Research Article

Long-term water quality trends in Tampa Bay (1974-2020).

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Abstract The Environmental Protection Commission of Hillsborough County (EPCHC) established a comprehensive surface water quality monitoring program in 1972 which encompasses all of Tampa Bay as well as major and minor tributaries within Hillsborough County. The program is one of the longest continuous monitoring programs in the United States and has grown to 272 total stations including 135 monthly stations plus an additional 52 monthly hydrographic profile stations and 85 minor tributary stations sampled quarterly. A multi-parameter water quality index (WQI) was developed by EPCHC for evaluating surface water quality trends in Tampa Bay. The WQI incorporates seven parameters including turbidity, Secchi depth, fecal indicator bacteria, chlorophyll a, total phosphorus, total nitrogen, and bottom dissolved oxygen. Tampa Bay water quality has shown dramatic improvements since the 1970s, particularly with decreases in chlorophyll a and fecal coliform which is likely attributed to the advent of advanced wastewater treatment in the early 1980s. These changes are reflected in increasing WQI scores over time with recent annual mean WQI scores falling within the "A" to "B" range as opposed to "D" and "F" scores which were prevalent in the 1970s – mid-1980s.

Keywords Historical Trends, Tampa Bay, Water Quality Monitoring,

Introduction

The Environmental Protection Commission of Hillsborough County (EPCHC) has been collecting monthly water samples and taking *in situ* field measurements at 52 stations within Tampa Bay since the 1970s (Figure 1) as part of the agency's long term surface water quality monitoring program. Tampa Bay water quality has shown improvements over time, most notably with decreases in chlorophyll a, nutrients and fecal coliform bacteria, since the initiation of advanced wastewater treatment (AWT) in the early 1980s (Sherwood et al 2016). Trends in water temperature and pH however indicate the influence of global climate change on Tampa Bay. The data collected by the EPCHC has been instrumental to bay area managers in developing restoration strategies for Tampa Bay and documenting the success of the bay's recovery.

Material and Methods

Surface, mid-depth and bottom *in situ* field measurements for temperature, salinity, pH, conductivity, and dissolved oxygen are taken at each station using a Hydrolab

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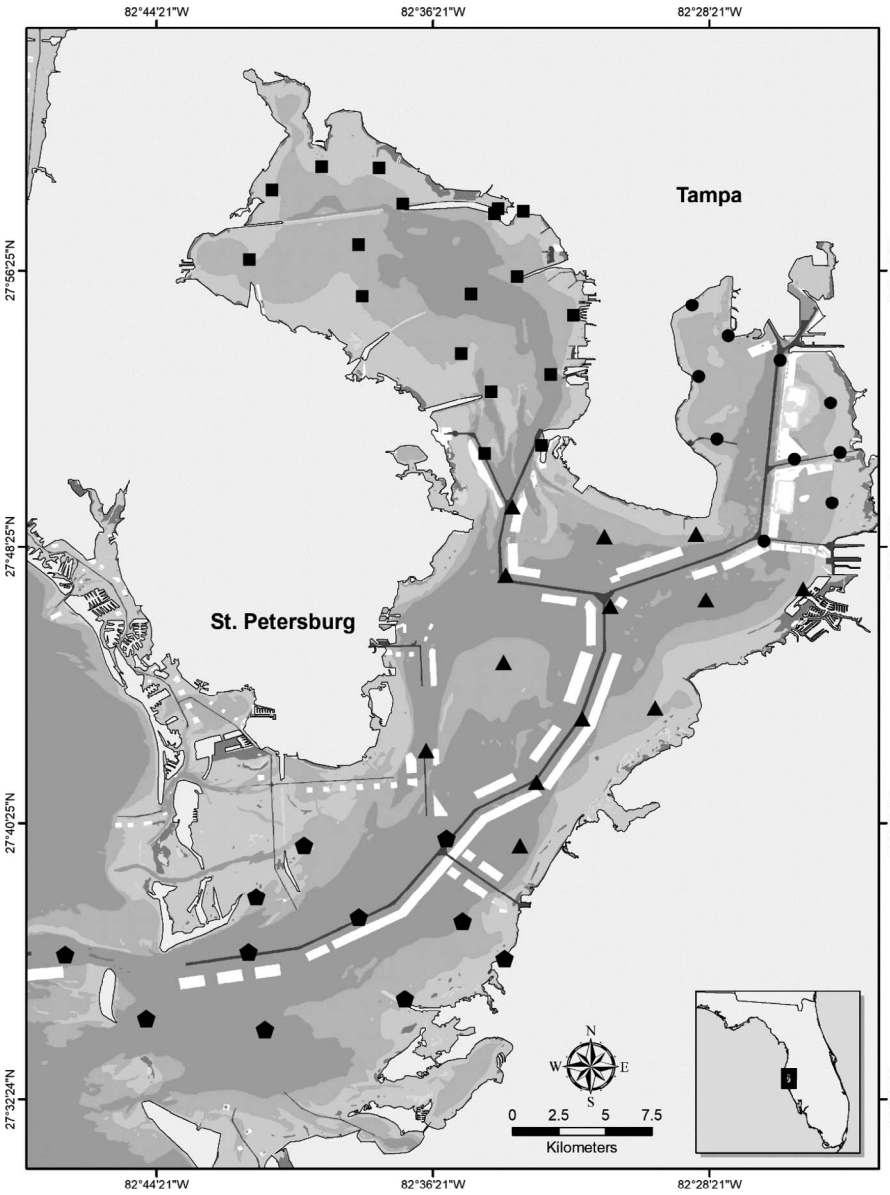

