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# Harmful algal species in the Central Basin of Puget Sound: Seasonal bloom patterns analyzed via FlowCAM technology

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# Harmful algal species in the Central Basin of Puget Sound: Seasonal bloom patterns analyzed via FlowCAM technology

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## Introduction

The Puget Sound Central Basin is part of the larger Salish Sea estuarine system. Long-term monitoring of this basin by King County has produced a robust dataset through the year-round collection of a suite of physical, chemical, and biological parameters. A phytoplankton monitoring program was established in 2008 using traditional microscopy methods and in 2014 a particle imaging system was added to the program. Complex interplay among a number of environmental factors contribute to the distribution and magnitude of annual phytoplankton blooms within the estuary, which regularly include several species considered potentially harmful because they have been associated with shellfish poisoning, fish kills, or other harmful effects on local biota. The study of these communities and their ecological drivers is vital to the preservation of wildlife and human health.

Potentially harmful taxa common to the Central Basin include: *Akashiwo sanguinea, Alexandrium catenella, Heterosigma akashiwo,* and some species of the common diatom genera *Thalassiosira*, *Chaetoceros* and *Pseudo-nitzschia* (Fig. 5). Significant changes in physical conditions have been recorded for the Salish Sea in the last several years, with notably higher than normal sea surface temperatures beginning in late 2014 related to the high temperature/low salinity anomaly, also known as the 'Blob'[8] (Fig. 4). This study focuses primarily on how shifting temperature conditions may have impacted the abundance and distribution of these taxa in the Central Basin.

## Methods

Surface water (<2 m) samples from 10 Central Basin stations spanning Point Wells to Vashon Island are collected twice a month and analyzed via FlowCAM (Fluid Imaging Technologies), an imaging particle analyzer. Up to 64 discrete parameters are recorded for each image. These parameters are used to sort images into taxa and to calculate abundance and biovolume for each category identified. Key water column indicators such as temperature, salinity, and nutrients are collected concurrently.

Abundance (particles/L) and biovolume (mm$^3$/L) for 6 species or taxonomic groups that include HAB species are shown here (Figs 2 & 3) from 3 stations representing distinct areas of the Central Basin (Fig. 1): Point Jefferson (mid-channel, higher oceanic influence), Point Williams (near a dense urban center, high boat traffic), and Dockton Park (shallow, protected bay). Because this program's FlowCAM image analysis stops at the genus level, this data may include a number of non-harmful diatom species in addition to those designated as HABs. Abundances represented here are measured as particle densities and include fragments of chains. Analysis of the distributions of these HABs among 3 geographically diverse stations supports greater understanding of the complex array of environmental factors that influence bloom dynamics.

