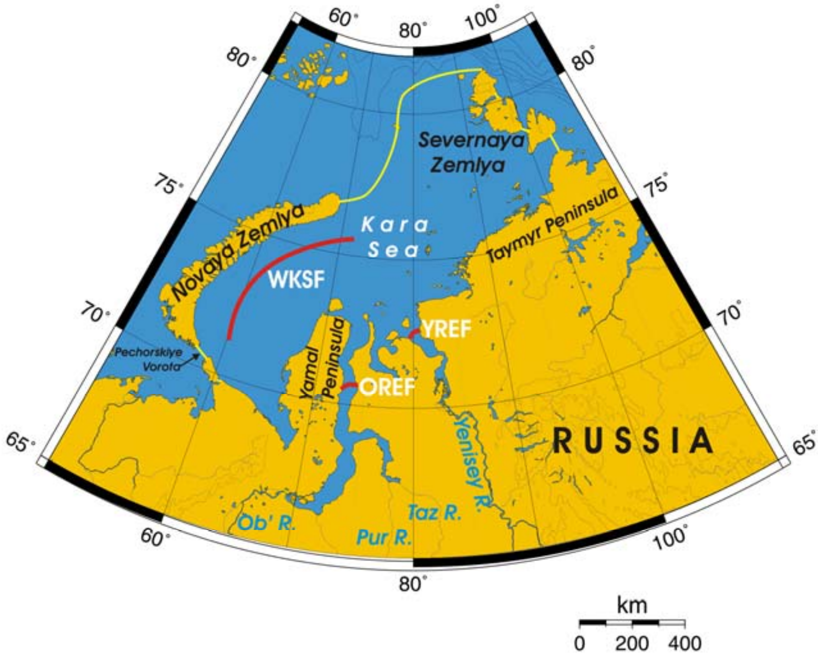

Figure XI-33.1. Fronts of the Kara Sea LME. OREF, Ob' River Estuarine Front; WKSF, West Kara Sea Front; YREF, Yenisey River Estuarine Front. Yellow line, LME boundary. After Belkin et al. (2009).

Sharp salinity and temperature fronts are observed in the outer parts of Ob' and Yenisey's estuaries called Obskaya Guba and Yeniseyskiy Zaliv, respectively, where riverine waters meet oceanic waters. In the southwestern part of the LME, a front exists between resident waters and the Atlantic inflow from the Barents Sea through Karskiye Vorota, a strait that connects the Kara Sea with the Pechora Sea, a southeastern extension of the Barents Sea.

Kara Sea LME SST (after Belkin, 2009)
Linear SST trend since 1957: 0.30°C.
Linear SST trend since 1982: 0.16°C.

The Kara Sea warming was slow, accentuated by a single event, the all-time maximum of 1995, which occurred concurrently with the Laptev Sea. Interannual variability here is moderate, with a magnitude of 0.5°C, similar to the Laptev Sea. Thermal history of the Kara Sea is negatively correlated with the Arctic Oscillation (AO) index. In this respect, the Kara Sea is similar to the Beaufort Sea LME. At the same time, the Kara Sea SST appears to be decorrelated from the adjacent Laptev Sea LME's SST since the latter is negatively correlated with the AO index (Climate Prediction Center 2007). This pattern can be explained by the lack of oceanographic connection between the Kara and Laptev seas. Indeed, the only significant connection between these seas is through the shallow Vilkitsky Strait, which is covered by sea ice year-round.

