MARINE FISH CATCHES IN NORTH SIBERIA (RUSSIA, FAO AREA 18)[1]

Daniel Pauly and Wilf Swartz

Fisheries Centre, University of British Columbia, Vancouver, BC; e-mail: d.pauly@fisheries.ubc.ca

ABSTRACT

The four Large Marine Ecosystems (Kara, Laptev, East Siberian and Chukchi Seas) that comprise Arctic Russia suffer from poor quality of fisheries data, and the FAO statistics for this area are too low to be credible. With the development of larger scale commercial fisheries in the region likely under global warming, it is imperative that past and current states of fisheries in the region are assessed, to provide a baseline with which to gauge any future development. Following an extensive online literature search, we were able to assemble a list of qualitative and quantitative descriptions of fisheries in the region (in particular catch statistics for anadromous *Coregonus* species from the 1980s to the early 1990s), from which we have generated time series of estimated catches for the region for the period from 1950 to 2004. We estimate that fisheries catches in the Kara Sea underwent a decline from around 15,000 tonnes in 1950 to an average of about 4,000 in the 1980s, and that they continue to decline, though at a lower rate. On the other hand, we had no basis for inferring a decline in the other three ecosystems. Instead, we estimated average catches in both the Laptev and East Siberian Seas to be around 4,000 tonnes·year^{-1}, and a catch of 100 tonnes·year^{-1} for the Russian section of the Chukchi Sea. We look forward to comments on these estimates, which, although tentative, are likely to be more accurate than the figures they are meant to replace.

INTRODUCTION

The Arctic, generally defined as the area within the 10°C summer isotherm, has about 4 million human inhabitants. FAO Fisheries Statistical Area 18, ranging from Novaya Zemlya in the east to the Hudson Bay in the west, is comprised of the Siberian coast (Russia), the Arctic coasts of Alaska (USA) and Canada, or about two-third of the entire Arctic region. FAO Area 18 is also an area with low fish catches and low fishery productivity. This is particularly the case along the Siberian coast, for which FAO reports catches which are too low to be credible (see www.fao.org), even considering the remoteness and harshness of the environment, which limits the development of fisheries. This may be due, in part, to Russia not joining FAO as a member until 2006. While the former USSR participated in the formation of the FAO, and had observer status, it never formally joined the organization.

This situation is likely to change under global warming, as the entire region is likely to become more accessible by sea, especially for fishing vessels. Hence, the development of fisheries in the region appears likely, if not inevitable. Thus, there is now an urgent need to establish a baseline against which future development can be assessed. Moreover, the assemblage of realistic historic fisheries catch time series for this part of the world will enable coverage of four Large Marine Ecosystems (LMEs), the Kara, Laptev, East Siberian and Chukchi Seas, for which hitherto, no reasonable fishery data have been available.

However, this report being a first attempt – at least in the English language – to establish a time series of fisheries catches for this part of the world, it must be stressed that it was written primarily as a starting point for our Russian and other colleagues with better data to work from (or against, as the case might be). We are under no illusion as to the quality of the data we present. We only believe that they are less wrong than what is available to date (mainly nothing), a theme to which we shall return in the Discussion.

An extensive online literature search was conducted, but yielded comparatively few sources of information on Russian Arctic fisheries in English, and even fewer in other languages that we master (French, German, Spanish and Japanese). Numerous references were found in which "fishing" by the indigenous peoples of Northern Siberia was mentioned (see also www.raipon.org), notably by anthropologists, but very few of

[1] Cite as: Pauly, D. and Swartz, W. 2007. Marine fish catches in North Siberia (Russia, FAO Area 18). p. 17-33. *In*: Zeller, D. and Pauly, D. (eds.) Reconstruction of marine fisheries catches for key countries and regions (1950-2005). Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

them provided quantitative information. This is, regrettably, also the case with anthropologists working in warmer climes (Pauly 2006).

However, one source of data was found which proved to be extremely useful, the working papers of the International Northern Sea Route Programme (INSROP) conducted from 1993 to 1999. This project involved scientists from Norway, Russia, Japan and other countries, and explored the implications of possible operation of a regular shipping lane from Northern Europe to Japan and beyond - the legendary Northeast Passage – and its potential impact on the Siberian marine ecosystems (see www.fni.no/insrop/).

The project also studied the potential effect of a Northern Sea Route (NSR) on marine mammals (Wiig *et al.* 1996, Belikov *et al.* 1998, Thomassen *et al.* 1999), seabirds (Gavrilo *et al.* 1998) and invertebrates (Larsen *et al.* 1995). Significant in the present context, the project also included a volume devoted mainly to fisheries (Larsen *et al.* 1996), which we used extensively here, complemented by a smattering of heterogeneous sources.

The fisheries catch data in Larsen *et al.* (1996), also presented in the atlas of Brude *et al.* (1998), were obtained from the State Institute of Lake and River Fisheries (GOSNIORKH), then the relevant line agency in Russia. These data pertain almost exclusively to catches made with fixed and drifting gill nets, drag seines, trap nets and under-ice nets, which are all small-scale, artisanal gears. There is another management body, the National Administration for Fishery Enforcement, Resource Restoration, and Fishing Regulation (GLAVRYBVOD), which "regulates the industrial harvest of fish, marine mammals and plants in Russia's internal waters, on the continental shelf and in the two-hundred-mile Exclusive Economic Zone" (Newell 2004, p. xvi), but its relationship – if any – with GOSNIORKH is not clear.

The available data are highly fragmented and could be vastly improved by more complete information becoming available from present institutional arrangements and/or from colleagues working on these fisheries and with these institutions. Indeed, we sincerely hope that our Russian and other colleagues with first-hand knowledge of the Arctic will correct and improve our view of their fisheries and ecosystems, and the figures presented here.

In this report, the available fisheries data and our estimates are presented by Large Marine Ecosystems, from east to west, the Kara Sea, the Laptev Sea, the East Siberian Sea and the Chukchi Sea (Table 1).

Table 1. Oceanographic features of the Kara, Laptev, East Siberian and Chukchi Seas Large Marine Ecosystems relevant to their fisheries.

Property (Units)	Kara Sea	Laptev Sea	E. Siberian Sea	Chukchi Sea
Area (km²)	797,171	499,039	926,721	556,899
Mean depth (m)	127	578	1350	1004
Ice free shelf area (km²)	948,120	623,356	370,178	455,197*
Inshore fishing area (km²)	272,590	125,348	131,891	38,445*
Major river systems [from west to east]	Ob, Yenisei, Pyasina, Taimyrskaya	Khatanga, Lena, Yana	Indigirka, Kolyma	None
Primary production ($mgC \cdot m^{-2} \cdot day^{-1}$)	410	479	182	382

*ice free shelf and inshore fishing areas for the Chukchi Sea denote the areas that fall within the Russian Exclusive Economic Zone

THE FISHERIES OF THE KARA SEA

The Kara Sea is bounded to the west by the Novaya Zemlya islands and to the east by the Severnaya Zemlya islands (Figure 1). Its oceanography is complex (see e.g., Fetzer *et al.* 2002). Being adjacent to the Barents Sea, the Kara Sea benefits from the occasional intrusion of 'warm' water and the 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 as species-poor as the Laptev and East Siberian Seas further to the east (Table 2). Also, the bulk of the fisheries catches is contributed by the same group, which also accounts for the bulk of the catch in the Laptev and East Siberian seas, that is, fishes of the genus *Coregonus*, (Subfamiliy Coregoninae, Family Salmonidae; see www.fishbase.org), collectively known as 'whitefishes', or 'sig' in Russian. Larsen *et al.* (1996) wrote that catches of "eight species of [the genus *Coregonus*] have been recorded, from which 6 species make up 70 to 90 % of the total recorded landings from the area". Based on this, we will assume that the catches of fish other than coregonids in the Kara Sea constitute 20% of total catches.