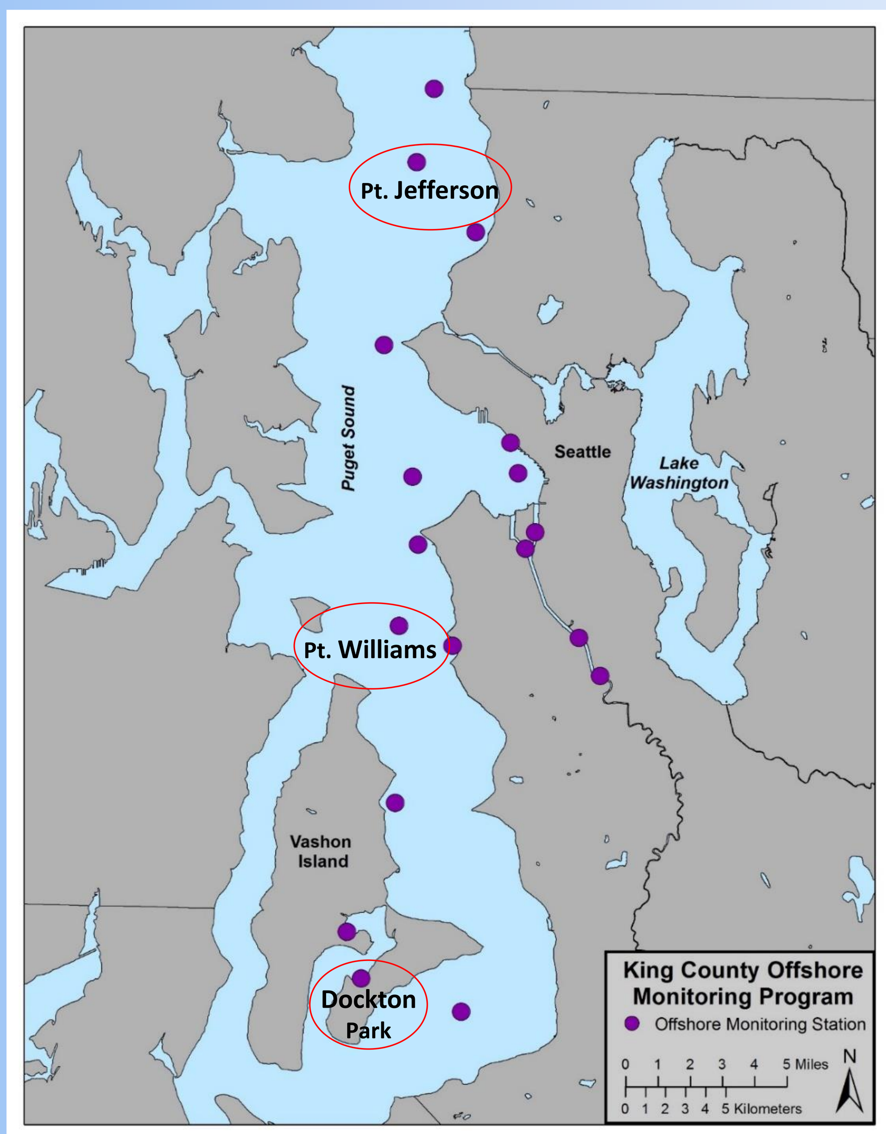


**Fig. 1**: King County's Central Basin sampling station locations. The 3 stations in this study are circled in red.