Figure 1. Map of Tampa Bay and EPCHC monthly water quality monitoring stations. Station symbols designate bay segment: circle = Hillsborough Bay; square = Old Tampa Bay; triangle = Middle Tampa Bay; pentagon = Lower Tampa Bay

multi-probe sonde. Effective light penetration is visually measured at each station with a Secchi disk. Water samples are collected at mid-depth for laboratory analysis for nutrients, chlorophyll, bacteria, turbidity, color and other water chemistry parameters. Overall water quality is summarized using a Water Quality Index (WQI) developed by EPC specific to Tampa Bay water quality targets (Karlen et al. 2014) and based on similar indices developed for Chesapeake Bay (Williams et al. 2009; Zhang et al., 2018). The Tampa Bay WQI is based on 7 parameters: Chlorophyll a; Total Nitrogen; Total Phosphorus; Bottom Dissolved Oxygen; Fecal Coliform; Secchi depth; Turbidity and scored on a pass/fail basis where the parameter is scored a 1 if it is meeting its water quality criteria or scored a 0 if it is not meeting the specified criteria. Individual parameter targets are derived either from Florida state water quality criteria or bay segment specific targets adopted by the Tampa Bay Estuary Program or are calculated based on historical data (Karlen et al. 2014). The final WQI is calculated as the mean of the 7 parameter scores for a given sample multiplied by 100 resulting in a final score on a 0-100 scale. The sample WQI scores can be further averaged by location and/or time period. Final WQI scores are further assigned a letter grade and color code as follows:

A [Dark Green] = 90 – 100; B [Light Green] = 80 – 90; C [Yellow] = 60 – 80; D [Orange] = 30 – 60; F [Red] = 0 – 30.

Results

Temperature and Bottom Dissolved Oxygen. Tampa Bay water temperature has shown an increasing trend over time (Figure 2A). Average annual bottom dissolved oxygen (DO) was above 4 mg/L in all bay segments, but Hillsborough Bay consistently had the lowest bottom DO across all years. There was an overall decrease in DO in the early to mid-1980s (Figure 2B), which corresponded to decreases in eutrophication during this time period.

Effective Light Penetration (Secchi depth). Effective light penetration (Secchi depth) showed an overall increase since the late 1970's across all four bay segments (Figure 2C). The greatest improvements were seen in HB and MTB which have met or exceeded their TBEP targets for most years since the mid-1980′s. OTB, however, consistently did not meet its target which may be due to higher chlorophyll levels and nutrient loading in that part of Tampa Bay.

Turbidity. There was a bay-wide trend of increasing turbidity through the late 1980's peaking in 1991, most notably in Hillsborough Bay (Figure 2D). Since then, turbidity has decreased across all bay segments.

pH. The pH in Tampa Bay declined in the early 1980's corresponding to decreases in eutrophication in the bay after the introduction of advanced wastewater treatment (AWT). The pH showed an increasing trend from the mid-1980′s until around 2010 (Figure 2E), however monthly pH values have been generally decreasing over the past 10 years (Figure 3). Extreme high pH values seen in July 2017 are attributed to a bloom of the dinoflagellate *Pyrodinium bahamense* in Old Tampa Bay, followed by a dramatic drop in September 2017 due to heavy rainfall from hurricane Irma (Figure 3).

