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A One Hundred and Seventeen Year Coastal Water Temperature Record from Woods Hole, Massachusetts

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ABSTRACT: We have compiled what we believe is the longest coherent coastal sea surface temperature record in North America. Near-surface water temperature measurements have been made almost daily at Great Harbor, Woods Hole, Massachusetts, since 1886 with remarkably few gaps. The record shows that there was no significant trend in water temperature at this site for the first 60 yr of observation. There was some cooling during the 1960s that was followed by a significant warming from 1970–2002 at a rate of 0.04°C yr^{-1}. During the 1990s annual mean temperatures averaged approximately 1.2°C warmer than they had been on average between 1890 and 1970; winter (December, January, and February) temperatures were 1.7°C warmer and summer (June, July, and August) temperatures were 1.0°C warmer. There has not been a statistically significant decrease in the annual number of winter days below 1°C or an increase in the annual number of winter days above 5°C. The number of summer days each year with water temperature above 21°C has not increased significantly. The dates of first observations of 10°C and 20°C water in the spring have not changed sufficiently to be statistically significant. There is a weak positive correlation between annual and winter water temperature and the annual and winter North Atlantic Oscillation index, respectively, during the period of record.

Introduction

Because of its obvious biological importance and relative ease of measurement, one might suppose that long-term records of coastal ocean water temperature would be common. This is not the case. While the earliest record of air temperature measurements in the United States began in New Haven, Connecticut, in June 1778 (Loomis and Newton 1866), regular measurements of coastal water temperature did not begin until almost a century later. The early water measurements were made in connection with fledgling laboratories operated by the U.S. Commission of Fish and Fisheries, by the keepers of lightships and lighthouses, by members of the U.S. Signal Corps, and by those who attended the tide staffs of the U.S. Coast and Geodetic Survey (now National Oceanic and Atmospheric Administration, NOAA). Monthly averages of water temperature obtained by these sources at stations along the Atlantic and Gulf coasts were summarized through 1956 by Bumpus (1957). Of the 194 records he reported, over 90% had been maintained for 25 yr or less and another 9% covered a 25–50 yr period. Only Brenton Reef Lightship off Newport, Rhode Island (64 yr) had a continuous record exceeding half a century ending in 1942. The earliest regular measurements of coastal water temperature in the United States may have been collected at the U.S. Coast and Geodetic Survey tide station at the Presidio in San Francisco, California, between 1855–1877, but that record contains a 44-yr long gap between 1877–1921 (Carvalho and Maul 1997). The Presidio measurements ended in 1993.

Virtually all of the traditional bucket thermometer observations taken by tide observers at NOAA tide stations ended by the mid-1990s because of the gradual conversion of the tide gauges from float-driven analog recorders requiring daily readings to digital recorders with automated data collection platforms that do not require tide staff readings. While manual daily water temperature observations stopped in the transition, water temperature measurements continue at each tide station using water thermistors. The thermistors are at fixed elevations on support structures so that they only correspond to near-surface temperature measurements at low tide. Hourly water temperatures (and 6-min water elevations) are available at the NOAA website (http://co-ops.nos.noaa.gov). A recent analysis of temperature trends at 14 tide gauge stations in the United States was largely confined to the 1920s through the early 1990s, with the earliest record from 1911 continuing through 1991 (Maul et al. 2001).

There is one location for which it is possible to assemble a much longer record by compiling data

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collected by different agencies, albeit with gaps of a few years between the ending of one program and the start of another. Daily water temperature measurements were collected by the Branch of Fish Culture of the U.S. Commission of Fish and Fisheries at Great Harbor, Woods Hole, Massachusetts, beginning at least as early as January 1886 and continuing for 33 yr until 1919 (Bumpus 1957; Taylor et al. 1957). After an 8-yr gap, the U.S. Bureau of Fisheries resumed the sampling through December 1941 with a short lapse in 1930–1931. After a 26-mo hiatus during World War II, the U.S. Coast and Geodetic Survey, through the Woods Hole Oceanographic Institution (WHOI), assumed responsibility for collecting water temperature data in association with the operation of its tide gauge effective in March 1944 (Bumpus 1957). The WHOI measurements continued with relatively little change through 1997 and are ongoing with newer instrumentation. We believe that the total set of measurements collected over a 117-yr period at Woods Hole represents the longest coherent record of coastal ocean water temperature in North America. Our purpose in this note is to make the research community aware of this unique resource and to present some analyses of the data as they bear on the question of recent warming along the southern New England coast.

