Northeast Aquatic Research
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June 2023

**To: Lake Hayward Property Owner's Association**
**RE: 2022 Lake Hayward Water Quality Monitoring Summary Report**

## Introduction

In 2022, LHPOA volunteers conducted water quality monitoring twice per month from May through October. Monitoring was conducted at two pre-established stations. The primary monitoring station, Station 1, is located at the site of deepest water in the lake. Station 2 is located northerly of Station 1 in shallower water. At Station 1, water clarity was recorded, and water temperature and dissolved oxygen values were measured at one-meter increments from the surface to the bottom. Water samples were collected from 1m, 6m, 9m, and 11m depths. All water samples were analyzed for total phosphorus, total nitrogen, and ammonia-nitrogen concentrations. The 1m sample was also analyzed for nitrate-nitrogen, while the 11m sample was also analyzed for total iron. One water sample was collected from Station 1 each month for phytoplankton identification and enumeration.

At the secondary station, Station 2, monthly monitoring consisted of water clarity measurements and water temperature and dissolved oxygen profiles. No water samples were collected here.

## Results

Interpretation of nutrient and water clarity results mostly follows the criteria set by CT DEEP to categorize CT lakes into different states of production **Table 1**. The descending categories, Oligotrophic at the top and Highly Eutrophic at the bottom, are based on the increase in phosphorus concentration. Nitrogen, although important, is seldom the driver of aquatic plant and algae growth. The decline in Secchi disk depth is due to the increased chlorophyll *a* (algae) that grow in proportion to the phosphorus concentration. Lakes grouped in the top category 'Oligotrophic' have little to no weeds and algae because the phosphorus concentration is very low (0 – 10ppb). Lakes grouped in the bottom category 'Highly Eutrophic' have excessive amounts of weeds and very green water resulting from high phosphorus concentration.

Based on Lake Hayward's historical water quality values, the goal is for Hayward to remain within the 'oligo-mesotrophic' category.

***Table 1**. Connecticut DEEP trophic categories and ranges of indicator parameters.*

| Category | T. Phosphorus | T. Nitrogen (ppb) | Secchi Depth | Chlorophyll *a* (ppb) |
|---|---|---|---|---|
| Oligotrophic | 0 -- 10 | 2 -- 200 | 6 + | 0 -- 2 |
| Oligo-mesotrophic | 10 -- 15 | 200 -- 300 | 4 -- 6 | 2 -- 5 |
| Mesotrophic | 15 -- 25 | 300 -- 500 | 3 -- 4 | 5 -- 10 |
| Meso-eutrophic | 25 -- 30 | 500 -- 600 | 2 -- 3 | 10 -- 15 |
| Eutrophic | 30 -- 50 | 600 -- 1000 | 1 -- 2 | 15 -- 30 |
| Highly Eutrophic | 50 + | 1000 + | 0 -- 1 | 30 + |

## Water Clarity

Water clarity at Station 1 in 2022 was generally similar to or better than the water clarity in recent years (**Figure 1**). The Secchi disk depth was recorded below 4 meters in all months except for August. The worst clarity of the season (2.9m) was recorded on August 16th. However, clarity quickly improved after that, and the best clarity of the season, along with the best clarity recorded at Station 1 in the past four years of sampling (6.2m) was measured just two weeks later, on September 1st.