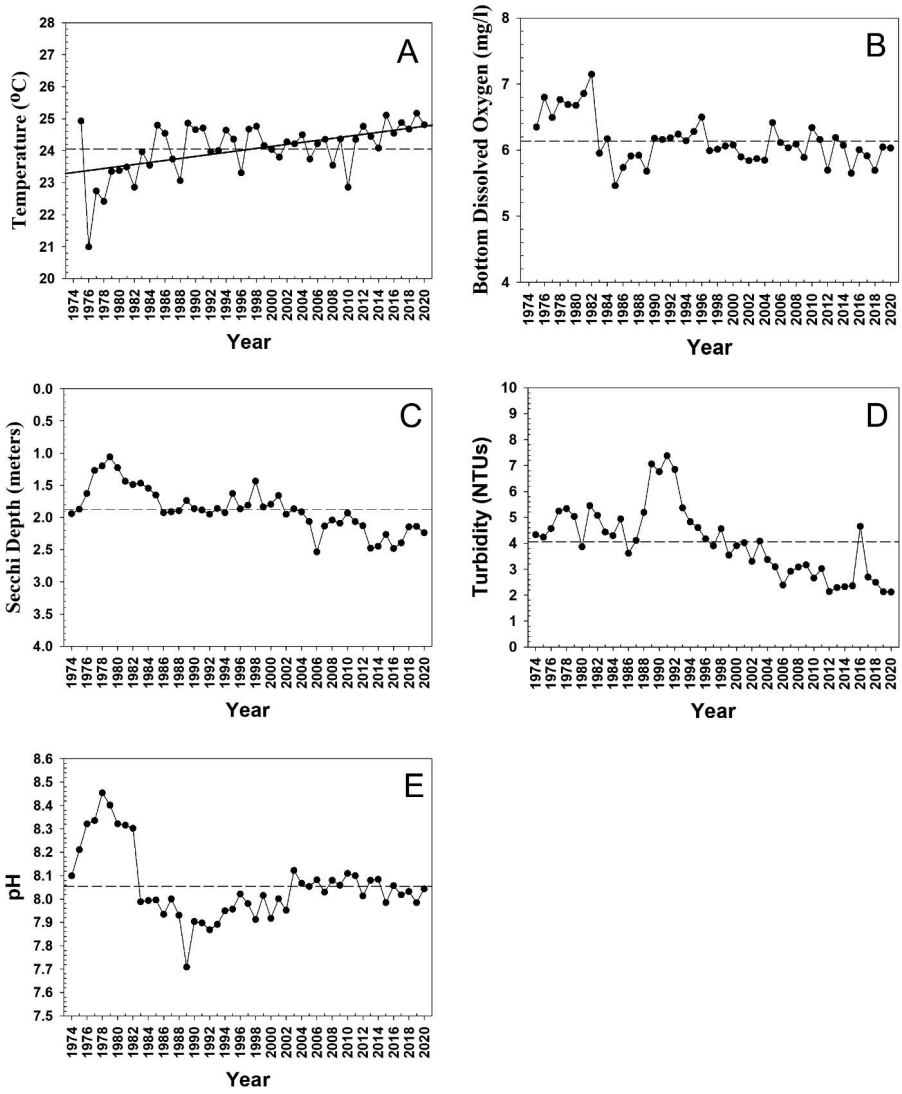

Figure 2. (A) Mean annual mid-depth water temperature 1974-2020. Dashed line represents historical mean. (B) Mean annual bottom dissolved oxygen 1974-2020. Dashed line represents historical mean. (C) Mean annual Secchi depth 1974-2020. Dashed line represents historical mean. (D) Mean annual turbidity 1974-2020. Dashed line represents historical mean.(E) Mean annual mid-depth pH 1974-2020. Dashed line represents historical mean.

Nutrients. Total nitrogen (TN) has generally been highest in Hillsborough Bay and between 1980-2000 bay-wide values show several peaks during high rainfall years (Figure 4A). Since 2000, TN values have been decreasing bay-wide (Figure 4A). Historic trends for total phosphorus (TP) show a decrease in all bay segments since the 1970's (Figure 4B) due in part to AWT.