Temperature Measurements

The water temperature measurements summarized by Bumpus (1957) for Woods Hole began in January 1880. We have not included any of the measurements before January 1886 in our record or analyses, because it is almost certain that the earlier measurements were made in Little Harbor, a much shallower and more constricted embayment adjacent to Great Harbor, the site of all of the remaining measurements. While the Woods Hole Fisheries Laboratory was established in 1875, its first decade was spent in a vacant building owned by the Light House Board and located on the west shore of Little Harbor. A new residency, laboratory, and dock facility were completed on Great Harbor in February 1885 (Galtsoff 1962). A National Marine Fisheries Service laboratory constructed in the late 1950s continues to occupy the site today.

Beginning in 1944, the WHOI measurements were made from the end of the dock behind Bigelow Laboratory, approximately 200 m from the fisheries dock used earlier. The WHOI dock was extended in 1968, but a hole was left in the new dock at approximately the same location where the earlier dock ended. Water temperatures were measured to the nearest 0.1°F (~0.05°C) by lowering a bucket thermometer through this opening so that measurements were made at approximately the same distance from shore. The exact depth of the water sampled in this way is not known, but the bucket passed through approximately the surface meter and the temperature obtained is best described as applying to the near-surface water. The sampling place was sheltered by a small unheated shed.

The bucket sampling continued through November 1997 when a WHOI ARC Systems electronic thermistor was suspended at a fixed depth in the near-surface water at the same location. While the thermistor readings continue to be collected and recorded, they suffer from a lack of intercalibration with the earlier bucket thermometer readings. According to the installer of the WHOI thermistor (Dufur personal communication), agreement with the traditional bucket measurements was within 0.3°C, but no formal intercalibration was carried out. While the WHOI thermistor is read four times each day—0230, 0830, 1430, and 2030—only the 2030 reading is normally entered in the database that is available online (http://dunkle.whoi.edu/dlaweb/data/h2o/frameset.html).

Fortunately, in August 1995 a NOAA thermistor was also positioned on the same WHOI dock at a fixed depth 1.7 m below mean lower low water and 2.0 m below local mean sea level (relative to the 1983–2001 National Tidal Datum) about 43 m from where the bucket samples were collected (Gill personal communication). These data are available at the NOAA website given earlier. As described later, the 28 mo of overlapping data collection allowed us to develop a correction factor that can be used to adjust the ongoing NOAA measurements to the earlier bucket thermometer readings.

Bumpus (1957) had access to the original observer sheets and described the earliest data collected by the U.S. Commission of Fish and Fisheries and the U.S. Bureau of Fisheries at Woods Hole as consisting of twice daily measurements collected at first high water and first low water after 0700, except for the period between 1893 and 1897, when there was one reading per day ''at no specified time'' (Bumpus 1957, p. 44). There appears to have been a single person, Vinal Edwards, responsible for the temperature measurements throughout the entire time between 1886 and 1919. In his history of the Fisheries Service at Woods Hole, Galtsoff (1962, p. 16) described Edwards as ''. . . a most remarkable man. Without a formal scientific education he was a born naturalist who possessed the essential characteristics of a true scientist, with a great ability for accurate observation, correct recording of facts, and enthusiastic devotion to the study of nature.'' Edwards was in the continuous service of the Woods Hole fisheries station from the time of his employment by Spencer Baird in 1871 until his death on April 5, 1919. A 7 yr and 10 mo gap in the Woods Hole record began with April 1919. When readings resumed in 1927 through 1941, they were taken at 0800, 1200, and 1600 (Bumpus 1957).

The U.S. Coast and Geodetic Survey (1968, p. 2) described their water temperature measurements as ''usually made once each weekday at whatever time the observer attends the tide gage.'' Bumpus (1957, p. 46) described the measurements from 1944 through 1956 as being made once each day ''usually near noon.'' Our examination of the observer sheets for this period found that there was an interval between fall 1949 and fall 1952 during which readings were more commonly taken around 1500. After this time they returned to midday and remained there until July 1959. For 38 yr, from July 1959 through November 1997, the observer at Woods Hole was again a single individual, Dorothy Rogers, who commonly took her measurements around 1000. It is one of the remarkable features of the 117-yr long Woods Hole water temperature record that over 70 yr of it were collected by just two people.

