X-24 Oyashio Current: LME #51

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The Oyashio Current LME is located in the northwest Pacific Ocean and is bordered by Russia (the Kamchatka Peninsula and Kuril Islands) and the Japanese island of Hokkaido. It covers an area of about 530,000 km^2, of which 0.19% is protected, and contains 0.09% of the world's sea mounts (Sea Around Us 2007). A sub-arctic climate characterises this LME, which is based on the distinctive cold Oyashio Current (or the Kuril Current) with its strong interannual variations in strength (Minoda 1989). The geographic remoteness and inaccessibility of the Kuril Islands, combined with the extreme environmental conditions have discouraged human settlement and contributed to making the Kuril Archipelago one of the least known regions of the world. The 2,000 km Kuril-Kamchatka island arc is part of the 'Ring of Fire', a chain of volcanoes encircling the Pacific Ocean (Simkin & Siebert 1994). Accounts pertaining to this LME include Minoda (1989) and UNEP (2006).

I. Productivity

The Oyashio Current LME is a Class II, moderately productive (150-300 $gCm^{-2}y^{-1}$) ecosystem (Figure X-24.3). The confluence zone of the cold Oyashio Current and the warm Kuroshio Current off northern Japan gives rise to some of the most productive marine areas of East Asia, with many species of fauna and flora and rich fishing grounds. The phytoplankton has 'traditional' spring bloom dynamics (Kasai *et al*. 1997) leading to a typical phytoplankton-macrozooplankton-fish food web. It is believed that the high zooplankton biomass depends on the cold waters of the Oyashio Current below the thermocline (Minoda 1989). The observed large fluctuations in the biomass and timing of zooplankton recruitment suggest that zooplankton grazing is an important factor in controlling the magnitude and the duration of the spring bloom (Saito *et al*. 2002).

Kamchatka and the Kuril Islands are of global importance. In 1996 five specially protected natural areas ('Kamchatka Volcanoes') were included among the UNESCO World Cultural and Natural Heritage Sites. The system of specially protected natural areas includes three reserves, three natural parks of regional importance, 25 protected areas, and 89 state nature monuments. The waters around Kamchatka are inhabited by the rare grey whale and several other species of marine mammals such as sea lions and otters.

Oceanic fronts (Belkin and Cornillon 2003; Belkin et al. 2009): The Oyashio Current Front originates at the western periphery of the Western Subarctic Gyre (Figure X-24.1). The upstream part of the Oyashio Current/Front is also called the East Kamchatka Current/Front and Kuril Current/Front. The Oyashio Current carries cold and fresh waters southwestward where they meet the warm and salty waters of the Kuroshio. As it flows southwestward, the Oyashio Current forms energetic eddies, up to 50-100 km in diameter, branches into the Okhotsk Sea via the Kuril Straits and undergoes water mass transformation owing to extremely intense tidal mixing in the Kuril Straits. A major permanent branch of the Oyashio Current penetrates into the Okhotsk Sea to form the West Kamchatka Current.