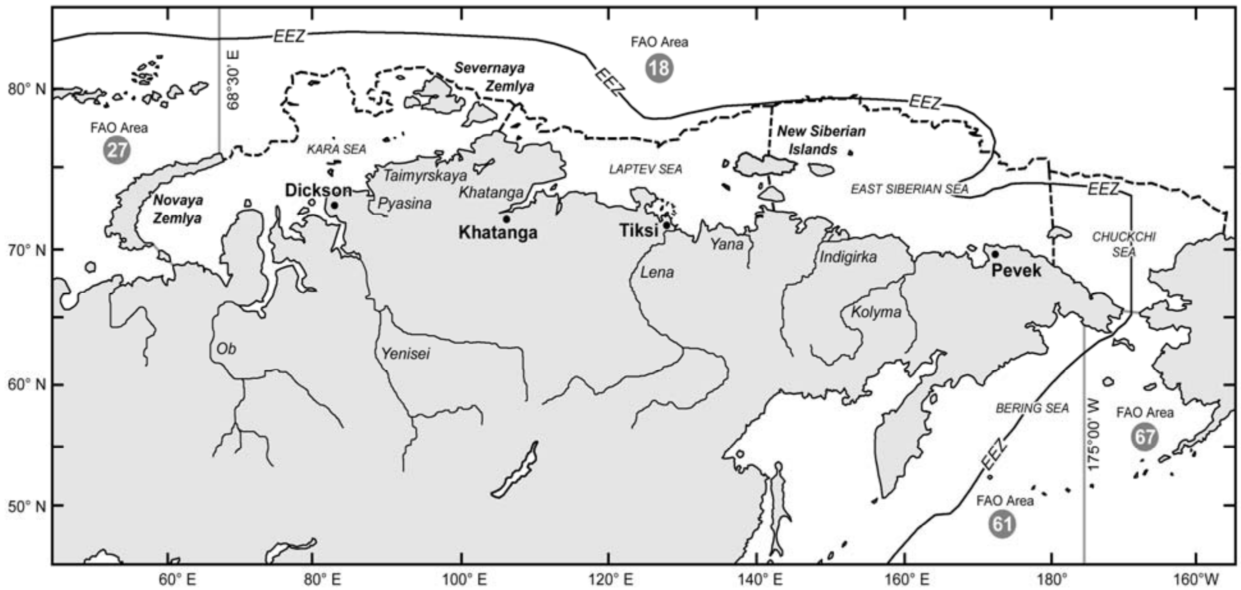

Figure 1. Map of Northern Siberia (Russian Federation), showing the extent of the Kara, Laptev, East Siberian and Chukchi Seas Large Marine Ecosystems, major rivers and their estuaries, and other features discussed in the text.

Coregonids are caught in the lower reaches of rivers, in the estuaries and in the surrounding coastal areas, notably in the giant estuaries of the rivers Ob and Yenisei. Slavin (1964) writes "the waters of the Ob are rich in fish. Up to 30,000 tons (66 millions lbs) are now landed there annually, including such rare species as white salmon and sturgeon."

Unfortunately, with the exception of *Coregonus muksun* for which scattered pre-1950 data exist, depicting elevated catches from the Yenisei River from 1934 to 1937 and from 1940 to 1943, the time series of catch data, from Larsen et al. (1996), based on reports from GOSNIORKH, cover only the years for 1980 to 1994 for the Ob Bay and 1989/1991 to 1994 for other tributaries. All four tributaries show a clear declining trend around a mean of 225 tonnes•year-1, which, extrapolated backward, would correspond to a coregonid catch of about 12,500 tonnes in 1950.

Moreover, Vilchek et al. (1996) writes that "The total catch in the Ob' in the late 1930s reached 34,140 tons or more, 22, 950 tons being from the lower reaches of the Ob'. By the mid-1940s the total catch in the Ob' basin was at a record level – 80, 400 tons; in the early 1950s it began to drop to 50, 000-55, 000 tons. Now the catches in the Ob' Gulf and the lower Ob' amount to only 150.8 and 374.5 tons, respectively. A similar picture can be observed in virtually all the rivers and seas of the Arctic".