In order to determine if the various changes in measurement time may have had a serious impact on the long-term record, we regressed the 0830 readings against the 2030 readings from the WHOI thermistor for each day of 2001 and found a very strong ($R^2 = 0.999$) linear relationship in which the morning temperature averaged 0.2°C warmer than the early evening. Average values for the 0230 and 1430 readings fell within this range. Given such a small offset, the likely error in thermometer and thermistor readings, and the lack of intercalibration between the bucket thermometer and the thermistor readings, we have not attempted to adjust the record for sampling time. The strong correlation among sampling times and the very small differences in mean temperature measured at four times each day over a year provide reassuring evidence that neither tides nor short-term hydrographic changes unduly confounded the temperature record from the site.

The Database

After compiling his monthly summary of the data for Woods Hole through 1956, Bumpus sent the observer logs with daily measurements to the U.S. Coast and Geodetic Survey in Washington. Attempts to retrieve those records from the NOAA archives have been unsuccessful because the original forms were sent to a private contractor for digitization (Lyles personal communication). Fortunately, copies of the measurements collected by WHOI were retained, and we have digitized the daily observations maintained in the WHOI archives between January 1945 and December 2002. During this 58-yr period, the average year encompassed 329 d of measurement and the sparsest year contained 211 d. Since 1960, only 1 yr had fewer than 300 observations and 95% of the years had measurements on more than 329 d or 90% of the year, impressive evidence of the dedication of the observers. We deleted 16 d from the total set of over 18,600 daily observations because the recorded temperature was ≤ -1.9°C, approximately the freezing point of coastal sea water. Only the years 1945 (5 d), 1948 (4 d), and 1981 (2 d) had more than 1 d removed in this process. It is more difficult to detect potential overestimates of the temperature. The warmest observation in the daily record was 25.3°C recorded on August 12 and 13, 1988, and the next warmest observation was 25.0°C recorded on August 11 and 14, 1988, and on August 7 and 8, 1980. We had no basis to exclude these data.

Of the 71 yr covered by Bumpus (1957) from 1886–1956, 13 have no data and one (1919) has only 3 mo of data. While this represents almost 20% of the time interval he summarized, the only gap longer than two consecutive years is an 8-yr period between 1918 and 1927. There are no missing years after 1943.

In eight isolated individual years where there was a single or partial month of observations missing and in 2 yr with a gap of two consecutive months, we patched the record by calculating the missing monthly mean or means using a second order polynomial regression derived from the 3 mo on either side of the gap. Five of the patches were used in the early Bumpus (1957) record and two in the record since 1956. These points are noted on the digital database that is available on the WHOI website given earlier. The 28 mo (August 26, 1995–December 31, 1997) during which both WHOI bucket thermometer and NOAA thermistor data (station #8447930) were collected allowed us to develop an intercalibration between the two sites and sampling schedules. While the sites were 43 m apart on the same dock, the NOAA site is at a fixed depth and is subject to more influence from water ebbing from Eel Pond, a small nearby coastal lagoon. The NOAA data are also collected hourly while the bucket measurements were only taken once each day. Out of a potential comparison base of 859 d, there were 763 d on which a full 24 h of NOAA data and a WHOI reading were available. We regressed the daily mean NOAA data against the WHOI bucket data for the 763 d when data from both locations were available (Fig. 1). This regression was used to adjust the NOAA read-

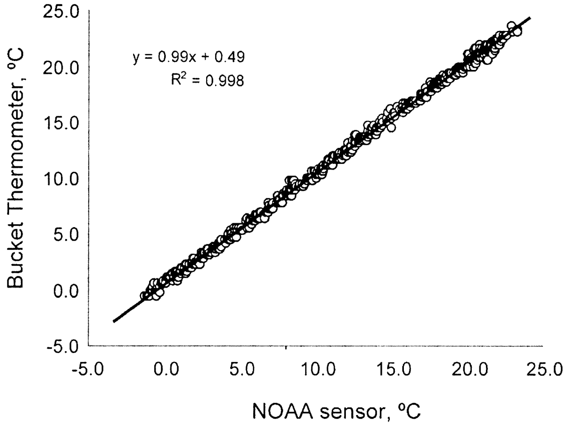

Fig. 1. Comparison of near surface water temperature measured once each day using a bucket thermometer deployed from a WHOI dock and the daily mean water temperature measured hourly by a NOAA thermistor at a fixed depth at a different position on the same dock (NOAA tide station #8447930). Measurements are from 763 days between August 26, 1995, and December 31, 1997. y = 0.99x + 0.49 (R^2 = 0.998).