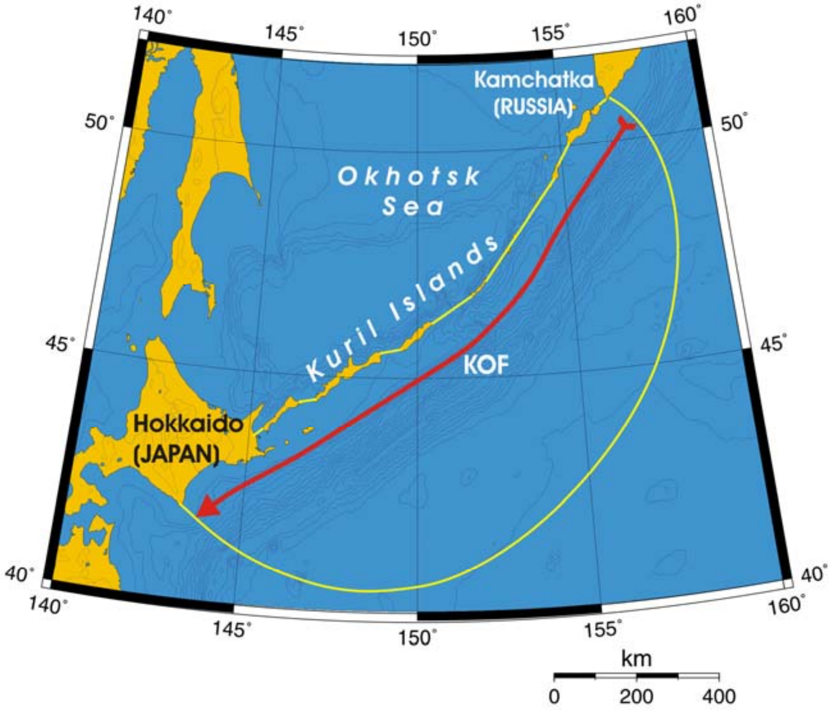


Figure X-24.1. Fronts of the Oyashio Current LME. KOF, Kuril-Oyashio Front. Yellow line, LME boundary. After Belkin et al. (2009).

Oyashio Current SST (Belkin 2009)(Figure X-24.2)
Linear SST trend since 1957: 0.48°C.
Linear SST trend since 1982: 0.60°C.

Over the last 50 years, the North Pacific experienced several "regime shifts" that affected ocean stratification and all trophic levels (Chiba et al. 2008; Overland et al. 2008). These regime shifts have been shown to correlate with the Pacific Decadal Oscillation (PDO), El-Nino-Southern Oscillation (ENSO), Artic Oscillation (AO), North Pacific Index (NPI) and other atmospheric indices (Minobe 1997; Mantua et al. 1997; Mantua and Hare 2002). The North Pacific regime shift of 1976-77 (Mantua et al. 1997; Hare and Manthua 2000) transpired in the Oyashio Current (but not in the Kuroshio Current). The Oyashio Current experienced a regime shift in the late 1980s from a cold epoch to a warm one, when SST rose by 1°C in just two years, a dramatic regional manifestation of the trans-Pacific regime shift of 1988-89 (Mantua et al., 1997; Hare and Mantua, 2000). The Oyashio Current is rather strongly correlated with the Okhotsk Sea LME, sometimes lagging 1 to 2 years behind the latter, suggestive of the Okhotsk Sea influence on the Oyashio Current. Another interesting feature of the Oyashio Current is a distinct 3- to 5-year periodicity.

According to Megrey et al. (2007), all three main groups of zooplankton increased during SST decrease; a similar correlation was observed in the subarctic sub-region of California, thus confirming a general tendency of negative correlation between zooplankton density and temperature. A caveat: the Oyashio sub-region at 42N, 155E in Megrey et al. (2007) is south of the LME, albeit still within the Oyashio Extension associated with the Polar Front (Belkin et al., 2002).

