XVIII ANTARCTIC

XVIII-57 Antarctic LME

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The Antarctic LME is defined by the Antarctic Convergence (or Antarctic Polar Front), the boundary oscillating between 48 and 60° S and separating the colder Antarctic surface waters from the warmer sub-Antarctic waters to the north. The boundary varies seasonally and as a result of winds, currents and sea conditions. The colder Antarctic surface waters sink beneath the warmer water masses. The LME covers a surface area of about 4.3 million km^2, of which 0.05% is protected, and contains 0.04% of the world's sea mounts (Sea Around Us 2007). The LME's geographic and climatic characteristics are characterised by extreme weather conditions and by the ice cap, holding 70% of the Earth's fresh water. Book chapters and articles pertaining to this LME include Scully *et al*. (1986), Scully (1993), Hempel (1990) and Hubold (2003). Most of the present synopsis is on the Weddell Sea where considerable focus on the study of krill (euphausiids) and their predators and prey by scientists, policy specialists and living marine resource managers have been directed by the Commission for the Conservation of Antarctic Living Marine Resources (CCAMLR) since 1985.

I. Productivity

One of the largest shelf areas around the Antarctic continent is found in the southern part of the Weddell Sea (Hempel 1990). The Antarctic Circumpolar Current flows around Antarctica and provides a partial return of water to the South Pacific, the South Indian Ocean and the South Atlantic Ocean. The Antarctic LME is a Class II, moderately productive ecosystem (150-300 $gCm^{-2}yr^{-1}$). This is linked with extreme weather conditions and limited light penetration due to the winter ice cover. In the Weddell Sea, the seasonal production cycle is strongly determined by ice formation in the fall and ice melting in the spring and summer (Hubold 2003). Upwelling and cold water currents flowing around Antarctica release nutrients that stimulate plankton blooms. The base of the marine food chain is supported by about 100 species of phytoplankton. Some 200 Antarctic finfish species are found south of the Antarctic Convergence, 25% of which are unique to the area. The species of zooplankton, fish, squid, benthic organisms, seals, whales and birds found at this latitude have sophisticated mechanisms for survival under very cold conditions. Low metabolic rates help them maintain a higher rate of protein synthesis. The food chain is often very short, with krill (*Euphausia superba*) serving as a forage species crucial to the sustainability and production of all other fisheries in the LME. Baleen whales, seals, penguins, squid, fish and seabirds all feed on krill (see contributions in Palomares *et al.* 2005). For specific information on the Weddell Sea, see Hempel (1990) and Hubold (2003). For a recent review of the circumpolar habitats of Antarctic krill, see Atkinson et al. (2008).

Oceanic fronts (Belkin *et al.* 2008)(Figure XVIII-57.1): The Antarctic Shelf-Slope Front (ASSF) is observed along most of the Antarctic shelf/slope, except for the southern Pacific Antarctic and also a part of the Weddell Sea. This front separates very cold shelf waters from warmer oceanic waters. A geostrophic current that flows westward along this front carries icebergs around the continent for thousands of kilometres, branching north into marginal Antarctic seas. This current and associated front is largely set up by strong and persistent katabatic winds that drain very cold air from the Antarctic Plateau. Local fronts exist off the Antarctic Peninsula, in the Prydz Bay, and in the Ross Sea.