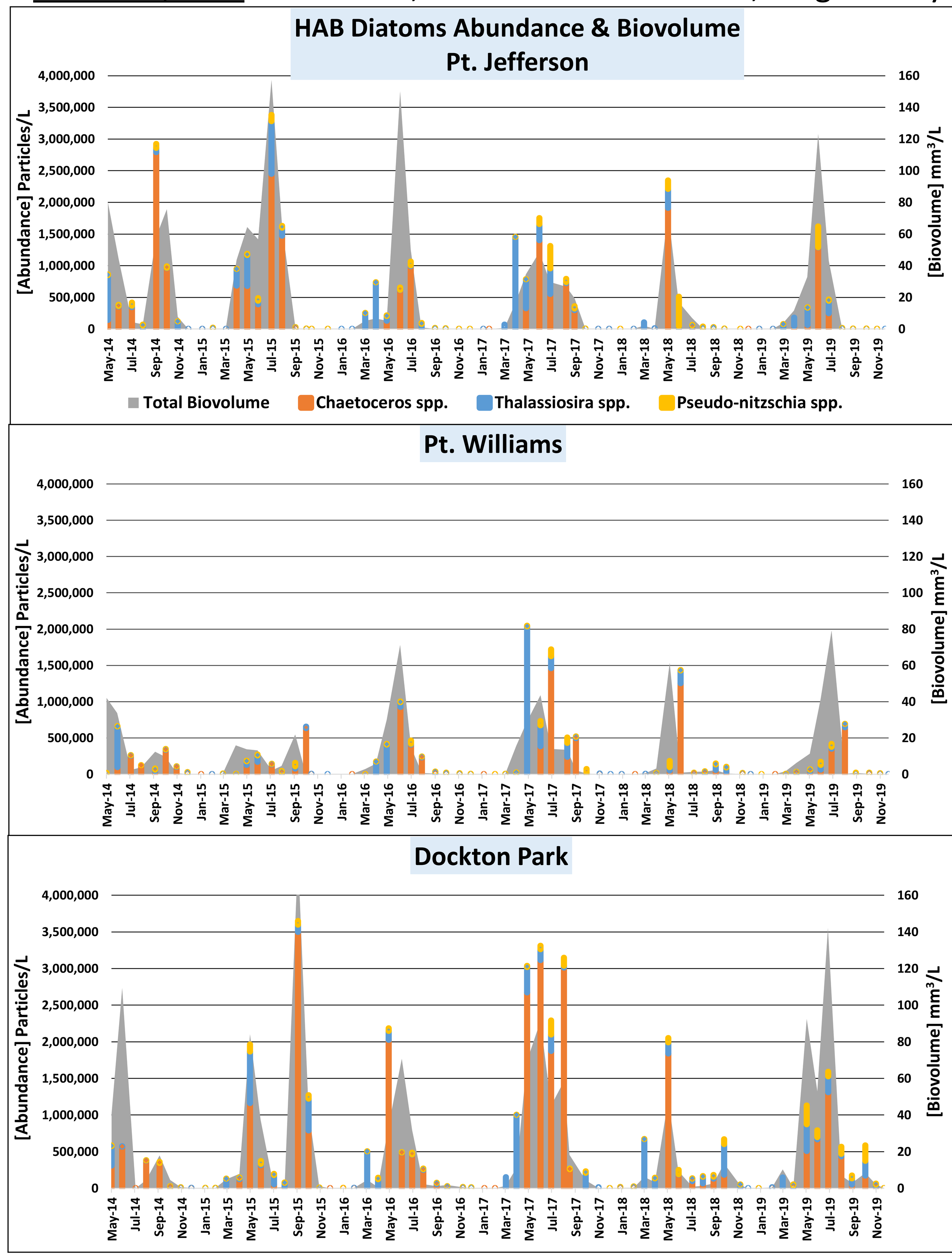


**Fig. 2:** Abundance (columns) and biovolume (grey peaks) of 3 diatom taxonomic groups (which contain HAB species) for 2014-2019.