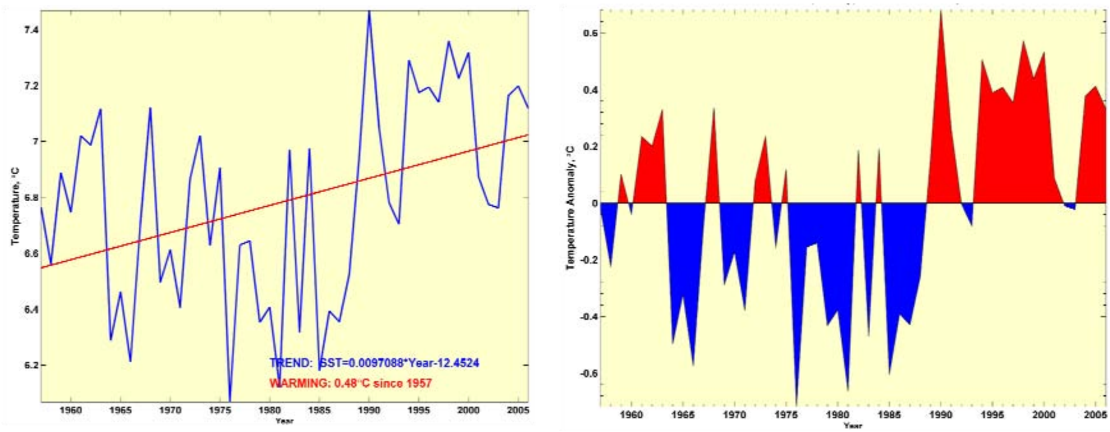


Figure X-24.2. Oyashio Current LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

***Oyashio Current LME Chlorophyll and Primary Productivity*:** The Oyashio Current LME is considered a Class II, moderately productive (150-300 $gCm^{-2}y^{-1}$) ecosystem.

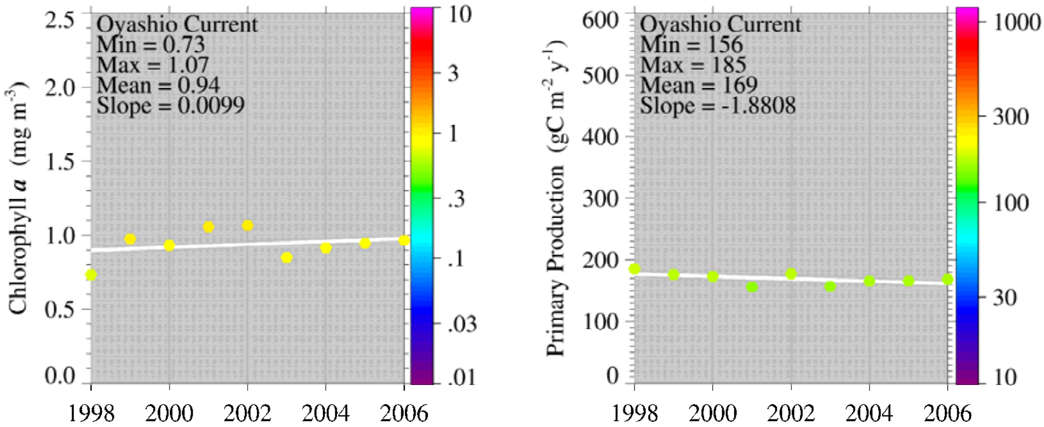


Figure X-24.3. Oyashio Current LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The Oyashio Current flows off the Pacific coast of the Kuril Islands, an important fishing ground for the Russian Federation. In addition to the capture fisheries, a large number of kelp, scallop, abalone and algae are cultured in the region.

Total reported landings in the LME exceeded 900,000 tonnes in 1984-1985, with large catches of Alaska pollock and South American pilchard, but recorded around 300,000 tonnes in 2004 (Figure X-24.4). From 1970 to 1989 the total reported landings was valued at over US$1 billion (in 2000 US dollars) with a peak of US$1.5 billion recorded in 1980-1985 (Figure X-24.5).