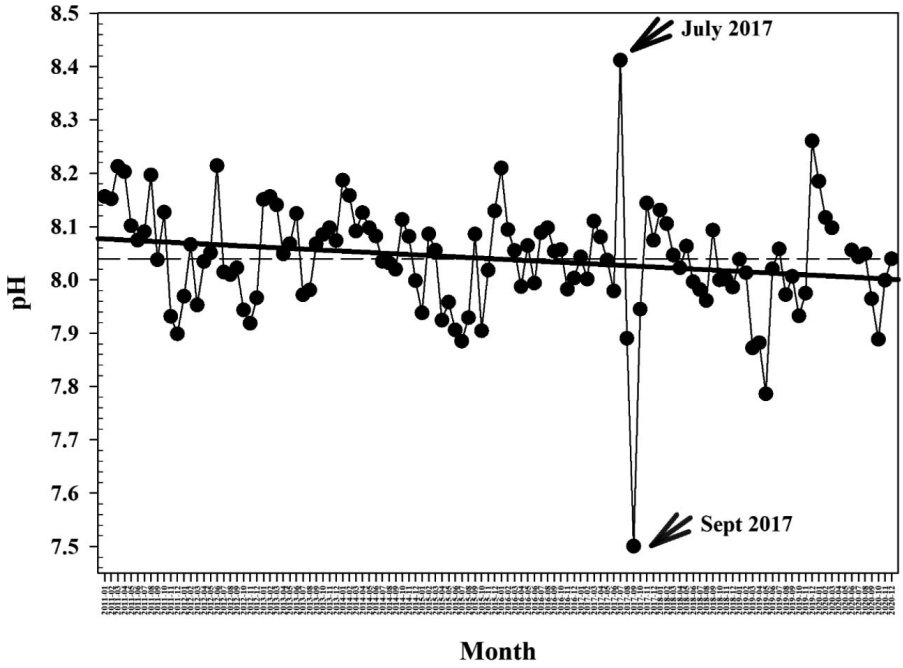

Figure 3. Mean monthly mid-depth pH 2011-2020. Dashed line represents historical mean. Peak on July 2017 due to *Pyrodinium bahamense* bloom, low value in September 2017 was due to Hurricane Irma

Chlorophyll a. There was a decline in Chl a concentrations in the early 1980's which can be attributed to the conversion to AWT. All bay segments have generally been at or below the target levels set by the TBEP since the late 1980s except for peaks during high rainfall years or algal bloom events (Figure 4C). Old Tampa Bay however has consistently failed to meet its targets and remains an area of concern.

Fecal Coliform. Annual mean fecal coliform levels in Hillsborough Bay exceeded 800 cfu/100 mL during the late 1970's but dropped dramatically since then (Figure 4D). A similar drop was noted bay-wide and can be attributed to the implementation of AWT systems at regional sewage treatment plants during this time period.

Water Quality Index. Historical trends in the WQI indicate overall improving water quality bay-wide and among the four bay segments (Figure 5; Table 1). The annual bay wide WQI grades were consistently in the "D" range during the earlier years of the monitoring program (1974-1985). Water quality started to show improvements in the late 1980's and bay-wide WQI grades of "C" were seen annually from 1980 – 2004 with one exception (1998) due to high rainfall that year. From 2005 – 2020 the bay-wide WQI grade has consistently been a "B" across most bay segments. Plankton blooms of *Karenia brevis* in Lower Tampa Bay and *Pyrodinium bahamense* in Old Tampa Bay however have resulted in lower WQI values in those bay segments during several recent years (Table 1).