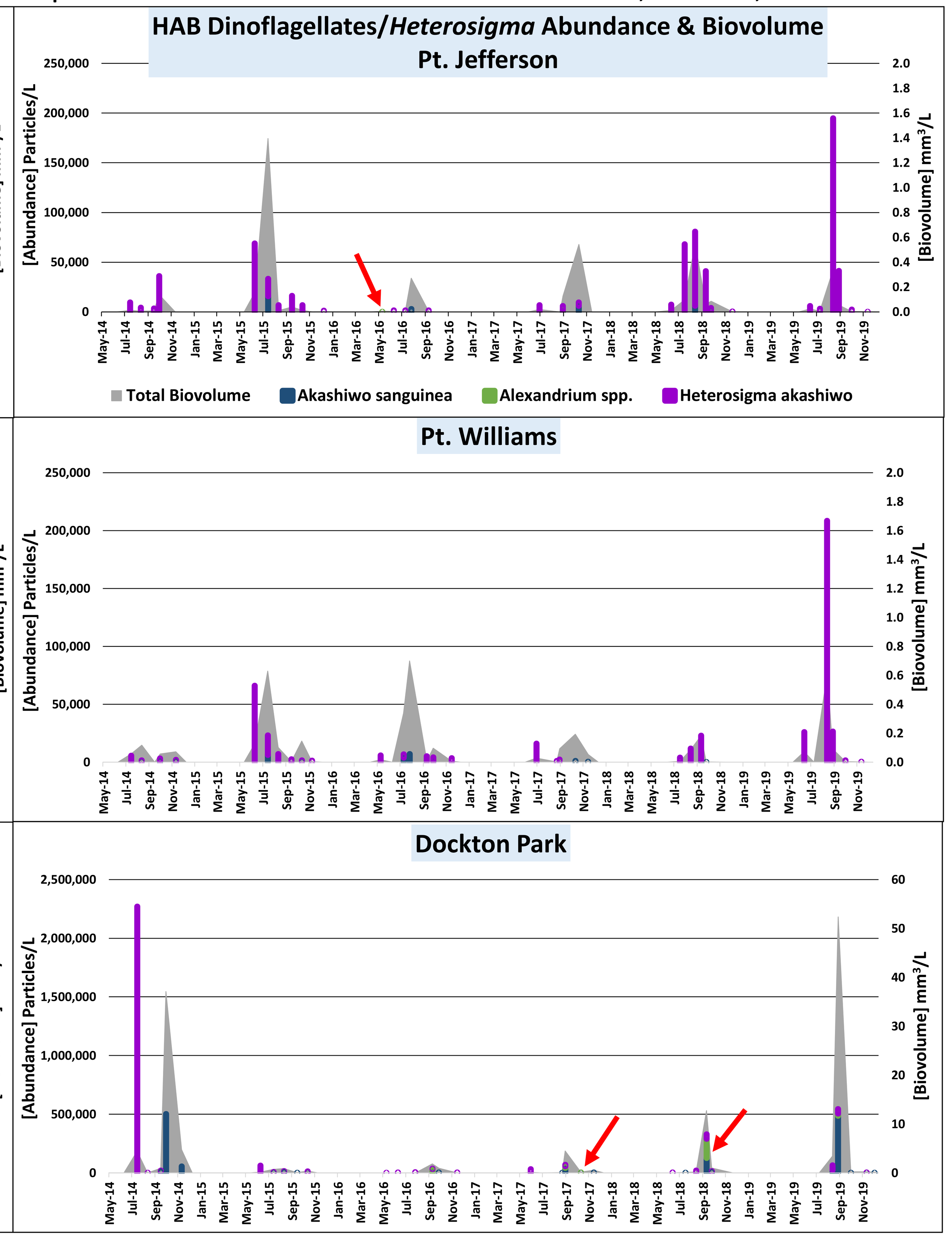


**Fig. 3:** Abundance (columns) and biovolume (grey peaks) of 2 HAB dinoflagellate taxa and *Heterosigma akashiwo* for 2014-2019.

## Findings

- The largest diatom blooms occurred at Dockton Park followed by those of Pt. Jefferson, while blooms at Pt. Williams were typically smaller. The largest abundances of diatoms occurred at Pt. Jefferson in July 2015 and Dockton Park in September 2015, when sea surface temperatures were elevated related to the 2014 Blob anomaly. In 2016, the warmest year, bloom size decreased at all stations. The next large bloom event occurred at all 3 stations in 2017, a cooler year (Fig. 2 & 4).
- *Chaetoceros* was the dominant diatom taxon at every station annually with peak abundances generally occurring between May and August (Fig. 2).
- *Thalassiosira* was the first diatom taxon to bloom between March and May at Pt. Jefferson and Pt. Williams in 2014, 2016, and 2017, with a particularly large bloom at Pt. Williams in May 2017, when temperatures were lower than the preceding 2 years. This taxon was also typically the first to bloom at Dockton Park, with the highest abundances occurring between March and May in 2015, 2016, 2017, and 2018 (Figs 2 & 4).
- Despite its low numbers, *Pseudo-nitzschia* was the most consistently present taxon at every station. Higher abundances were observed at Pt. Jefferson in July 2017 and June 2019 with the highest abundance occurring in June 2018, when sea surface temperatures were elevated compared to 2017 and 2019. Observations of this taxon in winter months appear to be increasing in frequency (Figs 2 & 4).
- Blooms of *Heterosigma akashiwo* at Pt. Jefferson and Pt. Williams were larger in 2015, 2018, and 2019 with the highest abundances for both stations observed in August 2019. Bloom magnitudes of this species appear to be consistently increasing since 2016 at these stations. The greatest abundance of this species was recorded at Dockton Park in July 2014, when sea surface temperatures were warmer than usual (Figs 3 & 4).
- *Akashiwo sanguinea* was present sporadically throughout the dataset, achieving the highest abundances at Dockton Park where it was a dominant HAB taxa in October 2014 and September 2019, when recorded sea surface temperatures were elevated (Figs 3 & 4).
- *Alexandrium* spp. was the least observed taxon in this study; only 3 notable blooms (red arrows, Fig. 3) were observed over a 6-year period among all 3 stations. The largest abundance of this taxon was observed at Dockton Park in September 2018 following a warmer summer season (Figs 3 & 4).