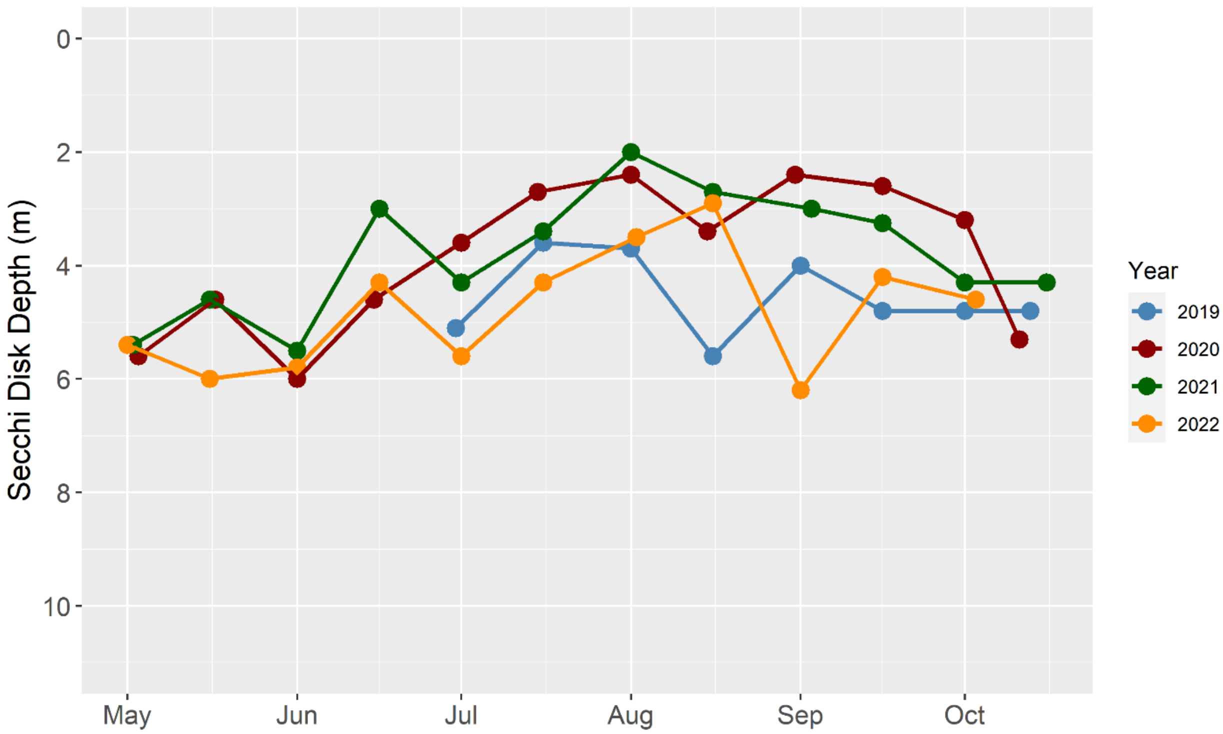


*Figure 1. Lake Hayward water clarity measured at Station 1, 2019 – 2022.*

## Water Temperature

Water column temperature profiles are shown in **Figure 2**. Each line represents a single date when the water temperature was measured at each 1-meter depth increment. When the lines are vertical or nearly vertical, the water column is fully mixed. At Station 1, this occurred in early May and again in October (with the assumption that the lake remains fully or nearly fully mixed through the winter and early spring).

Beginning in mid-May, the upper water of the lake warms, as shown by the lines changing from vertical to diagonal. By mid-May, the lake had become stratified, meaning there was a layer of water at the surface of equal temperature, a layer of water in the middle where temperature declines rapidly, and a layer of cold water at the bottom. The lake remained stratified through September.