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Acantholumpenus mackayi (Pighead prickleback)	√			√	North Pacific from Japan to the Okhotsk and Bering seas, and in Arctic Ocean. Some fisheries.
Acipenser baeri (Longnose Siberian sturgeon)	√	√	√		Anadromous. Found in Siberian rivers Ob, Irtysh, Yenisei, Lena, and Kolyma. Highly commercial.
Ammodytes hexapterus (Pacific sand lance)		√	√	√	Arctic and Pacific from Arctic Alaska to the Sea of Japan. Some commercial fisheries, sometimes targeted for fishmeal.
Anarrhichthys ocellatus (Wolf-eel)		√	√	√	In North Pacific from Sea of Okhotsk and Sea of Japan to the Aleutian chain and California. Minor commercial fisheries.
Anisarchus medius (Stout eelblenny)		√	√	√	North Pacific, Northwest Atlantic and Arctic. Some fisheries.
Arctogadus borisovi (East Siberian cod)		√	√	√	Arctic and North Atlantic including coasts of Siberia. Targeted for subsistence fisheries.
Arctogadus glacialis (Arctic cod)		√	√	√	Widely distributed in western part of Arctic basin. Minor commercial fisheries.
Artediellus scaber (Hamecon)	√			√	Southeastern part of Barents Sea to northern part of Bering Sea.
Aspidophoroides bartoni (Aleutian alligatorfish)				√	North Pacific and Arctic Ocean.
Bathymaster signatus (Searcher)		√	√	√	East Siberian Sea to eastern Kamchatka. From the Sea of Okhotsk to Washington, USA. Some fisheries.
Boreogadus saida (Polar cod)	√	√	√	√	Circumpolar in the Arctic. Highly commercial.
Careproctus reinhardti (Sea tadpole)	√	√			Kara and Laptev seas, Faroe-Shetland Channel to the Norwegian Sea, Spitsbergen, Murmansk and throughout Barents Sea.
Careproctus solidus		√			Laptev Sea.
Clupea pallasii (Pacific herring)	√	√	√	√	White Sea to Ob Bay in the Arctic and eastern Kamchatka to the Aleutian. Highly commercial.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Coregonus autumnalis (Arctic cisco)	√ *	√ *	√ *	√	Russian name: **омуль**. Anadromous, in Barents Sea and coasts and rivers of Siberia. Some commercial fisheries.
Coregonus laurettae (Bering cisco)	√ *	√ *	√ *	√	Russian name: **беринговоморский омуль**. Anadromous. From Alaska to Chukotsk and Kamchatka regions of Siberia. Some subsistence fisheries.
Coregonus muksun (Muksun)	√	√	√		Russian name: **муксун**. Anadromous. Low-salinity portions of the Arctic Ocean. From Kara River to Kolyma River. Highly commercial.
Coregonus nasus (Broad whitefish)	√ *	√ *	√ *	√	Russian name: **Чир**. Anadromous. In the Arctic basin east of Pechora River. Targeted for commercial and recreational fisheries.
Coregonus pidschian (Humpback whitefish)	√	√	√	√	Russian name: **сиг-пыжьян**. Anadromous. Distribution ranges from Sweden to the western Bering Sea and the Sea of Okhotsk. Some commercial fisheries.
Coregonus sardinella (Sardine cisco)	√ *	√ *	√ *	√	Russian name: **ряпушка сибирская**. Anadromous. From Bering Sea to Kolyma and Kara Rivers. Some commercial fisheries.
Cyclopteropsis jordani (Smooth lumpfish)	√				Kara Sea to Baffin Island at Admiralty Inlet, Canada.
Eleginus gracilis (Saffron cod)				√	North Pacific from Yellow Sea to Alaska and from Cape Lisburne, Chukchi Sea to Dease Strait. Highly commercial.
Eleginus nawaga (Navaga)	√	√	√	√	White, Barents and Kara seas from Kola Bay to Ob Bay. Some commercial fisheries.
Eumesogrammus praecisus (Fourline snakeblenny)				√	Sea of Okhotsk, Bering Sea and Arctic Alaska in the North Pacific.
Eumicrotremus andriashevi (Pimpled lumpsucker)				√	Northeastern Chukchi Sea to eastern Bering Sea.
Eumicrotremus derjugini (Leatherfin lumpsucker)	√	√	√	√	Arctic Ocean, Barents Sea, Franz Josef Land, Spitsbergen, eastern Greenland, Kara, Laptev, Siberian and Chukchi seas and the Sea of Okhotsk.
Eumicrotremus orbis (Pacific spiny lumpsucker)				√	Chukchi Sea and Sea of Okhotsk to Muroran, Hokkaido (Japan), Amchitka Island in the Aleutian chain and Puget Sound, Washington, USA. Some fisheries.
Gymnelus andersoni	√	√			Spitsbergen, north, central and eastern parts of the Barents Sea off Nova Zemlya and in the Kara Sea; in the Shokalskii Straight and western part of the Laptev Sea.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Gymnelus barsukovi		√	√	√	Western Laptev Sea to the Bering Strait; Canadian Arctic to Ungava Bay.
Gymnelus esipovi	√				Arctic Ocean.
Gymnelus hemifasciatus (Bigeye unernak)	√				Kara Sea east to Canada and in the Bering and Okhotsk seas.
Gymnelus platycephalus				√	Northern Bering Sea and Chukchi Sea.
Glymnocanthus pistilliger (Threaded sculpin)				√	Sea of Japan and the Sea of Okhotsk to the Chukchi Peninsula and Norton Sound, Alaska to Kiska Island in the Aleutian chain and southeastern Alaska. Some fisheries.
Gymnocanthus tricuspis (Arctic staghorn sculpin)	√	√	√	√	Eastern coasts of Greenland, Iceland, northern coast of Norway to White Sea and throughout Barents Sea to Spitsbergen and Novaya Zemlya.
Hemilepidotus papilio (Butterfly sculpin)				√	From Chukchi Sea in the Arctic to Sea of Okhotsk and the Aleutian in the North Pacific.
Hemilepidotus zapus (Longfin Irish lord)				√	Northern Kuril Islands, Bering Sea and Aleutian Islands, Alaska.
Hexagrammos stelleri (Whitespotted greenling)				√	Peter the Great Bay, Russia and the Sea of Japan to Cape Lisburne in the Chukchi Sea, Unimak Island in the Aleutian chain and Oregon, USA. Minor commercial and game fisheries.
Hippoglossoides robustus (Bering flounder)				√	Hokkaido, Japan and the Sea of Okhotsk north to northeast of Cape Lisburne, south to northwest of Akutan Island, Aleutian chain, Alaska.
Hippoglossoides stenolepis (Pacific halibut)				√	Hokkaido, Japan and the Sea of Okhotsk to the southern Chukchi Sea and Point Camalu, Baja California, Mexico. Highly commercial.
Icelus bicornis (Twohorn sculpin)	√	√	√	√	Greenland, Iceland, Jan Mayen, Spitsbergen, Barents and Kara seas, Bohuslän in Norway.
Icelus spatula (Spatulate sculpin)	√	√	√	√	Arctic Ocean to Ungava Bay, Gulf of St. Lawrence in Canada and Greenland; Kara Sea and southeastern part of Barents Sea. Some fisheries.
Lampetra camtschatica (Arctic lamprey)				√	Anadromous. Range from the Siberian coast to Anderson River in Canada. Some commercial fisheries.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Leptagonus decagonus (Atlantic poacher)	√				Arctic Ocean to Grand Bank and Gulf of St. Lawrence, Canada in western Atlantic; Spitsbergen and Finmarken coasts in Norway to White Sea, Barents Sea and Kara Sea; also Iceland and Greenland, and Okhotsk and Bering Seas.
Leptoclinus maculatus (Daubed shanny)				√	Arctic Alaska to Sea of Okhotsk, northern Sea of Japan, Unalaska Island in the Aleutian chain and Puget Sound, Washington, USA.
Limanda aspera (Yellowfin sole)				√	Korea and the Sea of Japan to the Sea of Okhotsk, Bering Sea, and Barkley Sound, Canada. Highly commercial.
Liopsetta glacialis (Arctic flounder)	√	√	√	√	Barents and White Sea to the coasts of Siberia and the Bering Seas to Bristol Bay, Alaska and the northern Sea of Okhotsk. Minor commercial fisheries.
Liparis gibbus (Variegated snailfish)	√	√	√	√	Arctic, North Pacific and North Atlantic.
Lumpenus fabricii (Sledner eelblenny)	√	√	√	√	Circumpolar.
Lycenchelys kolthoffi	√	√	√		North of Novaya Zemlya and northern part of Kara Sea and in Greenland, Hudson Strait, north of Iceland, Faroe Islands, Svalbard and Laptev Sea.
Lycenchelys muraena	√				Norwegian Sea, Kara Sea and Northwest- and East Greenland.
Lycodes eudipleurostictus (Doubleline eelpout)	√	√	√	√	Arctic Alaska, Smith Sound, northwest Greenland, Kara Sea, Barents Sea, Spitsbergen, Norway, Iceland, northeast Greenland, and western Greenland.
Lycodes frigidus		√	√	√	Northern Laptev Sea, East Siberian and Chukchi seas.
Lycodes jugoricus (Shulupaoluk)	√	√	√	√	White Sea and southern parts of the Kara Sea; Laptev Sea, New Siberian Isles, Near mouth of the Kolyma River and near Herschel Island in the Beaufort Sea.
Lycodes mucosus (Saddled eelpout)				√	From Sea of Okhotsk to Arctic Canada.
Lycodes palearis (Wattled eelpout)				√	Point Hope, Alaska in the Chukchi Sea to Peter the Great Bay (Sea of Japan), Agattu Island (Aleutian chain) and Oregon, USA.
Lycodes pallidus (Pale eelpout)	√	√	√	√	Kara Sea, western part of Laptev Sea, Beaufort Sea and Arctic Canada.
Lycodes polaris (Canadian eelpout)	√	√	√	√	Nearly circumpolar along Arctic coasts of Asia and North America.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Lycodes raridens (Marbled eelpout)				√	Sakhalin, Russia and the Okhotsk Sea to Bristol Bay and Alaskan Arctic.
Lycodes reticulates (Arctic eelpout)	√	√			West of Boothia Peninsula (Northwest Territories, Canada) and the northern parts of Kara and Laptev Seas.
Lycodes rossi (Threespot eelpout)	√	√	√	√	Kara Sea to Beaufort Sea.
Lycodes sagittarius (Archer eelpout)	√	√	√	√	Kara Sea to Beaufort Seas. May occur in the Barents Sea.
Lycodes seminudus (Longear eelpout)	√	√	√	√	Franklin Bay, North Western Territory and Alaska; also the Kara and Beaufort seas.
Lycodes turneri (Polar eelpout)	√			√	Arctic reaches of Canada to northern Gulf of Lawrence in Canada, Alaskan Arctic to the eastern Bering Sea.
Mallotus villosus (Capelin)	√	√	√	√	Circumpolar in the Arctic.
Megalocottus platycephalus (Belligerent sculpin)				√	North Pacific.
Myoxocephalus jaok (Plain sculpin)				√	Northern Sea of Japan to the Bering Sea and southeastern Alaska.
Myoxocephalus scorpius (Shorthorn sculpin)	√	√	√	√	Greenland, Jan Mayen Island, Iceland to Bay of Biscay; North and Baltic Seas, Spitsbergen and southern part of Barents Sea; throughout the Arctic Ocean.
Myoxocephalus stelleri (Steller's sculpin)				√	Northwest Pacific from northern Japan to the western Bering Sea.
Myoxocephalus verrucosus (Warty sculpin)		√	√	√	Laptev Sea and Chukchi Sea to the Kamchatka Gulf, Adak Island in the Aleutian chain and British Columbia, Canada.
Occella dodecaedron (Bering poacher)				√	Kotzebue Sound to the northern Sea of Japan, Sea of Okhotsk and Akun Island in the Aleutian chain and adjacent Arctic, including Gulf of Alaska.
Oncorhynchus gorbuscha (Pink salmon)				√	Anadromous. From Northwest Territories (Canada) to southern California, Bering and Okhotsk Seas. Highly commercial.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Oncorhynchus keta (Chum salmon)		√	√	√	Anadromous. Korea, Japan, Okhotsk and Bering Sea, Arctic Alaska south to San Diego, California, USA. Highly commercial.
Oncorhynchus kisutch (Coho salmon)				√	Anadyr River in Russia south towards Hokkaido, and from Point Hope in Alaska southwards to Chamalu Bay in Baja California, Mexico. Highly commercial.
Oncorhynchus nerka (Sockeye salmon)				√	Anadromous. Northern Japan to Bering Sea and to Los Angeles, California, USA. Highly commercial.
Oncorhynchus tshawytscha (Chinook salmon)				√	Anadromous. Alaska to Ventura River, California, USA. Bering Sea and Sea of Okhotsk, Hokkaido; Coppermine River in the Arctic. Highly commercial.
Osmerus mordax (Arctic rainbow smelt)	√	√	√	√	Anadromous. North Korea and the Sea of Okhotsk, British Columbia, north to the Bering Sea and the Arctic. Also known from the White Sea. Some commercial fisheries.
Platichthys stellatus (Starry flounder)		√	√	√	Catadromous. Korea and southern Japan, the Bering Strait and Arctic Alaska to Northwest Territories, Canada; also southern California, USA. Commercial fisheries.
Pleuronectes quadrituberculatus (Alaska plaice)				√	Peter the Great Bay to Point Hope in the Chukchi Sea south to Unalaska Island and east to Kayak Island in southeast Alaska. Some commercial fisheries.
Podothecus acipenserinus (Sturgeon poacher)				√	Western Bering Sea south of Cape Navarin to Commander Islands, and Pacific Ocean to Sea of Okhotsk off southwestern Kamchatka and northern Kuril Islands; eastern Bering Sea and Aleutian Islands from Attu Island to northern California.
Pungitius pungitius (Ninespine stickleback)				√	Anadromous. Circumarctic. Some subsistence fisheries.
Reinhardtius hippoglossoides (Greenland halibut)				√	Sea of Japan off Honshu north to Shishmaref, Alaska in the Chukchi Sea, throughout the Aleutian Islands, to northern Baja California, Mexico. N.E. USA to Spitsbergen (Svalbard Islands) and the Barents Sea. Highly commercial.
Salvelinus alpinus (Charr)			√	√	Anadromous. Arctic. Minor commercial fisheries.
Salvelinus malma (Dolly varden)			√**	√	Anadromous. Distributed over a large area of the Arctic coast toward the south of the Bering Strait.** Some commercial fisheries.
Salvelinus taranetzi (Taranets)			√**	√**	Anadromous. Widely distributed in the eastern sector of the Arctic.**
Somniosus pacificus (Pacific sleeper shark)		√	√	√	Japan and along the Siberian coast to the Bering Sea, southern California (USA), and Baja California, Mexico.