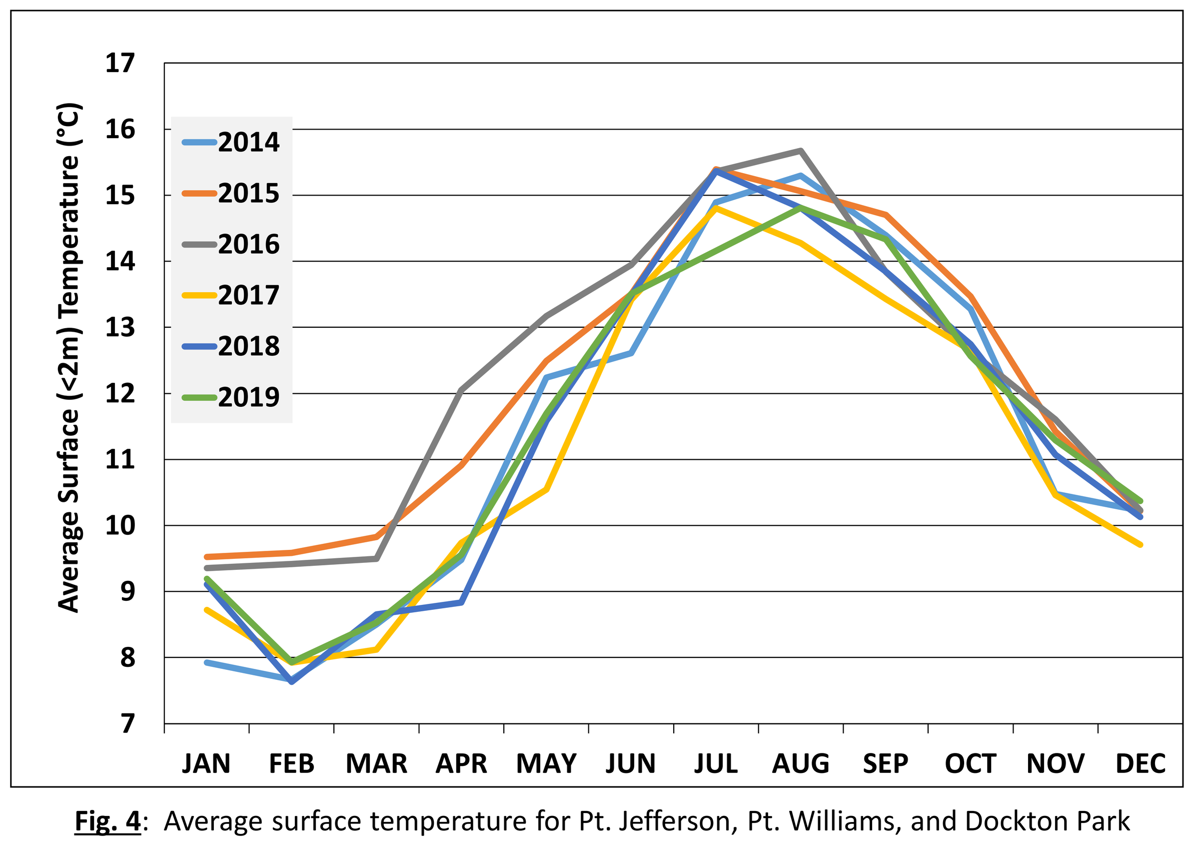


**Fig. 4**: Average surface temperature for Pt. Jefferson, Pt. Williams, and Dockton Park stations' from 2014 to 2019.

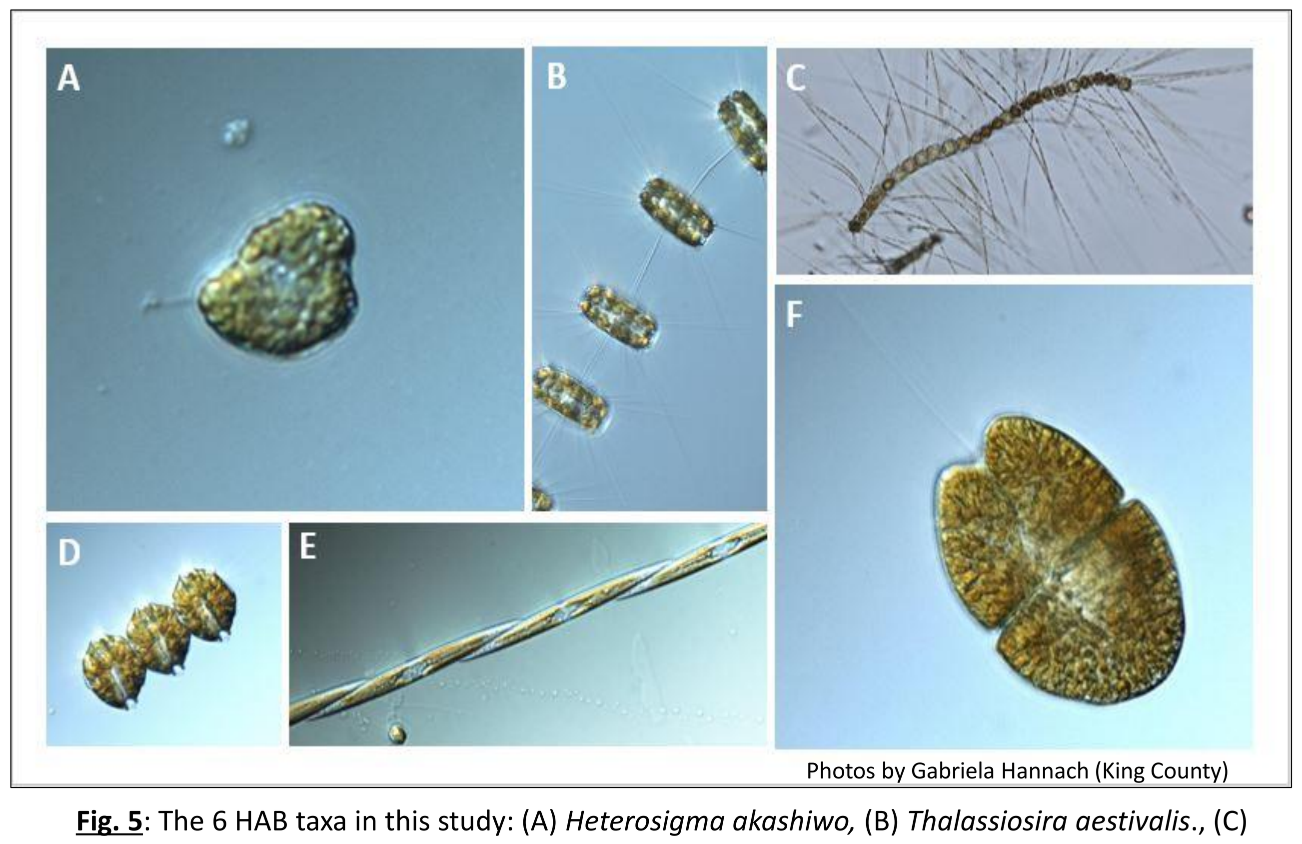


**Fig. 5**: The 6 HAB taxa in this study: (A) *Heterosigma akashiwo,* (B) *Thalassiosira aestivalis*., (C) *Chaetoceros convolutus,* (D) *Alexandrium catenella*, (E) *Pseudo-nitzschia* sp., (F) *Akashiwo sanguinea.*

## Discussion

Elevated sea surface temperatures observed on Washington's coast in 2014 had a persistent effect on those of Puget Sound[8] and possibly the prevalence of several HAB taxa. Phytoplankton growth and seasonality are closely tied to nutrient levels, but the sampling frequency used in this study showed no evidence that nutrient availability is responsible for interannual variability in phytoplankton patterns for these stations. Analysis of abundance, biovolume, and temperature data reveals distribution patterns that have important implications related to human health and that of the Salish Sea ecosystem at large.

Several HAB taxa common to Puget Sound appear to be increasing in abundance, echoing observed patterns worldwide[3, 4]. Observations of the dinoflagellates *Akashiwo sanguinea* and *Alexandrium* spp. have increased since 2015, especially in years when sea surface temperatures have been warmer than average for this region. This pattern is particularly concerning as *A. sanguinea* has been previously associated with fish kills[9] and seabird stranding events[6, 9] Additionally, several *Alexandrium* species common to Puget Sound are known to produce saxitoxins (the cause of Paralytic Shellfish Poisoning) as well as cyst seedbeds, which have been shown to play a role in bloom initiation[1, 9]. Observations of the toxic raphidophyte, *Heterosigma akashiwo,* have also risen remarkably at main channel stations, which is troubling as this taxon has been associated with fish kills[2, 9].