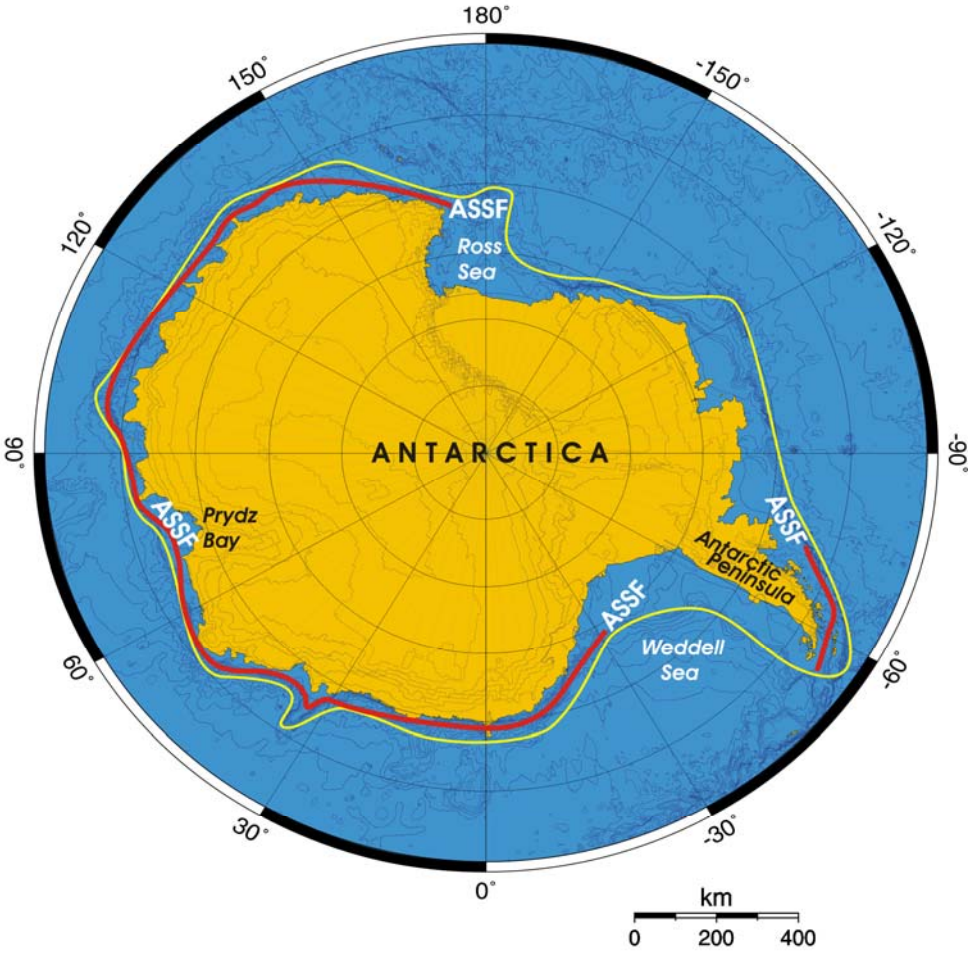

Figure XVIII-57.1. Fronts of LME the Antarctic LME. ASSF, Antarctic Shelf-Slope Front. Yellow line, LME boundary. After Belkin *et al.* (2008).

Antarctica LME SST (Belkin 2008)(Figure XVIII-57.2):

Linear SST trend since 1957: 0.11°C.
Linear SST trend since 1982: 0.01°C.

The long-term stability of the Antarctic Zone is striking: this is the only LME with no warming over 50 years. And yet, the lack of SST warming may be just an appearance because of the perennial sea ice cover in the near-coastal zone where the Antarctic LME is largely located. This LME was excluded from the analysis since the near-coastal zone is covered by drifting sea ice, landfast ice, and icebergs almost year round; therefore SST data here are deemed severely contaminated by the presence of ice.

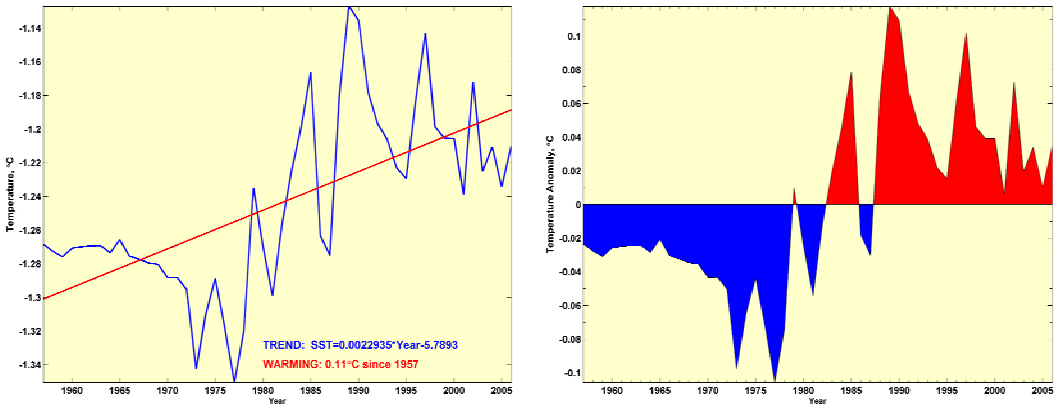

Figure XVIII-57.2. Antarctic LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

Antarctic LME Chlorophyll and Primary Productivity

The Antarctic LME is a Class II, moderately productive ecosystem (150-300 $gCm^{-2}yr^{-1}$)(Figure XVIII-57.3).