Table 2. Marine fish species (English common names) occurrence in the Kara, Laptev (Lapt.), East Siberian (E.S.) and Chukchi Seas (Chuk.) Large Marine Ecosystems. Unless stated otherwise, all information based on FishBase (www.fishbase.org).

Species	Kara	Lapt.	E.S.	Chuk.	Comments
Theragra chalcogramma (Alaska pollock)				√	From Kivalina, Alaska, to the southern Sea of Japan and to Carmel, California, USA.
Triglopsis quadricornis (Fourhorn sculpin)		√	√	√	North Atlantic and Arctic. Some subsistence fisheries.
Ulcina olrikii (Arctic alligatorfish)	√	√	√	√	Arctic Ocean to Western Atlantic (Hudson Bay and Labrador, Canada, and Greenland). Also from Barents to Chukchi Sea and Anadyr Gulf.

*based on reported catches in Larsen *et al*. (1996). **based on Glubokowsky and Cheresenev (1981).

We thus have four independent sources of evidence that catches of coregonids in the estuaries and lower reaches of rivers of the Kara Sea were higher in the past.

1. Slavin (1964) wrote of a catch of 30,000 tonnes·year^{-1}, presumably pertaining to the late 1950s early 1960s, which is nearly ten time the catches in the 1980s;
2. The catch data of GOSNIORKH for *Coregonus muksun* for the lower Yenisei River, from 1934 to 1943 (360-780 tonnes·year^{-1}), which is about twice the mean catch for this species in the 1980s;
3. The backward extrapolation of the GOSNIORKH data, which yields catches estimate for 1950 three to four time higher than the mean catch for the 1980s (with consistent trends for Ob Bay, lower Yenisei, Pyasina and Taimyskaya rivers examined separately); and
4. The quote from Vilcheck *et al.* (1996), which suggests that pre-1950 catches would have been over hundred times the catches in the 1990s.

From this evidence, we can assume that (3) would lead to an estimate for 1950 that is both realistic and conservative, and which can thus serve as an anchor point for interpolation between 1950 and 1980 (for Ob Bay) and up to 1991 for the other three tributaries. Indeed, we believe such values represent an underestimate of the earlier fisheries catch in the region. Under the Soviet regime, Siberia, including its coastal regions, experienced a series of human population booms. First, via the dispatching of criminals and political prisoners to camps from 1929 onward, followed by German and other prisoners of war from 1942 onwards, and finally followed by the workers needed for massive industrialization projects in the region during the 1960s and 1970s. With the collapse of the Soviet Union and the loss of subsidies from the central government, Siberia experienced a large emigration of non-indigenous populations through the 1990s, with the total population of the Russian 'North' declining by more than 14 percent between 1989 and 2002 (Hill 2004). With such drastic changes in the local human population, the fisheries catch from 1950 to 1980 could easily have exceeded our estimates.

For the period from 1995 to 2004, after the year of last available data, we assumed, optimistically, a decline that proceeds at half the rate estimated for the earlier period.

