

Temporal Changes in Delaware Waters Using Long-Term (1967–2019) Water Temperature Data

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Abstract: The present article provides long-term (1967–2019) water temperature data collected from Delaware water quality monitoring sites. In Delaware, there are approximately 140 water quality monitoring sites in Piedmont, Delaware Bay, Chesapeake Bay, and Inland Bay drainage basins. Long-term quarterly (i.e., four times a year: Q1—January–February–March; Q2—April–May–June; Q3—July–August–September; Q4—October–November–December) water temperature data were calculated from each water quality monitoring sites' continuous monthly data. This study focuses on water quality monitoring sites with significant (p -value identifying linear regression model) increasing or decreasing trends of water temperature. Quarterly water temperature data, statistical analysis, and maps showing increasing and decreasing trend from water quality monitoring sites with significant trends are presented in this article.



Citation: Paudel, B.; Brown, L.M. Temporal Changes in Delaware Waters Using Long-Term (1967–2019) Water Temperature Data. *Data* **2021**, *6*, 79. <https://doi.org/10.3390/data6080079>

Academic Editor:
Juan-Carlos Jiménez-Muñoz

Received: 1 July 2021
Accepted: 21 July 2021
Published: 24 July 2021

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Dataset: <https://www.waterqualitydata.us/portal/>.

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Keywords: Delaware; long-term monitoring; water temperature; stream; pond; temperature change

1. Summary

The water temperature data provided here were collected from Delaware water quality monitoring sites. These monitoring sites are in four designated watershed drainage basins along north to south gradients in the state (Piedmont, Delaware Bay, Chesapeake Bay, and Inland Bay) (Figure S1). Water temperature data were collected from 1967 to 2019 from streams (including tidally influenced sites) and ponds sites with discrete monitoring prior to 1998 (some missing data during this period) and continuous monthly monitoring from 1998 to 2019. Quarterly (i.e., 12 months of data were divided into four quarters, i.e., Q1: January–February–March; Q2: April–May–June; Q3: July–August–September; Q4: October–November–December) average water temperature data were obtained from 71 sites' continuous monthly measurements (Table S1; Excel file attached as Supplementary Materials file). The quarterly average data were analyzed for trends using linear regression. Estimated model fits were evaluated based on coefficient of determination (R-square), coefficient of variation, and p -value. The significant quarterly data from each site, and the significant model fit results, were plotted (Figures S2–S5) and tabularly summarized (Table S2). Water quality monitoring sites with a significant quarterly increasing or decreasing trend over the 52-year period were mapped by watershed (Figures S6–S9). Water temperature and its monitoring are important to see changes over time as fluctuations of water temperature could affect ecological conditions of water bodies, hence the Delaware Department of Natural Resources and Environmental Control started monitoring in the 1960s.

2. Data Description

The data provided here were contained in Excel files, including water temperature data collected from each watershed basin. Quarterly water temperature data since 1967 are provided in Table S1. Monthly temperature data were collected monthly by DE DNREC since the 1960s, however, there were numerous missing values over the 50+ years, which is why we have presented the quarterly average. Quarterly (i.e., 12 months of data were divided into four quarters, i.e., Q1: January–February–March; Q2: April–May–June; Q3: July–August–September; Q4: October–November–December) average water temperature data were collected from 71 stations' continuous monthly measurements from 30 different watersheds in four basins in three different counties in the state of Delaware.

Water temperature data collected from each station were analyzed for increasing or decreasing trends over the 50+ years. Station data that showed significant quarterly increasing or decreasing trends over the 50+ years are presented in Table S2. Linear regression results that show significant changes are presented (Table S2). In addition to the watershed names presented in Table S1, in Table S2, specific latitude and longitude are also provided.

Water quality monitoring stations collected from different watersheds are shown in Figure S1. The present data were visualized in figures that show model fit plots for sites with significant quarterly increasing or decreasing temperature trends (Figures S2–S5). In addition, sites with significant changes were mapped and are shown in Figures S6–S9.