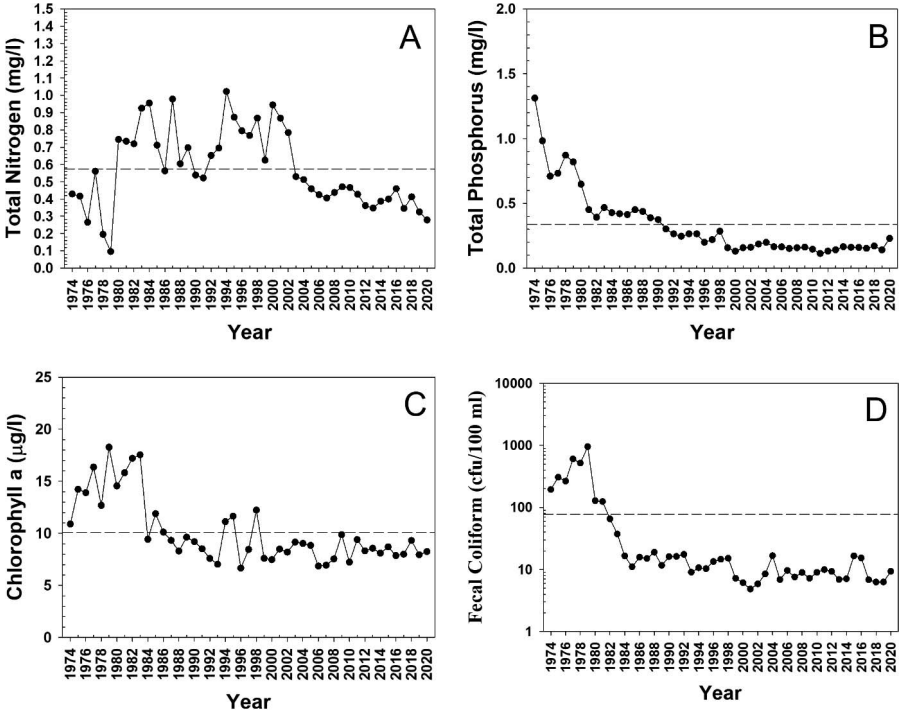

Figure 4. (A) Mean annual total nitrogen 1974-2020. Dashed line represents historical mean. (B) Mean annual total phosphorus 1974-2020. Dashed line represents historical mean. (C) Mean annual chlorophyll a 1974-2020. Dashed line represents historical mean. (D) Mean annual fecal coliform 1974-2020. Dashed line represents historical mean.

Discussion

Water quality conditions in Tampa Bay have shown tremendous gains since the early 1970's. Challenges remain however despite the improvements seen over the last 40 years. Climate change and population growth continue to add stress to Tampa Bay through increased stormwater runoff and nutrient loading, warmer water temperatures and lower pH. These effects have been seen especially in Old Tampa Bay which has experienced repeated blooms of the toxic dinoflagellate *Pyrodinium bahamense* (Karlen and Miller, 2011; Karlen and Campbell 2012; Corcoran et al 2017; Lopez et al 2019) and loss of seagrasses. Climatic events, such as Hurricane Irma in 2017, can also have noticeable impacts on the bay water quality as can isolated industrial accidents and infrastructure failures.

The historical improvements to Tampa Bay's water quality can be attributed to several factors. One event which likely has had the greatest impact was the Grizzle-Figg Advanced Wastewater Treatment Act passed in 1978 and the subsequent upgrades to wastewater treatment facilities discharging into Tampa Bay. The positive effects of this legislation are reflected in the dramatic decreases in fecal coliform, nutrients and Chlorophyll a concentrations observed through the 1980's

Table 1. Tampa Bay Water Quality Index scores by bay segment and bay-wide mean and grade. WQI Grade: A = 90-100 (Dark Green); B = 80-90 (Light Green); C = 60-80 (Yellow); D = 30-60 (Orange); F <30 (Red)