ings to values that would have been observed at the long term-station using the bucket thermometer. It is these adjusted NOAA temperatures that have been used for 1998 through 2002 in the analysis that follows. While it would obviously be desirable to use measurements from the long-term WHOI site for these recent years, the lack of intercalibration between the bucket thermometer and the WHOI thermistor leads us to work with the adjusted NOAA measurements. Since both the WHOI thermistor measurements and the NOAA thermistor measurements are ongoing, it can only be hoped that an intercalibration at the WHOI site will be added in the future.

WARMING AT WOODS HOLE

Taylor et al. (1957, p. 294) reported that the mean annual water temperature at Woods Hole during 1945–1951 (11.3°C) was significantly warmer than it had been during four 8 or 9 yr intervals between 1885–1941 (10.1–10.6°C) and argued that the warming was having significant ecological effects. They emphasized, however, that "No prediction of future temperature trends is offered." Their caution was well placed. The much longer record now available clearly shows that the warming they saw was soon reversed by a cooling during the 1960s, followed by a much more sustained warming that has persisted through the last three decades (Fig. 2). Analysis of variance showed that a linear regression through the mean annual temperature for the 60 yr between 1886 and 1946 has a slope that is not significantly different from zero. During the 32 yr between 1970 and 2002, the same analysis showed a highly significant ($p \leq 0.0001$) slope with temperature increasing at 0.04°C yr^{-1} ($R^2 = 0.39$). If we calculate the warming trend beginning in 1960, the slope is also highly significant ($p \leq 0.0001$) and equal to 0.04°C yr^{-1}($R^2 = 0.57$). Beginning the trend analysis in 1950 during the warm period identified by Taylor et al. (1957), yields a significant ($p \leq 0.0001$) trend of just 0.02°C yr^{-1} ($R^2 = 0.28$).

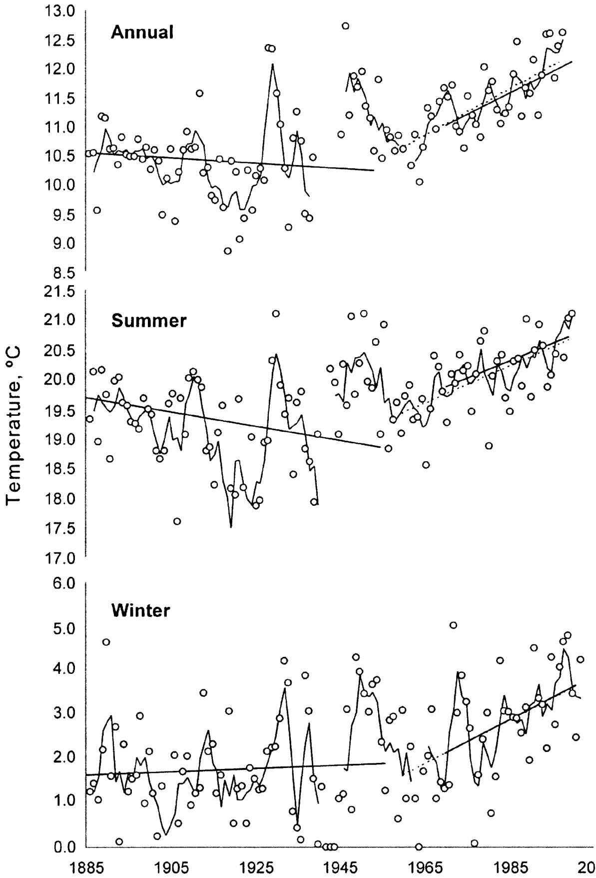

Fig. 2. Annual, summer (June, July, and August), and winter (December, January, and February) means of approximate daily water temperature measurements at Great Harbor, Woods Hole, Massachusetts, from January 1886 to December 2002. The curves are 3-yr running means. The solid straight lines are regressions through the periods 1886–1946 and 1970–2002. Slopes of the regressions for the first time interval are not significantly different from zero. All of the regression lines from 1970–2002 are significant with a winter warming trend of 0.05°C yr^{-1} and a summer warming of 0.03°C yr^{-1}. Statistics for the annual regressions are given in text. The broken straight lines are regressions for 1960–2002. They also have significant slopes with winter and summer warming trends the same as those for the 1970–2002 period.