3. Experimental Design, Materials and Methods

To assess water quality conditions, the Delaware Department of Natural Resources and Environmental Control (DNREC) has monitored water quality in its stream, lake, and coastal waters since the late 1960s. The monitoring sites are along the north–south gradient that covers four drainage basins, Piedmont (northern), Delaware Bay (central), Chesapeake Bay (central), and Inland Bay (southern), encompassing 45 watersheds [1,2]. At present, there are 139 monitoring sites in the state of Delaware (Figure S1). Out of 139 sites, monitoring in 23 sites occurs monthly and they are considered as category 1 sites, the other 116 sites are category 2 and are monitored on a 5-year rotation basis [3]. The two categories are solely for water quality monitoring purposes. Category 1 monitoring sites are either co-located with United States Geological Survey stream gauging station or are located at the mouth of a tidal river. Water quality monitoring for category 2 monitoring sites is based on a 5-year rotation scheme, in which monthly monitoring is conducted on two priority basins and bi-monthly monitoring occurs in another three basins [3]. Over the past 52 years, the frequency of monitoring varied depending upon the funding, scope, and objectives of projects during that time. For instance, during the late 1960s, the main objective of the DNREC was to monitor water quality conditions, while efforts during the early 1990s were to collect data to build and calibrate several water quality and hydrodynamic models. Due to budget constraints prior to the 1990s, data collection was limited to quarterly sampling. Beginning in the 1990s, to cope with the water quality impairments due to nutrient enrichment and high bacteria levels, the state of Delaware worked to establish total maximum daily loads (TMDLs) [4]. Most TMDLs were developed by 2006 [5]. Since then, more frequent monitoring (i.e., monthly samplings) was established to collect data to track water quality changes.

Grab sampling during field measurements was performed and temperature data were collected in the field using a dial thermometer (from 1967 until the late 1990s) and YSI sondes (model 6290 and YSI EXO since the late 1990s), and all the field collection protocols used USGS field manual [6]. For this analysis, 71 sampling sites were used to assess long-term water temperature changes. These sites all had at least 10 years of water temperature data records. Variation in temperature due to changing of the seasons was observed in quarterly data as compared to the yearly average. As water temperature data were averaged by the quarter, those years with missing values were removed. Data used in the analysis are listed in Table S1. The data were analyzed for long-term trends. Linear

regression analysis was performed using data for each quarter for all selected sites and the results are tabulated in Table S2. Linear regression analysis in SAS was performed using the PROC REG procedure and all the fitted plots were obtained with the SAS ODS graphics designer [7,8]. ESRI Arc GIS Pro version 2.7 was used to visualize the sites with significant quarterly increasing or decreasing trends.

4. User Notes

Data can be utilized to investigate the effects of global temperature changes on stream water temperature changes. These long-term (since 1967) water temperature data help fill potential data gaps needed to identify effects of climate change on water temperature. Furthermore, fishery scientists can utilize the stream water temperature data to look for relationships between temperature and population and/or species shifts. Scientists, managers, and other stakeholders can benefit from these stream temperature data and supporting analyses. The long-term water temperature data also allow for the investigation of temporal changes in stream temperature. In addition, water temperature data can be used to examine factors that may be causing ecological shifts in an area.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/data6080079/s1>, Figure S1: State of Delaware water quality monitoring sites, Figures S2–S5: Temperature fit plots for quarters 1–4, Figures S6–S9: Maps showing water temperature changes in Delaware for quarters 1–4, Table S1: Mean quarterly water temperatures for water quality monitoring sites since 1967, Table S2: Summary results from water quality monitoring sites that showed significant changes in quarterly water temperatures.

Funding: This work was supported by State general fund.

Data Availability Statement: All the figures (Figures S1–S9) and tables (Tables S1 and S2) mentioned in the text are available in the supplementary materials. Authors can download water quality data from <https://www.waterqualitydata.us/portal/> (accessed on 22 July 2021).

Acknowledgments: The authors would like to thank all the staff of the Delaware Department of Natural Resources and Environmental Control who participated in the data collection. The present study was fully supported by the Delaware state general funds since the beginning of water quality monitoring efforts. The authors are grateful for the guidance and suggestions from Steve Williams, Brad Smith, Mark Biddle, and David McQuaide. We appreciate efforts by Hassan Mirsajadi and David Wolanski in reviewing the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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