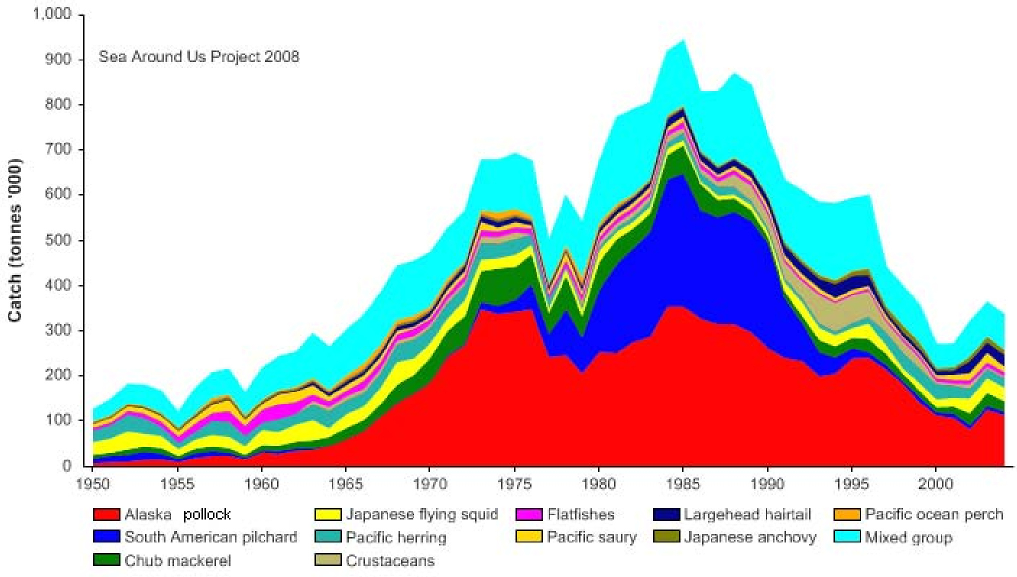


Figure X-24.4. Total reported landings in the Oyashio Current LME by species (Sea Around Us 2007).

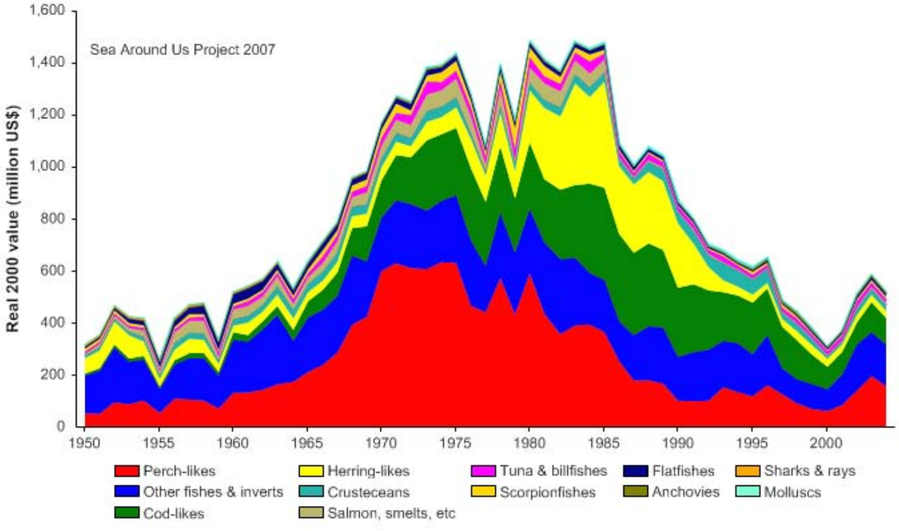


Figure X-24.5. Value of reported landings in the Oyashio Current LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME reached 25% of the observed primary production in the mid 1980s and in 1995 but has not reached such level since (Figure X-24.6). Japan and Russia have the largest footprint in this LME. With Russia selling the rights to fish inside its EEZ, a large number of foreign fleets, mainly those from China and South Korea, as well as a number of flag-of-convenience ships, operate within the LME. Illegal fishing is also of concern, although its extent in Russian territorial waters is not known with any certainty.