The extent of warming may also be shown by comparison of decadal means, though large interannual variability makes statistical separation cumbersome for the data set as a whole (Table 1). The impact of warming on the seasonal water temper-

TABLE 1. Mean annual, winter (December, January, and February), and summer (June, July, and August) near-surface water temperature (°C) in Great Harbor, Woods Hole, Massachusetts, for each decade during which there are at least eight years of data from 1890–1999. Mean deviations for each time interval from the entire record mean are also given. Total record means (±SD) for annual, winter, spring, summer, and fall are 10.9 (0.7), 2.2 (1.3), 6.8 (1.0), 19.7 (0.7), and 15.0 (0.7), respectively. Annual and seasonal means calculated from monthly means reported by Bumpus (1957) for 1890–1956 and from unpublished approximate daily measurements thereafter. Decadal means of annual means with different letters are significantly different from one another. Winter and summer means each fall into four overlapping groups that preclude any simple separation.

	Mean Temperature			Deviation		
Years	Annual	Winter	Summer	Annual	Winter	Summer
1890–1899	10.6^{c}	2.0	19.5	−0.3	−0.2	−0.2
1900–1909	10.3^{c}	1.2	19.3	−0.6	−1.3	−0.4
1910–1919	10.5^{c}	1.7	19.4	−0.4	−0.4	−0.3
1920–1929						
1930–1939	10.6^{c}	2.4	19.3	−0.3	−0.2	−0.4
1940–1949			19.6			−0.1
1950–1959	11.3^{b}	2.8	19.9	0.4	0.6	0.2
1960–1969	10.7^{c}	1.9	19.5	−0.2	−0.3	−0.2
1970–1979	11.2^{b}	2.5	19.9	0.3	0.3	0.2
1980–1989	11.3^{b}	2.7	20.1	0.4	0.5	0.4
1990–1999	11.9^{a}	3.6	20.4	1.0	1.3	0.7

ature cycle may be seen easily by comparing the monthly means for the 1890s with those observed during the 1990s (Fig. 3). As seen in the Great Lakes records (McCormick and Fahnenstiel 1999), warming is greatest in winter and spring.

While the mean annual water temperature only exceeded 11°C five times during the 50 yr of measurements between 1886 and 1948, it did so 26 times in the 30 yr between 1970 and 2000. Out of the most recent 30 yr for which we have adequate data, 27 had annual mean temperatures above the mean for the record as a whole (Fig. 4). While the recent warming is most dramatic during the winter (December, January, and February), it is also evident in the summer (June, July, and August; Figs. 2 and 4, Table 2). Water temperatures during the 1990s averaged 1.2°C warmer over the annual cycle than they did during the decades between 1890 and 1970, while the winters averaged 1.7°C warmer and the summers 1.0°C warmer. Spring and fall temperatures were increased by 1.2°C and 0.8°C, respectively.

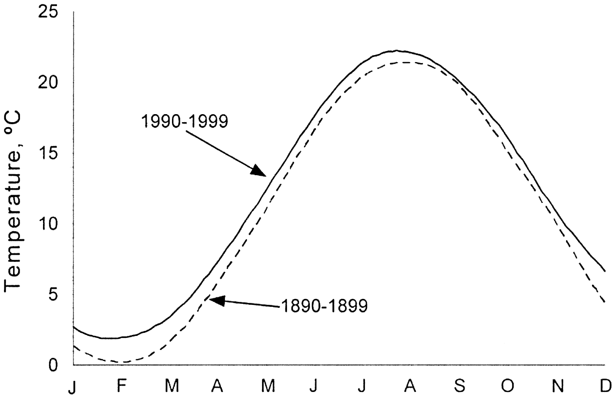

Fig. 3. Comparison of monthly mean near surface water temperatures at Woods Hole, Massachusetts, for 1890–1899 and 1990–1999. The mean water temperature of all of the months of the 1990–1999 decade were significantly higher at the 99% confidence level, except August and November, which were significantly higher at the 95% confidence level, and January and September, which were significantly higher at the 90% level. Smooth curves through the monthly means were fit with a cubic spline.