Complementing the reported catches of coregonids, we added small catches to accommodate other species, for which we found the following observations:

"Until 1968 longnose Siberian sturgeon (*Acipenser baeri*) was caught in the Ob Bay and the lower Yenisei [R]iver. The annual yield in the 1960's was approximately 300 tons, until species became protected in Ob Bay in 1968. The sturgeon is presently caught in the lower Yenisei, with a catch of 31 tons recorded in 1994. For comparison, the catch of sturgeon in Yenisei was 398 tons in 1957, gradually falling to 56 tons in 1966. [...] The decrease in sturgeon catches is claimed to have arisen from a combination of several factors; construction of dams, pollution and overfishing. Today whitefish are more important than sturgeon in the fisheries in the Yenisei River and estuary" (Larsen *et al.* 1996).

The state of the sturgeon fisheries during the 1990s is also described as follows:

"Sturgeon resources during the last 10 years have been decreasing and are now in a critical state. The reasons for the reduction of Siberian sturgeon resources are: irrational commercial fishing; reduction in natural production as the result of hydro-electric construction (dams for the Novosibirsk and Bukhtarmin hydroelectric stations cut off 40% of the spawning habitats of sturgeon in the Ob River basin); and oil pollution in the lower flow of the Ob River" (Ministry of Natural Resources 1998).

Another fishery in the Kara Sea is an ice fishery for smelt (*Osmerus mordax*): "No data are available on the landings of smelt in the Yenisei River, but as much of the fish is caught for direct consumption by private persons (non-fishermen), the landings from this seasonal fishery would hardly appear in any statistics. However, in Ob Bay, the recorded catch of smelt has varied from 516 tons in 1989 to 28 tons in 1991" (Larsen *et al.* 1996).

Based on the above statements, we have estimated the historical catch of *A. baeri* in the Kara Sea to be 300 tonnes·year^{-1} from 1961 to 1967, 56 tonnes·year^{-1} following the closure of Ob Bay in 1968 and 31 tonnes·year^{-1} after 1994, the year of the last reported catch data. Furthermore, we estimated higher catches in the 1950s (500 tonnes·year^{-1}) to accommodate the reported catch from the Yenisei River in 1957. As for the catch estimates of *O. mordax*, in the absence of additional information, we took the mean of the two reported figures as our estimates for all years except 1989 and 1991 (Table 3).

Table 3. Catches (tonnes) from the Kara, Laptev, East Siberian and Chukchi Seas Large Marine Ecosystems (LME) from 1950 to 2004. Bold numbers denote reported catch; italics mark estimated catch; regular font numbers indicate reported catches limited to some rivers and estuaries (for coregonids, the reported catches were from: Ob Bay 1980-1994 except 1983, lower Yenisei 1990-1994, lower Pyasina 1989-1994, lower Taimyrskaya 1991 to 1994, Khatanga Bay 1981-1990, Lena 1981-1990, Yana 1982-1991, Indigirka 1981-1990, and Kolyma 1981-1990). Estimated coregonid catches for the Kara Sea were extrapolated linearly for each species and estuary/river back to the total catch of 12,500 tonnes in 1950 and for 1995 to 2004 using half the rate of decline used in the estimate of 1950 to 1980 (or up to 1991 for Yenisei, Pyasina and Taimyrskaya). For the Laptev and East Siberian Seas, coregonid catches were estimated as a mean of the first three years of the reported catches (for older estimates) or the last three years of the reported catches (for recent estimates). C.n = *Coregonus nasus*, C.a = *C. autumnalis*, C.m = *C. muksun*, C.s = *C. sardinella*, C.l = *C. lavaretus*, A.b = *Acipenser baeri*, O.m = *Osmerus mordax*, Oth = others.

Year	Kara Sea								Laptev Sea						E. Siberian Sea						Chuk. Sea
	C.n	C.a	C.m	C.s	C.l	A.b	O.m	Oth	C.n	C.a	C.m	C.s	C.l	Oth	C.n	C.a	C.m	C.s	C.l	Oth	Oth
1950	*1073*	*1006*	*2284*	*6240*	*1897*	*500*	*272*	*1728*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1951	*1052*	*985*	*2239*	*6136*	*1863*	*500*	*272*	*1683*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1952	*1032*	*964*	*2194*	*6033*	*1830*	*500*	*272*	*1639*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1953	*1011*	*943*	*2149*	*5930*	*1796*	*500*	*272*	*1594*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1954	*991*	*922*	*2104*	*5827*	*1762*	*500*	*272*	*1549*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1955	*971*	*901*	*2059*	*5724*	*1728*	*500*	*272*	*1505*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1956	*950*	*880*	*2014*	*5621*	*1695*	*500*	*272*	*1460*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1957	*930*	*858*	*1969*	*5518*	*1661*	*500*	*272*	*1415*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1958	*909*	*837*	*1923*	*5415*	*1627*	*500*	*272*	*1370*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1959	*889*	*816*	*1878*	*5312*	*1594*	*500*	*272*	*1326*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1960	*869*	*795*	*1833*	*5209*	*1560*	*300*	*272*	*1481*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1961	*848*	*774*	*1788*	*5106*	*1526*	*300*	*272*	*1436*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1962	*828*	*753*	*1743*	*5003*	*1492*	*300*	*272*	*1392*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1963	*807*	*731*	*1698*	*4900*	*1459*	*300*	*272*	*1347*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1964	*787*	*710*	*1653*	*4797*	*1425*	*300*	*272*	*1302*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1965	*766*	*689*	*1608*	*4694*	*1391*	*300*	*272*	*1258*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1966	*746*	*668*	*1563*	*4591*	*1358*	*300*	*272*	*1213*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1967	*726*	*647*	*1517*	*4488*	*1324*	*300*	*272*	*1168*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1968	*705*	*626*	*1472*	*4385*	*1290*	*56*	*272*	*1368*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1969	*685*	*604*	*1427*	*4282*	*1256*	*56*	*272*	*1323*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1970	*664*	*583*	*1382*	*4179*	*1223*	*56*	*272*	*1278*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1971	*644*	*562*	*1337*	*4076*	*1189*	*56*	*272*	*1234*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1972	*624*	*541*	*1292*	*3973*	*1155*	*56*	*272*	*1189*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1973	*603*	*520*	*1247*	*3870*	*1122*	*56*	*272*	*1144*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1974	*583*	*499*	*1202*	*3767*	*1088*	*56*	*272*	*1099*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1975	*562*	*478*	*1157*	*3663*	*1054*	*56*	*272*	*1055*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1976	*542*	*456*	*1111*	*3560*	*1020*	*56*	*272*	*1010*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1977	*521*	*435*	*1066*	*3457*	*987*	*56*	*272*	*965*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1978	*501*	*414*	*1021*	*3354*	*953*	*56*	*272*	*921*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*

Table 3. Catches (tonnes) from the Kara, Laptev, East Siberian and Chukchi Seas Large Marine Ecosystems (LME) from 1950 to 2004. Bold numbers denote reported catch; italics mark estimated catch; regular font numbers indicate reported catches limited to some rivers and estuaries (for coregonids, the reported catches were from: Ob Bay 1980-1994 except 1983, lower Yenisei 1990-1994, lower Pyasina 1989-1994, lower Taimyrskaya 1991 to 1994, Khatanga Bay 1981-1990, Lena 1981-1990, Yana 1982-1991, Indigirka 1981-1990, and Kolyma 1981-1990). Estimated coregonid catches for the Kara Sea were extrapolated linearly for each species and estuary/river back to the total catch of 12,500 tonnes in 1950 and for 1995 to 2004 using half the rate of decline used in the estimate of 1950 to 1980 (or up to 1991 for Yenisei, Pyasina and Taimyrskaya). For the Laptev and East Siberian Seas, coregonid catches were estimated as a mean of the first three years of the reported catches (for older estimates) or the last three years of the reported catches (for recent estimates). C.n = *Coregonus nasus*, C.a = *C. autumnalis*, C.m = *C. muksun*, C.s = *C. sardinella*, C.l = *C. lavaretus*, A.b = *Acipenser baeri*, O.m = *Osmerus mordax*, Oth = others.