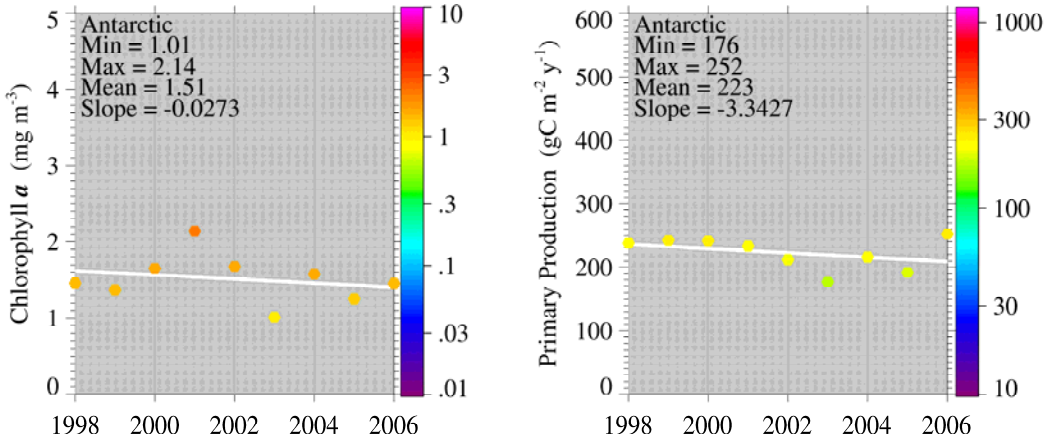

Figure XVIII-57.3. Antarctic LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery; courtesy of K. Hyde.

Western Antarctic Peninsula Near Surface Air Warming

The Antarctic Peninsula, the northernmost and mildest part of Antarctica, is also a hotspot of climate change, with average temperatures there having increased by more than two degrees Celsius. The British Antarctic Survey (BAS) reported in 2006, Journal of Climatology, that the westerly winds circling the pole have strengthened over the past 50 years and are the likely mechanism for the warming of the Peninsula. The stronger the westerlies, the more likely they are to cross the chain of mountains up to 2,800 m high that runs from north to south along the peninsula. As air masses move up the mountains, they lose moisture and tip into the lee side as dry, warm winds—like the föhn wind in the Alps and the Chinook in the Rockies (Schiermeier 2006).

II. Fish and Fisheries

Major interest in the Antarctic's marine living resources developed after the 1959 Antarctic Treaty. Species caught include krill (*Euphausia superba*), which has dominated the reported landings since early 1980s, rockcod (*Notothenia rossii*, *Lepidonotothen squamifrons*), icefish (*Champsocephalus gunnari*, *Chaenodraco wilsoni*) and toothfish (*Dissostichus mawsoni*). However, impacts on this LME by human activities go back at least to the days of peak whaling activities, where the removal of more than one million baleen whales in the 1950s and 1960s was hypothesized to have caused a huge 'krill surplus', accompanied by a parallel and concurrent massive depletion of finfish in the Southern Ocean (Ainley et al. 2007). By the early 1980s, krill accounted for more than 70% of the total catch. For information on krill and fish in the Weddell Sea, see Hempel (1990) and Hubold (2003). FAO (2003) has fisheries statistics after 1968. See FAO (2003, p. 29) for a graph of deep-water, epipelagic and total annual marine catches from 1950-1999.

There have been major fluctuations in the reported landings in this LME, with two major peaks at 112,000 tonnes in 1972 and 79,000 tonnes in 1978 (Figure XVIII-57.4). When the Soviet Union dissolved in 1991, the new republics drastically reduced their fishing activities in the Antarctic. Nevertheless, the decreasing total landings in recent years can be attributed to stock depletions. There is concern for the Patagonian toothfish (see Lack & Sant 2001). Antarctic cod and icefish are now in a depleted state. The countries that have been involved in the commercial fishing of krill are Japan, Russia, Chile, Taiwan, Korea, Spain, Poland and Germany. The potential for overfishing has grown significantly over the last two decades. These resources are subjected to fisheries management under the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR 1980). Unregulated fishing is said to account for five to six times reported catch data. A major stock of squid is thought to exist in this region, and there is interest in commercial fishing for squid by the nations catching krill in the Antarctic.