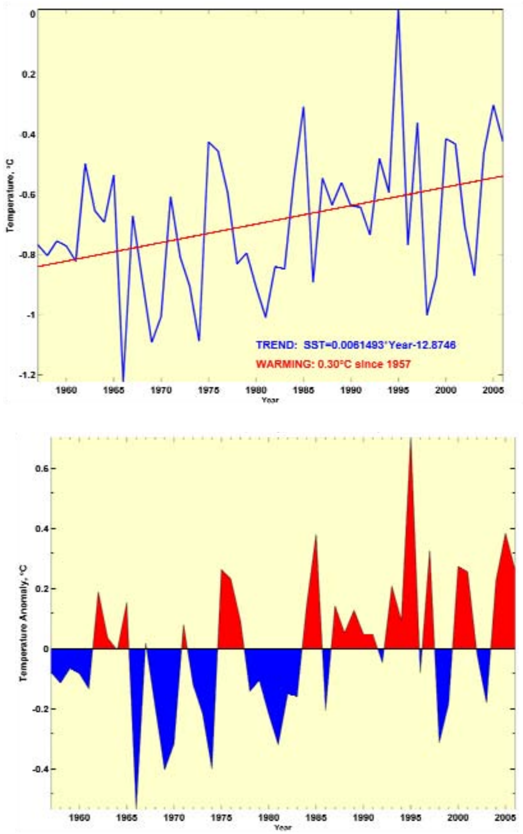

Figure XI-33.2a. Kara Sea LME annual mean SST (top) and SST anomalies (bottomt), 1957 – 2006, based on Hadley climatology. After Belkin (2009).

The standardized seasonal mean Arctic Oscillation (AO) index during cold season (**blue** line) is constructed by averaging the daily AO index for January, February and March for each year. The **black** line denotes the standardized five-year running mean of the index. Both curves are standardized using 1950-2000 base period statistics (Figure XI-33.2b. from Climate Prediction Center 2007).

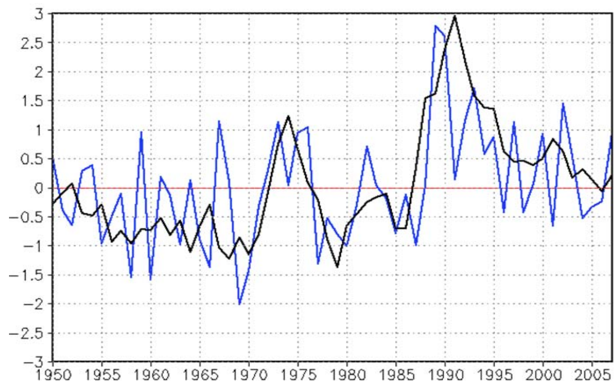

Figure XI-33.2b. Standardized Seasonal Mean (JFM) AO index (1950-2007), Climate Prediction Center 2007.

Kara Sea LME Chlorophyll and Primary Productivity: The Kara Sea LME is a Class I, high productivity ecosystem (>300 gCm^{-2}yr^{-1}).

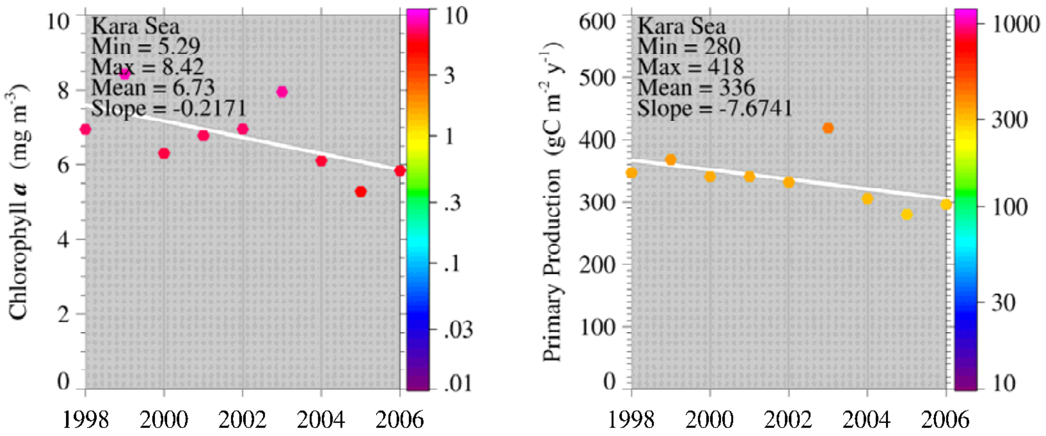

Figure XI-33.3. Kara Sea LME trends in chlorophyll *a* (left) and primary productivity (right). Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

As mentioned in the previous section, the Kara Sea benefits from the occasional intrusion of 'warm' water and its accompanying fauna, "as apparently occurred during 1919-1938, when a strong inflow of warm Atlantic water into the Kara Sea, Northern Russia, led to the eastward expansion of salmon" (Fleming and Jensen, 2002).