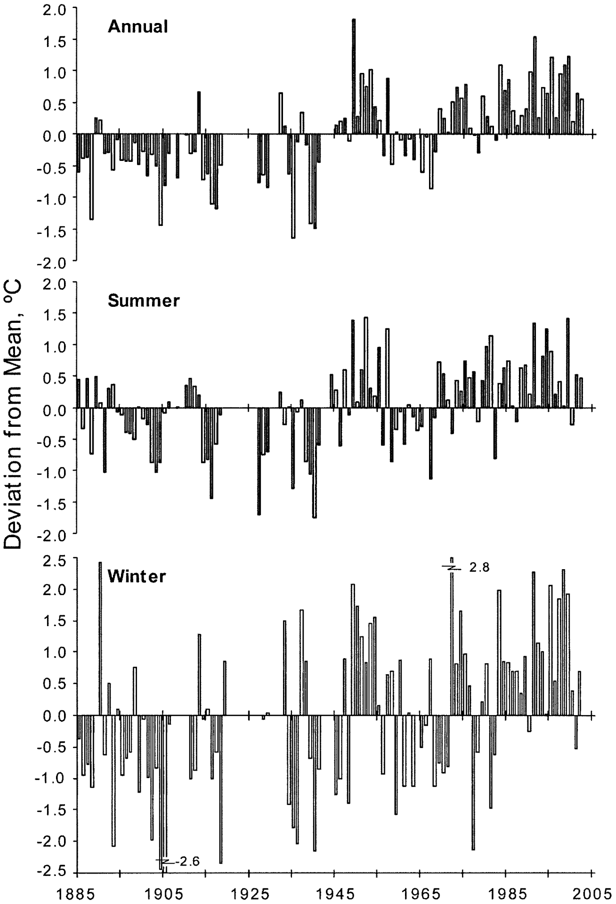

Fig. 4. Deviations of the annual mean, summer mean (June, July, and August), and winter mean (December, January, and February) water temperature at Great Harbor, Woods Hole, Massachusetts, from the mean for the period of record from January 1886 to December 2002.

The cooling seen in the water at Woods Hole during the 1960s is also present in air temperatures for the coastal northeast (Karl et al. 1994) and in water temperature at Boston Harbor and at Newport Harbor in nearby Narragansett Bay, Rhode Island (Fig. 5). There is also a strong overall correlation between the mean monthly water tempera-

TABLE 2. Years in which the mean monthly near-surface water temperature (°C) was warmest or coldest during winter (December, January, and February) and summer (June, July, and August) between 1886–2002 inclusive at Great Harbor, Woods Hole, Massachusetts.

Winter				Summer			
Coldest Month	Temp	Warmest Month	Temp	Coldest Month	Temp	Warmest Month	Temp
Feburary 1904	−1.7	December 2001	9.0	June 1916	15.0	August 2002	23.5
February 1905	−1.7	December 1953	7.8	June 1927	15.1	August 1999	23.1
February 1902	−1.7	December 1998	7.5	June 1940	15.1	August 1988	23.0
January 1904	−1.5	December 1982	7.2	June 1982	15.3	August 1980	23.0
February 1936	−1.4	December 1999	7.0	June 1935	15.3	August 1893	22.9

ture at Woods Hole and Newport Harbor during August 1955 to December 1994 when sampling coincided ($y = 0.89x + 1.36$; $R^2 = 0.98$, where y is the Newport temperature and x is the Woods Hole temperature). This indicates that the Woods Hole record may provide a useful proxy for historical water temperature trends in neighboring waters south of Cape Cod.

A review of the monthly means for the whole period of record revealed that the winter with the coldest month occurred in 1904 (−1.7°C) and the warmest month occurred in 2001 (9.0°C), giving a range of 10.7°C for the 117-yr period (Table 2). The warmest summer month fell in 2002 (23.5°C) and the coolest summer month in 1916 (15°C) for a record range of 8.5°C (Table 2).