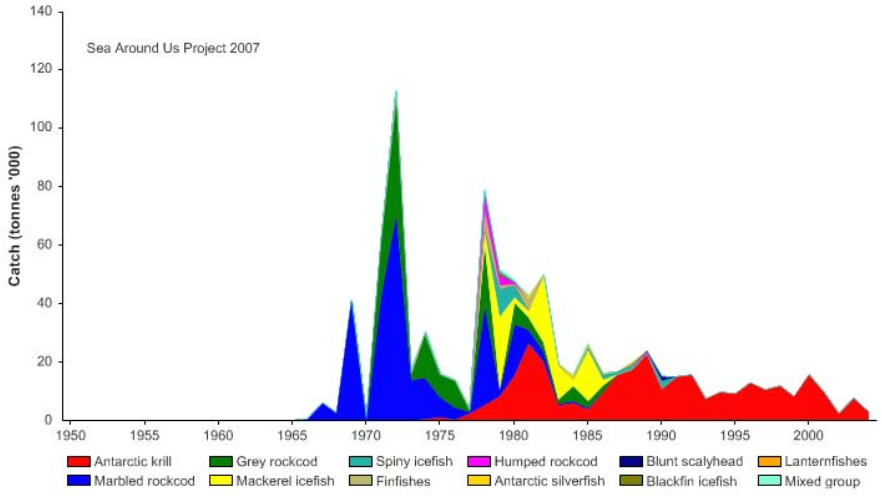

Figure XVIII-57.4. Total reported landings in the Antarctic LME by species (Sea Around Us 2007).

The trend in the value of the reported landings closely mirrored that of the landings, with two major peaks at just under US$120 million and US$80 million between early 1970s and early 1980s (Figure XVIII-57.5). However, it must be stressed that given the large amounts of unreported catch from this LME (see above), the estimates given in Figure XVIII-57.5 express only a small fraction of the value of Antarctic fisheries.

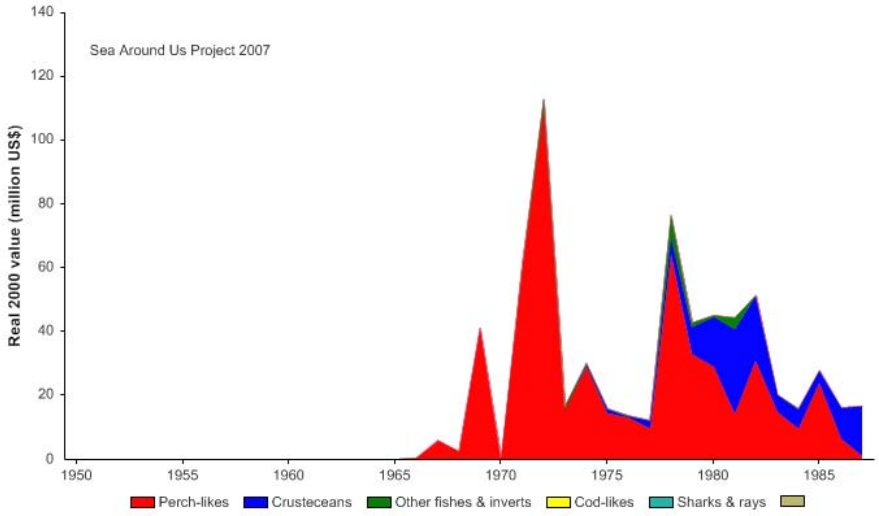

Figure XVIII-57.5. Value of reported landings in in the Antarctic LME by major commercial groups (Sea Around Us 2007).