However, except for these occasional strays, the fish fauna of the Kara Sea is species poor (see www.fishbase.org) with the bulk of the fisheries catches contributed by the genus *Coregonus*, (Subfamiliy Coregoninae, Family Salmonidae) known as 'whitefishes' or 'sig' in Russian. Six of their species make up about 80% of the total fisheries landing in the LME (Larsen *et al.* 1996,).

Figure XI-33.4 is adapted from Pauly & Swartz (in press), who used a variety of sources, notably Larsen *et al.* (1996) to reconstruct estimated catches from the Kara Sea for 1950 to 2004. The declining catches are explained in part by extreme pollution of the estuaries and coastal areas and by overfishing (Pauly & Swartz in press). Due to the tentative nature of these catch estimates, no indicators based on these data will be presented (but see Sea Around Us 2007).

III. Pollution and Ecosystem Health

Pollution: Pollution was assessed as generally moderate in the LME (UNEP 2005), which is impacted by a variety of anthropogenic contaminant sources (Layton *et al*. 1997, Povinec *et al*. 1997). Almost 40% of the area is influenced by continental waters and substantial amounts of pollutants introduced by the Ob' and Yenisei Rivers. Obsolete technologies and the lack of facilities for processing industrial waste cause major ecological problems. In the open waters of the Arctic the concentration of pollutants are low or absent. However, localised shelf areas and most coastal zones are considerably polluted. The state of a number of bays, gulfs and estuarine areas is considered to be critical and even catastrophic, and partly explains the decline in the fisheries catch

(Figure XI-33.4). In fact, the concentrations of some chemical contaminants exceed the threshold

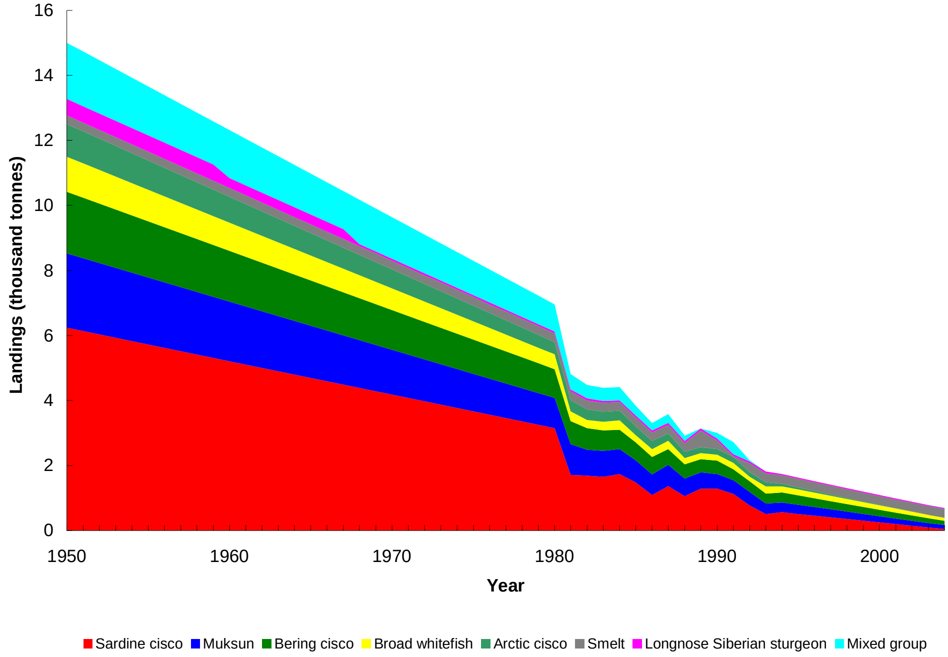

Figure XI-33.4. Total estimated catches (subsistence fisheries) in the Kara Sea LME (from Pauly & Swartz 2007).

limits defined for the country. This situation is aggravated by the accumulation of numerous contaminants in the bottom sediments. According to the chemical monitoring data of the Roshydromet network (GOIN 1996 a-d, Roshydromet 1997-2002) and the Arctic Monitoring Regional Centre, trace metals and petroleum hydrocarbons are the most widespread pollutants in the Kara Sea LME. By far the most important source of pollution is the Norilsk nickel processing plant that emits more than 1 million tons of sulfur every year (AMAP 1997).