We also examined the almost daily record at Woods Hole since 1945 to see how the changes in annual and seasonal means might be manifested in these data. For example, it seemed of interest to determine if the dates on which water temperatures first equaled or exceeded 10°C and 20°C might come earlier in the spring. The slopes of the linear regression lines correlating these dates with time are not significantly different from zero, so that the small changes apparent in the regression (6 d earlier for 10°C and 1.5 d for 20°C) cannot be accepted with confidence. The frequency of very warm days ($\geq$21°C) during summer was also not significantly different during any decade except the cool interval of the 1960s, when it was reduced ($p \leq 0.06$). The frequency with which the water temperature was $\geq$5°C during winter did not increase significantly through the record nor did the frequency of very cold (<1°C) days decrease.

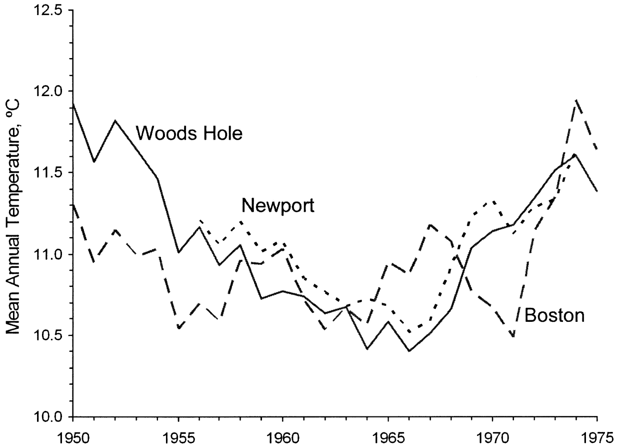

Fig. 5. Comparison of annual mean water temperatures based on approximately daily measurements at Woods Hole, Boston Harbor, and Newport, Rhode Island, showing cooling during the latter 1950s and most of the 1960s. Data from NOAA archives (Lyles personal communication). Lines are 3-yr running means.

The increase of at least 1.2°C in mean annual water temperature along the southern New England coast during the 1990s compared with conditions from 1890 through 1970 (Table 1) is much larger than recent estimates of warming for the surface 300 m of the world ocean (0.3°C between 1948–1998; Levitus et al. 2000) or for North Atlantic surface water from 1900–1991 (0.2–0.4°C; Cane et al. 1997). It seems increasingly clear that the large scale warming is due to anthropogenic greenhouse gasses (Barnett et al. 2001; Levitus et al. 2001). The rate of increase in the mean annual water temperature at Woods Hole since 1960 (0.04°C yr^{-1}) is slightly greater than the increase reported for a station in Newport Harbor between 1956 and 1997 (Hawk 1998). Maul et al. (2001) analyzed water temperature measurements at their sample of tide gauges by performing linear least squares regressions through the entire data set at each station (ranging from 29 to 79 yr in length) and reported the average trend over each of the varying time periods. The most rapid warming they reported was for Boston, Massachusetts (0.036°C yr^{-1}), followed by New York (0.018°C yr^{-1}), roughly consistent with our results. This consistency may be a fortuitous consequence of large interannual variability since our 32-yr averaging period is different from theirs ($n = 69$ and 61 yr for Boston and New York, respectively). We believe that the much longer Woods Hole record is particularly useful in showing that virtually all of the warming in the northeast relative to the conditions since the mid-1880s has occurred during the last 30 yr, and that it is most appropriate to divide the 117-yr record into two segments (Fig. 2). The Maul et al. (2001) analysis is intriguing because it suggests that the warming has been much less pronounced along the mid and southern Atlantic coast. At Key West, Florida, they found no significant temperature change between 1926 and 1994. A recent analysis of mean annual nearshore water temperatures from seven sites in the Great Lakes during various time periods in the 1900s found equivocal results, with two sites showing significant warming of 0.01°C yr^{-1}, two sites with a suggestion of warming, two sites with no temperature trend, and one site with cooling (McCormick and Fahnenstiel 1999). The lake data are very sensitive to the vertical position of the water sample relative to the thermocline and may provide a less sensitive record of long-term trends.

