the end of the melt season (i.e., perennial or multi-year ice) had decreased by about 1.3 m (4.3 ft) in most of the deep water portion of the Arctic Ocean. One limitation of submarine sonar data is sparse sampling, which complicates interpretation of the results (Serreze et al. 2007, pp. 1,533–1,536). Holloway and Sou (2002) noted concerns regarding the temporal and spatial sampling of ice thickness data used in Rothrock et al. (1999), and concluded from their modeling exercise that ''a robust characterization over the half-century time series consists of increasing volume to the mid-1960s, decadal variability without significant trend from the mid-1960s to the mid-1980s, then a loss of volume from the mid-1980s to the mid-1990s.'' Rothrock et al. (2003, p. 28) conducted further analysis of the submarine-acquired data in conjunction with model simulations and review of other modeling studies, and concluded that all models agree that sea ice thickness decreased between 0.6 and 0.9 m (2 and 3 ft) from 1987 to 1996. Their model showed a modest recovery in thickness from 1996 to 1999. Yu et al. (2004, p. 11) further analyzed submarine sonar data and concluded that total ice volume decreased by 32 percent from the 1960s and 1970s to the 1990s in the central Arctic Basin.

Fowler et al. (2004) utilized a new technique for combining remotely-sensed sea ice motion and sea ice extent to ''track'' the evolution of sea ice in the Arctic region from October 1978 through March 2003. Their analysis revealed that the area of the oldest sea ice (i.e., sea ice older than 4 years) was decreasing in the Arctic Basin and being replaced by younger (first-year) ice. The extent of the older ice was retreating to a relatively small area north of the Canadian Archipelago, with narrow bands spreading out across the central Arctic (Fowler et al. 2004, pp. 71–74). More recently, Maslanik et al. (2007) documented a substantial decline in the percent coverage of old ice within the central Arctic Basin. In 1987, 57 percent of the ice pack in this area was 5 or more years old, with 25 percent of this ice at least 9 years old. By 2007, only 7 percent of the ice pack in this area was 5 or more years old, and ice at least 9 years old had completely disappeared. This is significant because older ice is thicker than younger ice, and therefore requires more energy to melt. The reduction in the older ice types in the Arctic Basin translates into a reduction in mean ice thickness from 2.6 m in March 1987 to 2.0 m in March 2007 (Stroeve et al. 2008).

Kwok (2007, p. 1) studied six annual cycles of perennial (multi-year) Arctic sea ice coverage, from 2000 to 2006, and found that after the 2005 summer melt, only about four percent of the thin, first-year ice that formed the previous winter survived to replenish the multi-year sea ice area (NASA/JPL News Release, April 3, 2007). That was the smallest amount of multi-year ice replenishment documented in the study, and resulted in perennial ice coverage in January 2006 that was 14 percent smaller than in January 2005. Kwok (2007, p. 1) attributed the decline to unusually high amounts of ice exported from the Arctic in the summer of 2005, and also to an unusually warm winter and summer prior to September 2005.

Length of the Melt Period

The length of the melt period (or season) affects sea ice cover (extent and area) and sea ice thickness (Hakkinen and Mellor 1990; Laxon et al. 2003). In general terms, earlier onset of melt and lengthening of the melt season result in decreased total sea ice cover at the end of summer (i.e., the end of the melt season) (Stroeve et al. 2005, p. 3). Belchansky et al. (2004, p. 1) found that changes in multi-year ice area measured in January were significantly correlated with duration of the intervening melt season. Kwok found a correlation between the number of freezing and melting temperature days and area of multi-year sea ice replenished in a year (NASA/JPL News Release, April 3, 2007).

Comiso (2003, p. 3,506), using data for the period 1981–2001, calculated that the Arctic sea ice melt season was increasing at a rate of 10 to 17 days per decade during that period. Including additional years in his analyses, Comiso (2005, p. 50) subsequently found that the length of the melt season was increasing at a rate of approximately 13.1 days per decade. Stroeve et al. (2006 pp. 367–374) analyzed melt season duration and melt onset and freeze-up dates from satellite passive microwave data for the period 1979 through 2005, and found that the Arctic is experiencing an overall lengthening of the melt season at a rate of about 2 weeks per decade.

The NSIDC documented a trend of earlier onset of the melt season for the years 2002 through 2005; the melt season arrived earliest in 2005, occurring approximately 17 days before the mean date of onset of the melt season (NSIDC 2005, p. 6). In 2007, in addition to the record-breaking September minimum sea ice extent, NSIDC scientists noted that the date of the lowest sea ice extent shifted to later in the year (NSIDC Press Release, October 1, 2007). The minimum sea ice extent occurred on September 16, 2007; from 1979 to 2000, the minimum usually occurred on September 12. This is consistent with a lengthening of the melt season.

Parkinson (2000) documented a clear decrease in the length of the sea ice season throughout the Greenland Sea, Kara and Barents Seas, Sea of Okhotsk, and most of the central Arctic Basin. On the basis of observational data, Stirling et al. (cited in Derocher et al. 2004) calculated that break-up of the annual ice in Western Hudson Bay is occurring approximately 2.5 weeks earlier than it did 30 years ago. Consistent with these results, Stirling and Parkinson (2006) analyzed satellite data for Western Hudson Bay for November 1978 through 2004 and found that, on average, ice break-up has been occurring about 7 to 8 days earlier per decade. Stirling and Parkinson (2006) also investigated ice break-up in Foxe Basin, Baffin Bay, Davis Strait, and Eastern Hudson Bay in Canada. They found that ice break-up in Foxe Basin has been occurring about 6 days earlier each decade and ice break-up in Baffin Bay has been occurring 6 to 7 days earlier per decade. Long-term results from Davis Strait were not conclusive, particularly because the maximum percentage of ice cover in Davis Strait varies considerably more between years than in western Hudson Bay, Foxe Basin, or Baffin Bay. Conversely, Stirling and Parkinson (2006) documented a negative short-term trend from 1991 to 2004 in Davis Strait. In eastern Hudson Bay, there was not a statistically significant trend toward earlier break-up.

Understanding Observed Declines in Arctic Sea Ice

The observed declines in the extent of Arctic sea ice are well documented, and more pronounced in the summer than in the winter. There is also evidence that the rate of sea ice decline is increasing. This decline in sea ice is of great importance to our determination regarding the status of the polar bear. Understanding the causes of the decline is also of great importance in assessing what the future might hold for Arctic sea ice, and, thus, considerable effort has been devoted to enhancing our understanding. This understanding will inform our determination regarding the status of the polar bear within the foreseeable future as determined in this rule.

In general terms, sea ice declines can be attributed to three conflated factors: warming, atmospheric changes (including circulation and clouds), and changes in oceanic circulation (Stroeve and Maslowski 2007). Serreze et al.