Suspended solids in the Ob' and Yenisei River deltas carry high levels of PCBs and DDT (AMAP 1998). These toxic pollutants are found in practically all bays and estuarine zones and their chronic impacts on marine organisms cause serious concern. Long-range atmospheric transport may account for the high HCH concentrations in open areas (GOIN 1996a-d, Roshydromet 1997-2002). Although radioactive materials are dumped into the Arctic seas, there is no evidence of high concentrations of radionuclides in the LME (AMAP 1997, 2002). Pollution from solid waste is caused by domestic waste and metal barrels on the shores.

Oil and gas development, in particular oil extraction, oil spills, washing from the shore, and pipeline transportation, pose a significant environmental threat. The maximum permissible concentration of petroleum hydrocarbons has been exceeded in some areas, for example, in Cape Kharasavei and near the Arctic settlements Amderma and Dickson (GOIN 1996a). Pollution of water and bottom sediments in the hydrocarbon fields occurs from ejection of drilling slime, occasional and permanent leaks of fuel, lubricants, gas condensate and drilling and other liquids.

Habitat and community modification: Habitat and community modification was assessed as slight, with degradation of some habitats in localised areas (UNEP 2005). Modification of the highly vulnerable habitats in the Kara Sea basin has occurred as a result of rapid industrial development of the Russian Arctic region after the 1970s. The growth of oil and gas extraction is connected with the construction of ground and underwater cross-country pipelines, building of roads and sea ports, construction of artificial structures, noise and vibration that affect animals, and thermic impacts and change of habitat of migrant birds and fishes. Another threat to the habitats is posed by the mining and metallurgic industries. The immediate causes of modification of the neritic system, lagoons and estuaries are increased chemical pollution and oil spills.

The health of the LME may worsen in the future as a result of the rapid development of the oil and gas industry on the Arctic shelf, increased volume of oil and gas transport, as well as the accidental introduction of alien species with ship ballast water.

IV. Socioeconomic Conditions

Economic development associated with oil extraction, mining and fish farming will result in changes in diet and nutritional health and exposure to air-, water- and food-borne contaminants in northern peoples who rely on marine systems for food (AMAP 1998, Weller & Lange 1999, Freese 2000). Morbidity directly connected with chemical pollution is of particular concern in this LME. The biomagnification of persistent contaminants in Arctic food webs is affecting the health of Arctic inhabitants whose diet is based on species at high trophic levels in both marine and terrestrial ecosystems. Contaminant levels in some Arctic indigenous groups can be 10 to 20 times higher than in most temperate regions (AMAP 1997). Heavy metals, PAHs and other persistent toxic substances have a strong mutation effect in humans. (See Chukchi Sea LME for further information.)

V. Governance

Under the aegis of the PAME working group of the Arctic Council three LME pilot projects --West Bering Sea, Beaufort Sea (U.S. and Canada) and Barents Sea (Norway and Russia) are being undertaken. Climate change adaptability is a priority among the critical issues being addressed by the Arctic Council according to Norway's Minister of Foreign Affairs, Jonas Gahr Støre's speech to the Arctic Council Ministerial Meeting in Salekhard, Russia on 26 October 2006. The GEF CEO has endorsed two projects with the Russian Federation: Support to the National Programme of Action for the Protection of the Arctic Marine Environment, Tranche 1 (International Waters focal area project) and An Integrated Ecosystem Management Approach to Conserve Biodiversity and Minimize Habitat Fragmentation in Three Selected Model Areas in the Russian Arctic (ECORA), (a multi-focal area project).

References

AMAP (2002). Arctic Pollution 2002. Arctic Monitoring and Assessment Programme, 2002, Oslo, Norway.

AMAP (1997). Arctic Pollution Issues: A State of the Arctic Environment Report. Arctic Monitoring and Assessment Program, Oslo, Norway.

AMAP (1998). Wilson, S.J., Murray, J.L. and Huntington, H.P. (eds), Arctic Pollution Issues. Arctic Monitoring and Assessment Programme, Oslo, Norway.