Low abundances of toxigenic varieties of the diatom genus *Pseudo-nitzschia* can produce enough domoic acid (cause of Amnesic Shellfish Poisoning) to cause shellfish harvest closures, which can result in significant losses for commercial, recreational, and tribal shellfish harvests[9, 10]. Observations of this taxon have increased through winter months, especially in warmer years. *Chaetoceros* most often achieved the highest abundances and persisted the longest for all stations; *Thalassiosira* was consistently among the first diatom taxa to bloom each year at every station. These observations suggest that *Chaetoceros* and *Thalassiosira* populations in this basin are fairly resilient to changes in temperature.

Bloom magnitudes were generally larger at the Dockton Park station likely related to its shallow, protected waters; however, blooms of *H. akashiwo* and *Pseudo-nitzschia* spp. appear to be increasing at main channel stations as well as observations of *A. sanguinea* and *Alexandrium* spp. at Dockton Park station. These findings agree with previous studies that these HAB taxa may continue to increase in abundance in Puget Sound as sea surface temperatures rise related to climate change[5] and regional climatic events like the 'Blob'[7]. Further study of the relationships among HAB taxa and their ecological drivers is of critical importance in order to better understand the future implications of these patterns and mitigate the possible deleterious effects of harmful algae blooms on the larger Salish Sea ecosystem and human health.

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