Year	Kara Sea								Laptev Sea						E. Siberian Sea						Chuk. Sea
	C.n	C.a	C.m	C.s	C.l	A.b	O.m	Oth	C.n	C.a	C.m	C.s	C.l	Oth	C.n	C.a	C.m	C.s	C.l	Oth	Oth
1979	*481*	*393*	*976*	*3251*	*919*	*56*	*272*	*876*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1980	460	372	931	3148	886	*56*	*272*	*831*	*240*	*816*	*411*	*1184*	*205*	*857*	*216*	*356*	*53*	*805*	*262*	*508*	*100*
1981	296	351	950	1709	708	*56*	*272*	*475*	233	1019	257	1192	156	*857*	**185**	**314**	**42**	**765**	**368**	*502*	*100*
1982	249	329	803	1682	669	*56*	*272*	*418*	**233**	**632**	**467**	**1139**	**236**	*812*	**331**	**346**	**36**	**829**	**200**	*523*	*100*
1983	265	308	800	1652	632	*56*	*272*	*404*	**316**	**716**	**509**	**1274**	**235**	*915*	**133**	**409**	**82**	**821**	**217**	*499*	*100*
1984	295	287	765	1740	594	*56*	*272*	*408*	**151**	**910**	**392**	**1195**	**165**	*844*	**167**	**596**	**80**	**917**	**299**	*618*	*100*
1985	222	266	682	1478	557	*56*	*272*	*313*	**258**	**970**	**511**	**1421**	**212**	*1012*	**645**	**483**	**51**	**1020**	**280**	*744*	*100*
1986	244	245	632	1092	542	*56*	*272*	*223*	**172**	**877**	**487**	**1429**	**112**	*923*	**690**	**380**	**58**	**1431**	**785**	*1003*	*100*
1987	261	224	653	1365	482	*56*	*272*	*269*	**237**	**852**	**503**	**1240**	**185**	*905*	**425**	**318**	**104**	**1341**	**293**	*744*	*100*
1988	182	202	546	1058	439	*56*	*272*	*158*	**223**	**625**	**695**	**1145**	**195**	*865*	**339**	**247**	**76**	**1432**	**338**	*730*	*100*
1989	188	181	505	1288	407	*56*	**516**	*0*	**260**	**519**	**618**	**1107**	**188**	*808*	**505**	**122**	**122**	**1713**	**451**	*874*	*100*
1990	178	175	456	1285	408	*56*	*272*	*173*	**258**	**531**	**618**	**922**	**142**	*741*	**357**	**428**	**155**	**1729**	**289**	*887*	*100*
1991	**194**	**182**	**414**	**1131**	**344**	*56*	**28**	*369*	262	554	644	1021	213	*808*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1992	**139**	**147**	**411**	**771**	**334**	*56*	*272*	*32*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1993	**221**	**129**	**333**	**503**	**305**	*56*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1994	**197**	**70**	**302**	**564**	**301**	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1995	*186*	*60*	*282*	*512*	*284*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1996	*176*	*50*	*262*	*461*	*267*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1997	*166*	*41*	*243*	*409*	*250*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1998	*156*	*32*	*223*	*358*	*233*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
1999	*146*	*23*	*204*	*306*	*217*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
2000	*135*	*14*	*186*	*255*	*200*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
2001	*125*	*5*	*168*	*203*	*183*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
2002	*115*	*0*	*149*	*152*	*166*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
2003	*105*	*0*	*131*	*100*	*149*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*
2004	*97*	*0*	*113*	*54*	*132*	*31*	*272*	*0*	*256*	*557*	*644*	*1040*	*194*	*807*	*400*	*266*	*118*	*1625*	*359*	*830*	*100*

THE FISHERIES OF THE LAPTEV SEA

The Laptev Sea, bounded by the Severnaya Zemlya islands in the west and New Siberian Island and Kotelny Island in the east (Figure 1), is a mostly shallow water body with a complex oceanography (Kosobokova *et al.* 1998, Thiede *et al.* 1999). It is frozen nearly year round, with an extremely short summer, during which some parts of the water become ice-free as the coastal ice recedes, and into which the several large rivers discharge immense quantities of freshwater (Table 1). The fish fauna of the Laptev Sea is extremely impoverished, as it is remote from both the Barents Sea on the west and Bering Sea to the east (Figure 1, Table 2). According to an economic review of the Sakha Republic (Yakutia) by the Japan External Trade Organization (JETRO), there is no commercial marine fishery operating along the Republic's 5,000 km long coast facing the Laptev and East Siberia seas (Japan External Trade Organization 2004). For this same area, however, Isaev and Newell (p. 243 in Newell 2004) write that [small-scale] "fishing annually yields about 8,000 tons, mainly in the lower reaches of the Lena, Yana, Indigirka, and Kolyma Rivers". This catch estimate pertains to both the Laptev and East Siberian Seas, which we assume to be distributed equally, or 4,000 tonnes·year^{-1} for each LME, based on the similar size in their inshore fishing areas (to be described in a later section).

Coregonid species, again, form the bulk of the fishery in the Laptev Sea, but detailed records are available only from the lower reaches of the Lena and Yana rivers, and from Khatanga Bay for the years 1981 to 1991 (Larsen *et al.* 1996). These data, amounting to about 3,000 tonnes·year^{-1} on average, do not show any consistent trend unlike those from the Kara Sea. Thus, as evidence is lacking which would support any trend related estimation, the mean catch of the first three years with data (1980-1982) is extrapolated backward to 1950; similarly, the mean catch of the last three years is extrapolated forward from 1992 to 2004.

There is no information available on catches of any other species. Larsen *et al.* (1996), however, estimate a range of 10 to 30% of total catches being non-coregonid in Arctic Russia. We therefore applied the upper value of this range to both the Laptev and East Siberian seas as our estimated catches of other fish, which when combined with our estimates of coregonid catches brought our total catch close to the estimate of 4,000 tonnes·year^{-1} derived from Newell (2004; see Table 3).

THE FISHERIES OF THE EAST SIBERIAN SEA

The East Siberian Sea LME covers an area bounded by Kotelny Island in the west and Wrangel Island in the east. Like the Laptev Sea, it is remote from the Barents and Bering Seas and hence its fish fauna is species-poor (Table 2). A few large rivers, however, discharge into the East Siberian Sea, notably the Indigirka and Kolyma Rivers, and thus we find the familiar assemblage of coregonids being exploited by small-scale fisheries in the lower reaches and estuaries of these rivers.

According to Newell (2004, p. 43), rivers which discharge into Chaun Inlet, near Pevek (Figure 1), "have commercially valuable stocks of humpback salmon and dolly warden (*Salvelinus malma*)," that are threatened by overfishing.

The catch data used here are from GOSNIORKH as reported by Larsen *et al.* (1996), and the same assumptions were applied to their extrapolations as were applied for the Laptev Sea (Table 3). An estimate of 30% was assumed for catches of non-coregonid fish, yielding, for the 1980s, an annual average catch of 3,087 tonnes·year^{-1}, a figure conservative with regards to the estimate derived from Newell (2004; see above).