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, in press.

Climate Prediction Center, National Weather Service (2007) Monitoring weather and climate www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/season.JFM.ao.gif

Freese, C.H. (2000). The Consumptive Use of Wild Species in the Arctic: Challenges and Opportunities for Ecological Sustainability. Report submitted to World Wildlife Fund, Arctic Programme, Toronto, Ontario, Canada.

GOIN (1996a). Annual of Marine Water Quality with Respect to Hydrochemical Indices for 1992. Obninsk, Russia. (In Russian).

GOIN (1996b). Annual of Marine Water Quality with Respect to Hydrochemical Indices for 1993. Obninsk, Russia. (In Russian).

GOIN (1996c). Annual of Marine Water Quality with Respect to Hydrochemical Indices for 1994. Obninsk, Russia. (In Russian).

GOIN (1996d). Annual of Marine Water Quality with Respect to Hydrochemical Indices for 1995. Obninsk, Russia. (In Russian).

Larsen, L.H., Palerud, R., Goodwin, H. and Sirenko, B. (1996). The marine invertebrates, fish and coastal zone features of the NSR area. INSROP Working Paper No 53, 42 p.

Layton, D., Vaughn, P., Yarrington, L., Maxwell, R., Preller, R., Bean, J., Carroll, J., Fuhrmann, M., Rigor, I. and Tucker, W. (1997). Transport of radionuclides in the Arctic seas, in: Layton, D., Edson, R. and Napier, B. (eds), Radionuclides in the Arctic Seas from the Former Soviet Union: Potential Health and Ecological Risks. Arctic Nuclear Waste Assessment Program (ANWAP). United States Office of Naval Research, Washington, D.C.

Lukianova, T.S. (2005) Estimation of bottom fauna biomass distribution in the Arctic Ocean. Proceedings of the XII Congress of the Russian Geographic Society, St.Petersburg, vol.5, pp. 124-129 (in Russian).

Pauly, D. and Swartz, W. (2007). Marine fish catches in northern Siberia (Russia, FAO Area 18). In: Zeller, D. and Pauly, D. (eds.) Reconstruction of marine fisheries catches for key countries and regions (1950-2004). Fisheries Centre Research Reports,15(2): 17-33.

Povinec, P.P., Osvath, I., Baxter, M.S., Ballestra, S., Carroll, J., Gastaud, J., Harms, I., Huynh-Ngoc, L., Liong Wee Kwong, L. and Pettersson, H. (1997). IAEA-MEL's contribution to the investigation of Kara Sea radioactivity and radiological assessment. Marine Pollution Bulletin 35:235-241.

Roshydromet (1997). Review of the Environmental Pollution of the Russian Federation for 1996. M. Roshydromet, Moscow, Russia. (In Russian).

Roshydromet (1998). Review of the Environmental Pollution of the Russian Federation for 1997. M. Roshydromet, Moscow, Russia. (In Russian).

Roshydromet (1999). Review of the Environmental Pollution of the Russian Federation for 1998. M. Roshydromet, Moscow, Russia. (In Russian).

Roshydromet (2000). Review of the Environmental Pollution of the Russian Federation for 1999. M. Roshydromet, Moscow, Russia. (In Russian).

Roshydromet (2001). Review of the Environmental Pollution of the Russian Federation for 2000. M. Roshydromet, Moscow, Russia. (In Russian).

Roshydromet (2002). Review of the Environmental Pollution of the Russian Federation for 2001. M. Roshydromet, Moscow, Russia. (In Russian).

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=58

UNEP (2005). Tsyban, A.V., Titova, G.D., Shchuka, S.A., Ranenko, V.V. and Izrael, Y.A. Russian Arctic, GIWA Regional Assessment 1a. University of Kalmar, Kalmar, Sweden. http://www.giwa.net/publications/r1a.phtml

Vetrov, A.A., and Romankevich, E.A. (2004) Carbon Cycle in the Russian Arctic Seas. Springer, Berlin etc., 331 pp.

Weller, G. and Lange, M. (1999). Impacts of Global Climate Change in the Arctic Regions, International Arctic Science Committee, Centre for Global Change and Arctic System Research, University of Alaska, Fairbanks, U.S.