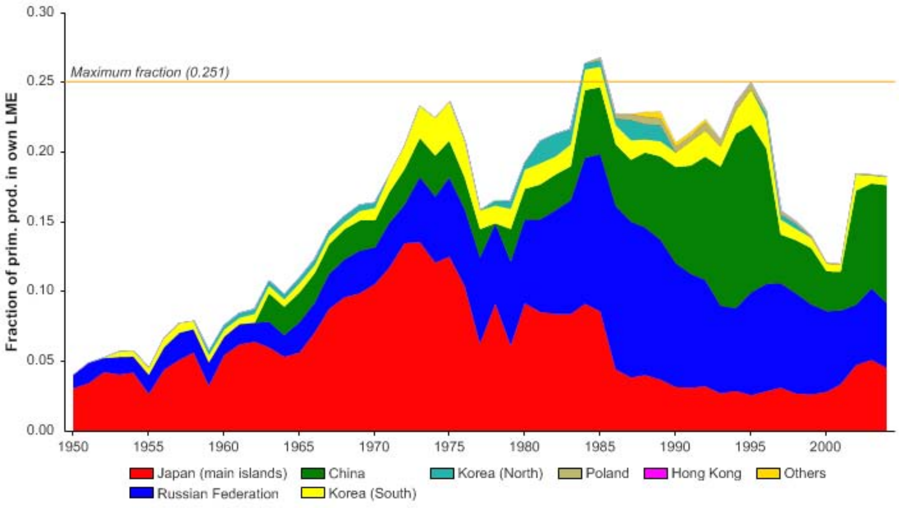


Figure X-24.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Oyashio Current LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e. the MTI; Pauly & Watson 2005) shows large fluctuations, reflecting the cyclic nature in the relative abundance, and hence the landings, of the low-trophic South American pilchard in the LME (Figure X-24.7 top); The FiB index shows a period of expansion in the 1950s and 1960s, after which the index levels off, indicating that the decrease in the mean trophic level resulting from the high proportion of South American pilchard in the reported landings in the 1980s was compensated for by its large landings (Figure X-24.7, bottom).

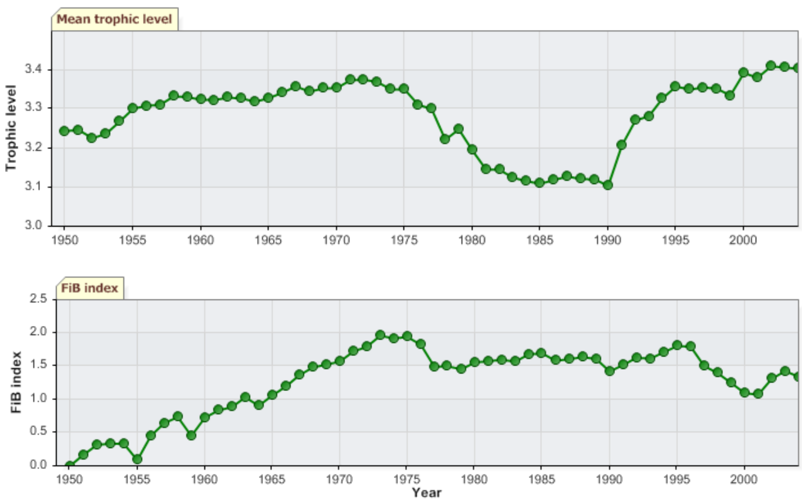
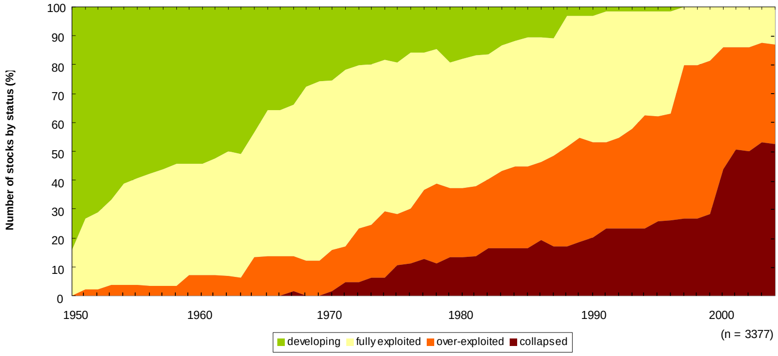


Figure X-24.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Oyashio Current LME (Sea Around Us 2007)

The Stock-Catch Status Plots indicate that the number of collapsed stocks have been rapidly increasing, accounting for 50% of the commercially exploited stocks in 2004, with an additional 30% of the stocks being overexploited (Figure X-24.8, top). Overexploited stocks contributed 80% of the catch biomass in 2004 (Figure X-24.8, bottom).