It should be noted here that unlike the catches in the Kara Sea which underwent a decline in fisheries catches, we can expect a more stable yield in the East Siberian Sea, and to some extent the Laptev Sea. This may likely be driven by a relatively larger proportion of indigenous inhabitants in the region, who are less inclined to emigrate following the collapse of regional industries (Larsen *et al.* 1996), and the lower levels of environmental degradation from the intensive industrialization of the regions (Newell 2004).

THE FISHERIES OF THE CHUKCHI SEA

The Chukchi Sea LME, being adjacent to the Bering Sea (Figure 1), includes a greater number of fish species than the East Siberian Sea, notably species which also occur in Arctic Alaska and the northern Pacific (Raymond 1988 in Larsen *et al.* 1996), for example the char, *Salvelinus alpinus* (Table 2). The "GOSNIORKH does not possess data on landings from areas east of the Kolyma river" (Brude *et al.* 1998), presumably because there are no large river systems feeding into the Chukchi Sea. However, the area has a number of smaller rivers rich in anadromous salmonids.

Given the absence of data, we estimated the catch from the Chukchi Sea as a 'Fermi solution' (von Baeyer 1993), i.e., by breaking down the problem at hand, and making informed guesses about each of the parts, whose errors are likely to cancel each other at the end.

The non-indigenous human population of the Chukotka Republic which borders the Chukchi Sea, is believe to be "rapidly dwindling in the whole region" (Newell 2004, p. 285), with about 17,000 indigenous people in total, comprising mostly Chukchi, Yukagirs, Yupik, Koryak and Even people (Newell 2004, p. 285). The overwhelming majority of this population appears to live in the southern parts of the Republic along the coast of the Bering Sea and the Sea of Okhotsk (Newell 2004, map 8.2, p. 308). For the purpose of this report, we shall assume that 5 percent of the total population (or about 1,000 inhabitants) occupy the coast of the Chukchi Sea, and that the following description of their lifestyle applies: "lacking money, coastal native people have again turned to the sea as source of food [...]. Most now survive exclusively on marine mammal meat, fish, and marine invertebrates [...]. Small surplus quantities of fish and meat [...] are sold to tourists, or traded [...]. Hunting at sea is once again becoming a prestigious calling in coastal cultures" (Newell 2004, p. 310). Therefore, if we assume that each of the 1,000 persons along the Chukchi Sea coast consumes 100 kg of fish·year^{-1} (a high value), a catch of 100 tonnes·year^{-1} would be required.

Alternatively, we could assume, in the absence of any evidence to the contrary, that annual catches along the Chukchi Sea coast are, on a per-area basis, 10% of those in the East Siberian Sea[1]. Such an estimate yields 2.3 kg·year^{-1}·km^{-2} of inshore fishing area. Given the size of inshore fishing area computed for the Chukchi Sea (Table 1), we computed 90 tonnes·year^{-1} as the likely catch for the region. This is close to the figure of 100 tonnes·year^{-1} estimated above, which we retained. This is also based on the concept that, as a "spontaneous number", it has the advantage of not suggesting a high precision (Albers and Albers 1983).

It is interesting to note that since the collapse of the Soviet Union, the region has attracted interest from the Alaskan sport fishing industry, and chartered trips have been organized targeting various Pacific salmon and Arctic char (Jenkins 1991) and their role in the local fisheries is expected to grow. We assume that the catches made by these fisheries easily fit into our estimate for the Chukchi Sea.

DISCUSSION

Figure (2) presents our estimated time series of catch, by species, for the entire North Siberian region, including the estimates for the catches of 'other fishes', based on Larsen *et al.* (1996) and other sources. These estimates are meant to provide an alternative to the official landings data reported by FAO on behalf of Russia, which are summarized in Table (4). These reported landings pertain to species usually caught by industrial trawlers, not likely to operate in any of the ecosystems reported upon here. These data are also incompatible with information provided in a report of the Ministry of Natural Resources (1998):

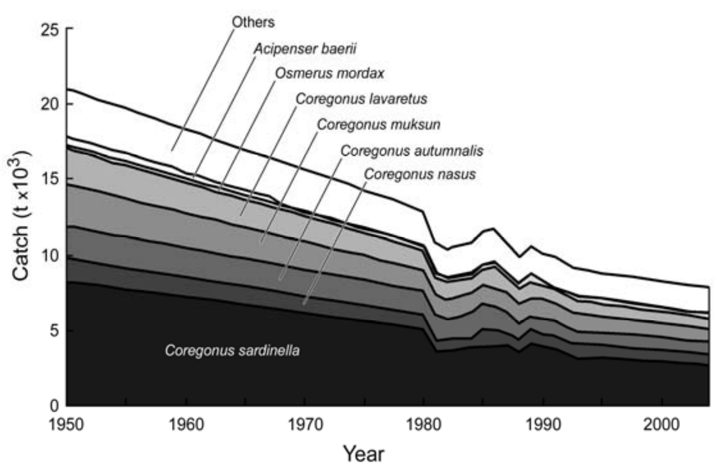

Figure 2. Estimated marine fisheries catch by species for the Russian Arctic Large Marine Ecosystems (Kara, Laptev, E. Siberian and the Russian section of the Chukchi Seas) from 1950 to 2004.

"Commercial fishing in the Kara and eastern Arctic seas is not viable. The largest amount of bioresources (mainly semi-migratory fish of the 'sig' family:

[1] The reference area used here is the 'inshore fishing area', previously used by Chuenpagdee *et al.* (2006) to compare fisheries yields by small-scale fisheries throughout the world, and which are defined as waters of up to 200 m in depth or up to 50 km from shore, whichever is nearest to the coastline.

muksun, pelyad, sig, ryapushka, and omul) are produced in the pre-mouth zones of the Ob and Yenisey Rivers. Along other areas of the coast, fish resources are small (Yakutia, Chukotka) and fishing is only for the subsistence needs of the local population."

Table (3) and Figure (2) are based on data and inference which are highly uncertain. However, the overall catch level may be within the correct range, as can be inferred by comparison with the catch data in Berg *et al.* (1949; E. Pakhomov, Earth & Ocean Sciences, UBC, pers. comm.). This is in contrast to the data presently available from the FAO, which reports landings 60 times lower than presented here (Table 4). Another concern is the distinction between marine, brackish-water and freshwater catches. We are almost certain that by relying heavily on the reported catches of anadromous coregonids in our estimates, we have included significant, and, for our purpose, unwanted freshwater catches (although we have omitted catches of *Coregonus peled*, an exclusively freshwater species, from our study). Nonetheless, we believe that such a potential overestimate in the catches of anadromous species is compensated for, at least in part, by unreported small-scale fisheries for marine species in larger estuaries such as that of Ob and Lena rivers or in areas such as Khatanga Bay. Indeed, it is more or less universal for small-scale subsistence fisheries to be overlooked in governments' statistical systems (Pauly 2006, Zeller *et al.* 2006, Zeller *et al.* 2007).

The region discussed here suffers to a substantial extent from various forms of industrial pollution, the result of decades of ruthless attempts to extract natural resources from the area without environmental safeguards (Gordeev *et al.* 2006, Newell 2004, Vilchek *et al.* 1996). Thus, it would be tempting to attribute the decline of fish catches observed during the period for which there is data solely to high levels of pollution, especially in the Kara Sea area. This is believed to be the case for the coregonid fisheries in the White Sea (Ministry of Natural Resources 1998), and generally for the Russian Arctic (Vilchek *et al.* 1996). Yet, massive demographic changes have also occurred during this period, as ethnic Russians that immigrated into the region during the Soviet era are leaving the area following the collapse of the Soviet regime. Those who remain are indigenous peoples, with few options but to (re-)turn to small-scale fishing and hunting.