Year	HB	OTB	MTB	LTB	Bay-wide	Grade
2020	90.57	83.10	90.93	81.17	85.96	B
2019	92.60	85.19	93.42	83.13	88.04	B
2018	85.60	83.37	89.68	79.37	84.33	B
2017	89.64	83.80	93.41	87.10	87.89	B
2016	85.83	80.36	86.31	75.50	81.66	B
2015	91.90	85.52	90.24	79.10	86.37	B
2014	91.27	89.42	91.67	85.71	89.44	B
2013	89.64	86.97	91.87	86.11	88.42	B
2012	88.45	87.24	90.38	82.94	87.20	B
2011	90.48	76.92	86.02	87.53	84.05	B
2010	89.56	81.08	88.49	78.37	83.79	B
2009	85.99	82.01	87.91	82.74	84.30	B
2008	86.31	86.57	89.98	79.62	85.71	B
2007	90.83	82.40	87.85	85.33	85.95	B
2006	91.79	89.62	93.95	82.64	89.42	B
2005	86.90	81.86	86.51	76.09	82.57	B
2004	85.32	76.64	86.61	71.23	79.36	C
2003	79.24	72.04	83.23	70.18	75.73	C
2002	81.47	74.43	85.12	69.68	77.36	C
2001	80.83	69.40	75.50	66.59	72.54	C
2000	80.60	77.85	76.43	58.61	73.99	C
1999	83.42	77.83	82.44	65.87	78.08	C
1998	60.37	64.06	54.91	52.06	59.48	D
1997	77.82	71.23	73.49	72.03	73.52	C
1996	78.55	70.51	78.57	75.47	74.86	C
1995	66.29	66.18	68.48	59.20	65.64	C
1994	64.88	64.41	64.83	59.83	63.84	C
1993	79.62	67.36	76.70	67.95	72.18	C
1992	73.06	69.16	74.43	66.28	70.57	C
1991	67.14	65.81	70.72	66.03	67.31	C
1990	67.64	55.56	63.97	63.54	61.74	C
1989	60.00	54.39	60.42	58.45	57.85	D
1988	63.23	66.01	70.07	67.89	66.85	C
1987	57.38	52.05	62.00	68.61	59.15	D
1986	60.93	62.48	71.26	73.41	66.67	C
1985	48.67	59.44	58.13	66.34	58.49	D
1984	57.86	45.62	57.14	62.93	54.64	D
1983	48.68	48.41	50.00	53.82	50.04	D
1982	48.05	50.45	50.27	57.95	51.58	D
1981	43.63	42.18	43.82	45.78	43.65	D
1980	53.10	37.04	35.43	38.46	40.18	D
1979	45.95	38.07	39.38	41.23	40.66	D
1978	45.71	45.55	38.46	43.10	43.36	D
1977	48.99	40.48	42.91	45.31	43.92	D
1976	50.16	43.22	53.57	48.54	48.26	D
1975	52.86	43.60	48.95	48.36	47.76	D
1974	54.06	45.76	48.33	46.29	48.34	D

HB = Hillsborough Bay; OTB = Old Tampa Bay; MTB = Middle Tampa Bay; LTB = Lower Tampa Bay; Bay-wide = overall mean

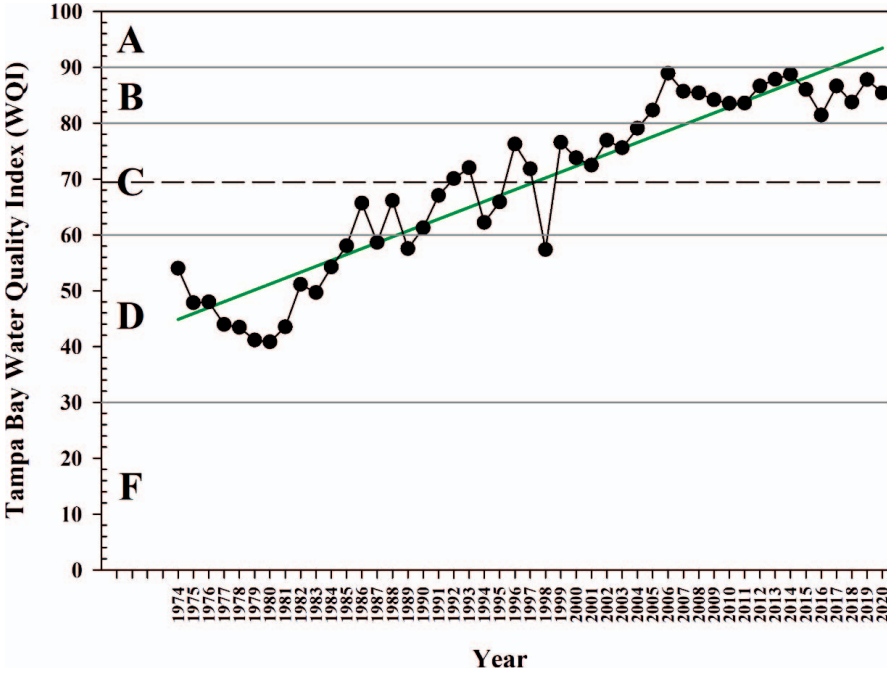

Figure 5. Mean annual Water Quality Index score 1974-2020. Dashed line represents historical mean. WQI Grade: A = 90-100; B = 80-90; C = 60-80; D = 30-60; F <30.

in our monitoring data (Greening and Janicki 2006; Morrison et al 2006). Other factors which likely contributed to the overall improvement in Tampa Bay's water quality include stormwater improvement projects, local fertilizer ordinances, stronger wetlands protection and environmental regulations and investments in restoration projects over the years (Beck et al 2019). Throughout this time the EPCHC monitoring program has been central for providing the data needed for making scientifically sound management decisions and tracking long term water quality improvements in Tampa Bay.

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