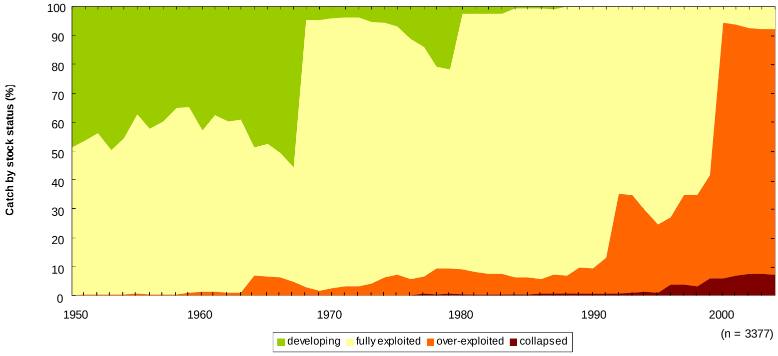


Figure X-24.8. Stock-Catch Status Plots for the Oyashio Current LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

Overcapacity of the fishing fleet is a problem and the decrease in demersal shrimp and fish landings has been attributed to intense exploitation. Chub mackerel decreased in 1976, and by 1979 the fishery had disappeared in Hokkaido (Minoda 1989). The salmon catch decreased in 1977 but subsequently stabilised (Minoda 1989). Japanese efforts to breed and release salmon have led to an increase in chum salmon. The collapse of the populations of certain species (particularly red king crab) in the past has not been attributed to any one cause such as overfishing. Drift netting is an important pelagic fishing method in the Oyashio Current LME. Other methods include beam trawling for demersal species (UNEP 2006).

The effects of climate regime shift on ENSO events, western boundary currents and upper-ocean stratification and their biological consequences are reviewed by Sugimoto *et al*. (2001). The fisheries resources in this LME are also affected by climate variability. For instance, a significant weakening of the southward intrusion of the Oyashio Current off the east coast of Japan during 1988-1991 resulted in a decrease in chlorophyll concentrations and mesozooplankton biomass in late spring-early summer in the Kuroshio-Oyashio transition region. Changes occurred in the dominant species of small pelagic fish, through successive recruitment failures of Japanese pilchard. In addition, the southern edge of salmon habitats is expected to shift northwards as a result of global warming. The stands of cold-water seaweed may also decline, which may lead to a reduction of populations of abalone, sea urchins and other invertebrates that feed on this type of seaweed (UNEP 2006).

The biomass of fish stocks depends on the biomass of lower trophic levels (prey), primary production, and also directly on oceanic and atmospheric conditions. The fish catches in the Kuroshio-Oyashio region strongly depend on two oceanographic patterns related to (1) Oyashio's southward intrusions (OSI) or meanders east of Honshu, and (2) Kuroshio's Large Meander (KLM) south of Honshu. Typically, there are two quasi-stationary southward meanders of the Oyashio east of Honshu (Qiu, 2001). Their southward limits SL01 and SL02 correlate with SST and SSS in the Oyashio LME since the Oyashio meanders contain subarctic water that is markedly colder and fresher than resident water east of Honshu. The OSI strongly affect recruitment, biomass, and catch of such species as pollock, sardine and anchovy. The years when the OSI are well developed and protruded southward are cold years favorable for sardine because sardine uses these meanders as feeding grounds. The KLM development correlates with sardine recruitment and catch owing to the proximity of the KLM to the southern spawning and fishing grounds of sardine (Sakurai, 2007).