Be that as it may, the present contribution was assembled essentially for the purpose of generating a straw man, which Russian and other colleagues interested in Arctic fisheries can now begin to shoot at.

Table 4. Official landings data reported by FAO for Area 18 on behalf of Russia and the former USSR, for the period 1950-2004.

Reported taxa	Year[a]				Total landings (t)
	1967	1968	1969	1970	
Greenland halibut	100	1,400	800	200	**2,500**
Roundnose grenadier	1,100	5,900	2,600	500	**10,100**
Miscellaneous marine fish	-	-	-	100	**100**
Total	**1,200**	**7,300**	**3,400**	**800**	**12,700[b]**

[a] Only the 4 years included here had non-zero landings. [b] This compares with 754,815 t in Table (3) for 1950-2004, i.e., 60 times more.

Acknowledgements

We thank C. Ragner of the Norwegian Institute for making available to us the reports which made this contribution possible. Our thanks also go to B. Campbell for the GIS work, and A. Atanacio for drawing the figures. A special thanks to E. Pakhomov, Earth & Ocean Sciences, UBC, for comments which, we hasten to add, do not make him responsible for any of the interpretations presented here. This work is a product of the *Sea Around Us* Project, funded by the Pew Charitable Trusts, Philadelphia.

REFERENCES

Albers, W. and Albers, G. (1983) On the prominence structure in the decimal system. p. 271-287 *In*: R.W. Scholz (ed.). Decision making under Uncertainty. Amsterdam, Elsevier.

Belikov, S., Boltunov, A., Belikova, T., Belevich, T. and Gorbunov, Y. (1998) The Distribution of Marine Mammals in the Northern Sea Route Area. INSROP Working Paper No. 118, 49 p.

Berg, L.S., Bogdanov, L.S., Kozhin, N.I. and Rass, T.S. (Editors) (1949) Коммерчески рыбы СССР [Commercial fishes of the USSR]. Pshchepromizdat, 787 p. [in Russian].

Brude, O.W., Moe, K.A., Bakken, V., Hansson, R., Larsen, L.H., Lovas, S.M., Thomassen, J. and Wiig, O. (1998) Northern Sea Route Dynamic Environmental Atlas. INSROP Working Paper No. 99, 58 p.

Chuenpagdee, R., Liguori, L., Palomares, M.D. and Pauly. D. (2006) Bottom-Up, Global Estimates of Small-Scale Marine Fisheries Catches. Fisheries Centre Research Reports 14(8), 112 p.

Fetzer, I., Hirche, H.J. and Kosolova, E.G. (2002) The influence of freshwater discharge on the distribution of zooplankton in the southern Kara Sea. Polar Biology 25: 404-415.

Fleming, I.A. and Jensen, A.J. (2002) Fisheries: Effects of Climate Change on the Life Cycles of Salmon. p. 309-312. *In*: I. Douglas (ed.). Volume 3, Causes and consequences of global environmental changes. Encyclopedia of Global Environmental Change.

Gavrilo, M., Bakken, V. and Isaksen, K. (1998) The Distribution, Population Status and Ecology of Marine Birds selected as Valued Ecosystem Components in the Northern Sea Route Area. INSROP Working Paper No. 123, 145 p.

Glubokowsky, M.K. and Cheresenev, I.A. (1981) Unresolved problems concerning the phylogeny of chars (*Salvelinus*) of the Holarctic: I. Migratory chars of the East-Siberian Sea basin. Journal of Ichthyology 21(5): 1-15.

Gordeev, V.V., Andreeva, E.N., Lisitzin, A.P., Kremer, H.H., Salomons, W. and Mashall-Crossland, J.I. (2006) Russian Arctic Basins: LIICZ Global Chage Assessment and Synthesis of River Catchment – Coastal Areas Interaction and human Dimension. LOICZ Report and Studies No 29, 95 p.

Hill, F. (2004) Siberia: Russia's economic heartland and daunting dilemma. Current History (Oct): 324-31.

Japan External Trade Organization (2004) Russia Far East economic review. (www.jetro.go.jp/biz/world/russia_cis/ru/kyokuto/2004_02.html) [in Japanese]

Jenkins, J.L. (1991) Sportfishing in the Soviet Far East? The Angling Report Jan. 1991. Available at: www.anglingreport.com [accessed September 26th, 2007]

Kosobokova, K. N., Hanssen, H., Hirche, H.J. and Knickmeier, K. (1998) Composition and distribution of zooplankton in the Laptev Sea and adjacent Nansen basin during summer 1993. Polar Biology 19: 63-76.

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.

Larsen, L.H., Evenset, A. and Sirenko, G. (1995) Linkages and impact hypothesis concerning the Valued Ecosystem Components (VEC's): Invertebrates, Fish, the Coastal Zone and Large River Estuaries and Deltas. INSROP Working Paper No.12, 38 p.

Ministry of Natural Resources (1998) Safety and environmental regime for Russian offshore oil and gas operations. The feasibility study: the joint Russian-American-Norwegian project. Ministry of Natural Resources of the Russian Federation, 152p.

Newell, J. (2004) The Russian Far East: A Reference Guide for Conservation and Development. Daniel & Daniel Publishers, McKinleyville, CA, 466 p.

Pauly, D. (2006) Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. Maritime Studies (MAST) 4(2): 7-22.

Slavin, S.V. (1964) Economic development of the Siberian North. Arctic 17(2): 104-108.

Thiede, J., Timokhov, L., Bauch, H.A., Bolshiyanov, D., Dmitrenko, I., Eicken, H., Fahl, K., Gukov, A., Hölemann, J., Hubberten, H.W., van Juterzenka, K., Kassens, H., Melles, M., Petryashov, V., Pivovarov, S., Priamikov, S., Rachold, V., Schmid, M., Siegert, C., Spindler, M. and Stein, R. (1999) Dynamics and History of the Laptev Sea and its Continental Hinterland: A Summary. p. 695-711 *In*: H. Kassens et al. (eds.) Land-Ocean System in the Siberian Arctic: Dynamics and History. Springer-Verlag, Berlin.

Thomassen, J., Dallmann, W., Isaksen, K., Khlebovich, V. and Wiig, O. (1999) Evaluation of INSROP Valued Ecosystem Components: Protected areas, Indigenous People, Domestic reindeer and Wild reindeer. INSROP Working Paper No. 162, 62 p.

Vilchek, G.E., Krasnovskaya, T.M. and Chelyukanov V.V. (1996) The environment in the Russian Arctic: Status Report. Polar Geography 20(1): 20-43.

von Baeyer, H.C. (1993) The Fermi Solution: Essays on Science. Random House, New York. 172 p.

Wiig, O., Belikov, S.E., Boltunov, A.N. and Garner, G.W. (1996) Selection of marine mammal Valued Ecosystem Components and description of impact hypotheses in the Northern Sea Route Area. INSROP Working Paper No. 40, 70 p.

Zeller, D., Booth, S., Craig, P. and Pauly, D. (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25: 144-152.

Zeller, D., Booth, S., Davis, G. and Pauly, D. (2007) Re-estimation of small-scale fisheries catches for U.S. flag island areas in the Western Pacific: the last 50 years. Fisheries Bulletin 105: 266-277.