Although based on partial catches, Figure XVIII-57.6 (top), which shows the mean trophic level of reported landings (i.e., the MTI, Pauly & Watson 2005), shows a rapid and strong decline in the 1970s and 1980s, reflecting the transition in landings from fish (mainly rockcod) to krill. Indeed, Figure XVIII-57.6(top) resembles Figure 4B in Pauly *et al.* (1998), in reference to Antarctica (defined by FAO areas 48, 58 and 88), which documented a case where as fishes being depleted, fisheries turned to the forage species (i.e., krill) one full trophic level lower. Figure XVIII-57.6 may be seen, therefore, as a contribution to the contemporary discussion on the respective roles, in this LME, of bottom-up control (e.g., fluctuation of ice cover) vs. top-down control (e.g., depletion of the higher trophic levels) (see Ainley 2007) Note that the present MTI account (as do all MTI figures in this volume) is exclusive of marine mammals, and thus ignores the mass removal of baleen whales in Antarctic waters (Ainley et al. 2007).

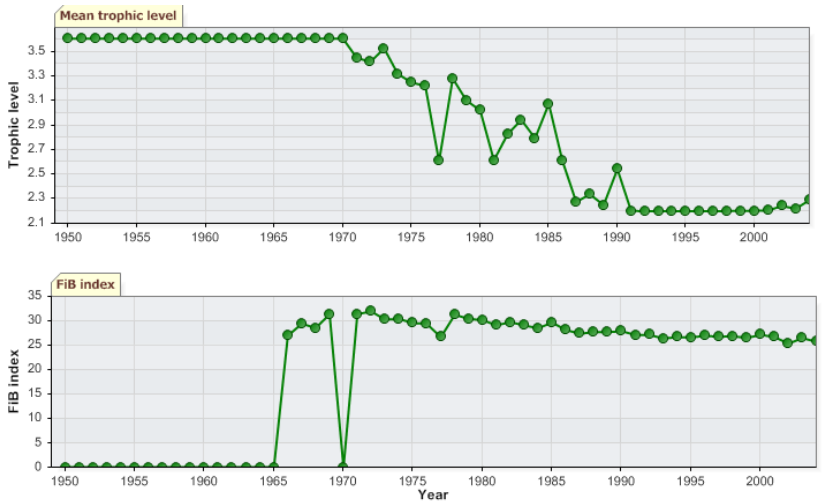

Figure XVII-57.6. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Antarctic LME (Sea Around Us 2007).

III. Pollution and Ecosystem Health

Overfishing is becoming an issue in the Antarctic LME. While the LME is remote and has no native coastal populations, it is a fragile environment in which there is growing pressure from human activity. Strict regulation is needed to maintain its relatively untouched and pristine condition. The impacts of human activities are examined on the Ohio State University, Byrd Polar Research Center, Polar Meteorology Group site at http://polarmet.mps.ohio-state.edu/. The Group examines the effects of tourists and scientists at laboratory stations, and the potential impacts of oil exploration and mining activities. According to an Australian abc.net report in 2000, an Antarctic Division study of the now abandoned Wilkes and Casey stations has found chemical contaminants (copper, lead, zinc and cadmium) leaching from rubbish dumped in old tip sites, machinery parts and fuel drums during the summer melt. Efforts for site clean-up are underway. Tourists are now required to follow a strict code of environmental conduct. For human impacts in the Antarctic Weddell Sea, see Hubold (2003).

There are other impacts on this LME due to anthropogenic environmental change. Depletion of the ozone layer has increased UV radiation that has a negative impact on surface phytoplankton productivity and on other taxa. In 1997 the NY Times reported UV damage in the eggs and larvae of icefish, the Antarctic fish that lack hemoglobin (http://topics.nytimes.com). As the ocean becomes more acidic when CO_2 increases in the atmosphere and becomes carbonic acid when dissolved into sea water (Plymouth Marine Laboratory 2006), impacts to the food web in the Antarctic are likely to be disruptive. Policy document 12/05 (2005), a report from The Royal Society, UK, outlines the impacts of increased acidity on the Southern Ocean.

Since 1974, 5,213 square miles of ice shelves have disintegrated in the Antarctic Peninsula (Zabarenko 2007). Professor Chris Rapley, director of the British Antarctic Survey and VP of the Committee for Antarctic Research, says that ice shelves may have an important role in stabilizing the ice sheet in Antarctica and that future loss of the largest ice shelves in the Antarctic could eventually cause accelerated and dramatic sea level rise (ENS 2005).