Various conceptual hypotheses have been put forth to relate ocean-atmosphere variability to fish catch. For example, Tian et al. (2003) related the abundance of Pacific saury to remote large-scale forcing originating as far away as the equatorial Pacific and the Arctic. Yatsu et al. (2008) linked stock fluctuations of the Pacific stock of Japanese sardine to the Aleutian Low intensification, Oyashio expansion, and mixed layer depth deepening and lower SST in the Kuroshio Extension - as well as less arrival of the two most important predators, skipjack tuna and common squid.

Multi-decadal fluctuations of, and strong correlation between, sardine and anchovy catches that fluctuate out-of-phase are well-known, although the mechanisms behind these phenomena remain poorly understood (e.g. Chavez et al., 2003). The most recent results by Takasuka et al. (2008) shed new light on these fluctuation patterns, as they found that sardine and anchovy statistical distributions with regard to temperature are distinctly different. In the NW Pacific, they found anchovy to be warm and eurithermal, and sardine to be cold and stenothermal. In the NE Pacific (California Current), this pattern is reversed.

III. Pollution and Ecosystem Health

Pollution: Since the greater part of the Oyashio Current LME is located far from the coastal areas of Japan and Russia, it is less affected by river and air pollution resulting from rapid economic growth and industrial production. Overall, pollution was found to be negligible (UNEP 2006), although solid waste is of concern in areas close to human settlements, including seasonal camps. Numerous navigation routes used by thousands of vessels all year round increase the potential for oil pollution in this LME. Up to five spills per year occur on average, especially on the Kuril route. Oil pollution is expected to increase with the development of new oil deposits and increased oil transport by tankers from Sakhalin. There is some concern over radioactive contamination from old, decommissioned nuclear submarines and other sources in this LME.

Habitat and community modification: The main cause of habitat modification is coastal development (e.g., port construction and operation), but this is relatively small-scale and not thought to lead to habitat loss. The release of chum salmon fry from hatcheries may lead to competition with other fish larvae for food, resulting in community modification. Global climate change is expected to influence the ENSO phenomenon, winter monsoon, western boundary currents, and upper ocean stratification, with biological consequences on coastal and marine habitats.

IV. Socioeconomic Conditions

The population of the east coast of Kamchatka and Kuril Islands is about 300,000, with a relatively low population density of about 2 inhabitants/km^2. In the north of the peninsula, the indigenous people of Kamchatka, the Koryaks, the Itelmen, the Chukchies and the Evenks have maintained their traditional way of life. The LME is rich in natural resources, including fish, minerals and potentially large oil and gas reserves. Fishing and fish processing, fuel and energy (e.g., geothermal, wind-driven, and hydroelectric power plants), ship repair, and tourism are the major economic activities of the Kamchatka region. At present, fisheries make up 80% of the industrial and economic activities of Kamchatka and the Kuril Islands, while aquaculture (of fish and other marine organisms) is of major interest in Hokkaido. The socioeconomic impacts of illegal fishing by foreign boats and the possibility of fish stock collapse along with temporary bans on salmon fishing as a result of weak salmon runs are of concern in the region.

V. Governance

The long-term dispute between Russia and Japan over sovereignty of the South Kuril Islands resulted in a dispute over fishing rights in the Oyashio Current LME, which is under a serious environmental threat, especially the southern Kuril Islands where the biota is considerably more diverse than the central and northern islands. Action is needed to explore, document and protect the unique and delicate flora and fauna of these islands. At present, the south Kuril Islands are governed by Russian administration as part of Russia's Sakhalin oblast' (district). Japan claims these four islands – Iturup, Kunashir, Shikotan, and the Habomai Rocks - and refers to them as the "Northern Territories". In 2000, Russia and Japan signed a programme for joint economic development of South Kurils.

Until 1993, the International North Pacific Fisheries Commission, composed of Canada, Japan and the U.S., was a regulatory agency for fisheries in the Oyashio Current LME. This Commission was dissolved with the entry into force of the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean.

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