Working with a 40-yr water temperature record from Narragansett Bay, Hawk (1998) reported a very weak ($R^2 = 0.28$) but statistically significant positive relationship between winter (defined as January, February, and March) water temperature and the winter North Atlantic Oscillation (NAO) index (Hurrell 1995). Using NAO index data provided online by the Climate Analysis Section, National Center for Atmospheric Research (NCAR), Boulder, Colorado (Hurrell 1995), we found similar very weak but statistically significant positive linear correlations in the 1886–2000 water temperature record from Woods Hole, including mean annual temperature deviation and annual NAO index ($p \leq 0.03$, $R^2 = 0.05$), mean winter (December, January, and February) temperature deviation and winter NAO ($p \leq 0.0001$, $R^2 = 0.17$), and mean winter temperature and winter NAO index (Fig. 6). While the significance of the slopes is consistent with the hypothesis that the NAO index may play some role in the yearly variation of the coastal water temperature in this region, the predictive power of the weak correlations is very small (Prairie 1996).

The biological consequences of a transient warming of the coastal water in New England attracted attention (perhaps prematurely, but presciently) almost half a century ago (Taylor et al. 1957). The more dramatic increases of recent decades have stimulated further research and speculation, notably with regard to the relative abundance of fish species (e.g., Jeffries and Johnson 1974; Jeffries and Terceiro 1985; Jeffries 2002), the suppression of the winter–spring bloom of phytoplankton (e.g., Keller et al. 1999, 2001; Oviatt et al. 2002), the acceleration of the seasonal development of ctenophore populations (Sullivan et al. 2001), a northern extension of the range of the oyster disease Dermo (Cook et al. 1998), and the decline of eelgrass (Bintz et al. 2003; Keser et al. 2003). If the relatively modest temperature increases documented so far have been responsible for some of the major ecological changes attributed to them, the consequences of further warming, should it occur, will almost certainly be profound (Scavia et al. 2002).

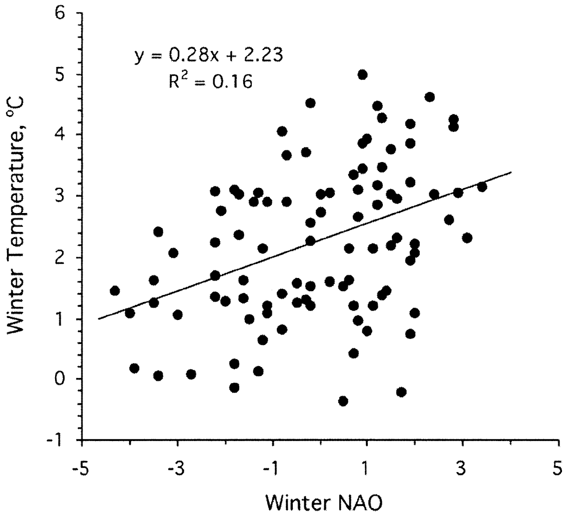

Fig. 6. Relationship between the winter (December, January, and February) mean of approximate daily water temperature measurements at Great Harbor, Woods Hole, Massachusetts, and the North Atlantic Oscillation index (NAO) for 1886–2000. The line is a functional regression (Ricker 1972) with a slope that is significantly different from zero ($p \leq 0.0001$). NAO index data provided online by the Climate Analysis Section, NCAR, Boulder, Colorado (http://www.cgd.ucar.edu/~jhurrell/nao.html).

ACKNOWLEDGMENTS

This paper is dedicated to the memory of Vinal Edwards of the Fisheries Station, Woods Hole, long deceased, and the late Dorothy Rogers, recently retired from the Woods Hole Oceanographic Institution. Their care and dedication provided over 70 years of the data presented herein.

The regular measurement of coastal water temperature at Woods Hole and many other locations began and was sustained through its early decades because of the broad and perceptive views of Spencer Fullerton Baird, Assistant Secretary of the Smithsonian Institution. In 1871, Baird was appointed by President Ulysses S. Grant as the first U.S. Commissioner of Fisheries and his efforts laid the foundation for what has become the National Marine Fisheries Service.

We have been helped greatly in assembling this record by numerous people, including Sandy Williams, Rocky Geyer, Terry Rioux, and John Farrington at WHOI, Jay Dufur, formerly at WHOI, Stephen Gill of NOAA, Jennifer Stone Gaines of the Woods Hole Historical Museum, and Michael Pilson, Candace Oviatt, and Perry Jeffries at the Graduate School of Oceanography, University of Rhode Island. This work was supported in large part by the Rhode Island Sea Grant College Program.

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