Negri et al. reported in 2004 for the first time, butylin contamination of near-shore sediments in the Ross Sea, Antarctica. The high concentration of 2290 μg Sn kg^{-1} sediment was recorded in one sample (Negri et al. 2004), likely caused by antifouling paints from ice-breaker ship hulls.

Long range atmospheric transport by global distillation is thought to be the main mechanism for moving POPS to high latitudes. Roosen et al.(2007) have reported concentrations of pesticides in soils from Adélie penguin colonies at Hop Island, 10 to 100 times higher than in reference locations.

IV. Socioeconomic Conditions

Pirate fishing has doubled in the 10 years from 1991 to 2001 as reported by P. Brown in the Guardian (2001). Lloyd's Maritime Information Services shows around 1,300 industrial fishing vessels flying flags of convenience. Among the species being depleted by pirate boats is the Patagonian tooth fish, marketed as Antarctic ice fish and caught on long lines which also kill albatross and other sea birds. Patagonian tooth fish are worth £8 a kilo for sushi and sashimi and the illegal trade in this catch alone is worth £300m annually (Brown 2001).

Whaling activities took place between the 1930s and the 1980s. See the Fish and Fisheries for information on foreign fishing fleets harvesting marine resources and

specifically krill in the Antarctic LME. For more information on the commercial fishing of krill, see Hubold (2003).

The Antarctic continent has no indigenous inhabitants, but a history of researchers at various stations and, recently, tourists (abc.net 2000). Scientists live in research stations on a seasonal basis or year round to study weather and climate, oceanography, geology and glaciology. In 1999, over 10,000 tourists visited Antarctica, nearly all of them on commercial cruise ships. The International Association of Antarctica Tour Operators reports 37,522 tourists visiting Antarctica plus 2,430 staff and 19,890 crew members in 2006-2007 (www.iaato.org). No other economic activities are taking place in the LME. Iron ore, chromium, copper, gold, nickel, platinum, coal and hydrocarbons have been found in this region but are not being exploited (see Governance). The continent holds 70% of the Earth's freshwater.

V. Governance

Antarctica and the surrounding waters have a special status that required international cooperation. Seven countries originally made claims on Antarctica: England (1908), (New Zealand (1923), France (1924), Australia (1933), Norway (1939), Chile (1940) and Argentina (1943). There are special agreements pertaining to Antarctica's resources and its environmental protection. The Antarctic Region comes under an independent Regional Seas Programme. International cooperation takes place within the framework of the Antarctic Treaty, which covers the region south of 60° S latitude. The Treaty came into force in 1961 after ratification by the twelve countries then active in Antarctic science. Today 44 countries have ratified the Treaty. Its objectives are unique in international relations: to demilitarise Antarctica and establish it as a nuclear-free zone; to use it for peaceful purposes only; and to promote international scientific cooperation. In 1991, the Protocol on Environmental Protection to the Antarctic Treaty was signed, which *inter alia*, establishes the Committee for Environmental Protection. The Protocol entered into force 1998 and is aimed at ensuring the continued health of the Antarctic environment as a whole. It also includes an annex on waste disposal and waste management, but these restrictions could be difficult to enforce.

The Commission for Conservation of Antarctic Living Marine Resources (CCAMLR) was established to manage the LME's living marine resources using an ecosystems approach. Its international and ecological approach is a milestone in the conservation and management of living marine resources (see Scully *et al*. 1986, Scully 1993). Measures have been adopted by this convention to monitor and assess the level of marine debris from fishing vessels and the impact on marine living resources. There is a ban on oil exploration. Other conventions affecting Antarctica are: Agreed Measures for the Conservation of Antarctic Fauna and Flora (1964); the Convention for the Conservation of Antarctic Seals (1972); the Convention on the Regulation of Antarctic Mineral Resource Activities (1988); and the Convention on the Regulation of Mineral Resource Activities (CRAMRA 1991), which bans oil and mineral exploration for 50 years. The internationally coordinated CCAMLR-2000 Krill Synoptic Survey took place in January-February 2002 to determine krill pre-exploitation biomass in the west Atlantic subareas 48.1, 48.2, 48.3, and 48.4 in order to set precautionary catch limits for the krill fisheries in that region (Hewitt et al. 2004)

The Antarctic region is an international science laboratory where scientists study weather and climate, oceanography, geology and glaciology. Reporting of data for the Antarctic LME started in 1966.

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