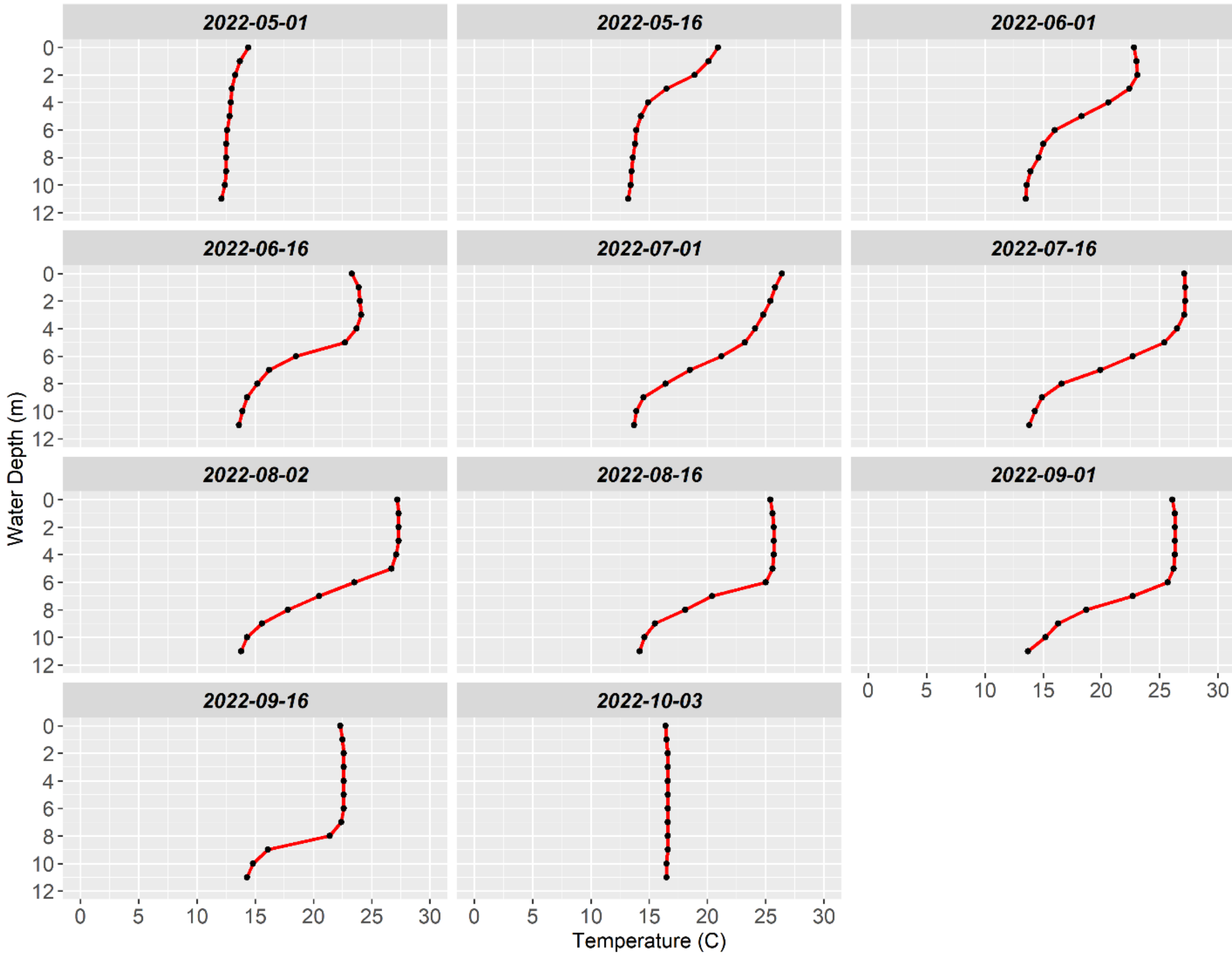


*Figure 2. Lake Hayward water temperature profiles from 2022 measured at Station 1.*

## Dissolved Oxygen

The 2022 dissolved oxygen (DO) profiles are shown in **Figure 3**. On May 1st, the lake was nearly fully oxygenated at ~10 ppb, with only the very bottom water at 11 meters reaching anoxia (DO <1 mg/L). This decrease in dissolved oxygen at the bottom could also be the result of the probe sitting in the sediment at the lake bottom, rather than a true anoxic state within the lake water on this date. Water deeper than approximately five meters begins to lose dissolved oxygen in early June. The anoxic boundary (the interface between water with dissolved oxygen and water without) rose in the water column until reaching a maximum height of 5.7 meters, as measured down from the surface, in early August (**Figure 4**). After this sampling date, the anoxic boundary began to decrease. The lake was nearly fully oxygenated by the last sampling date in early October.

At Station 2, anoxic water was only present from mid-July through early August, with dissolved oxygen present to the lake bottom on all other sampling dates (**Table 2**).

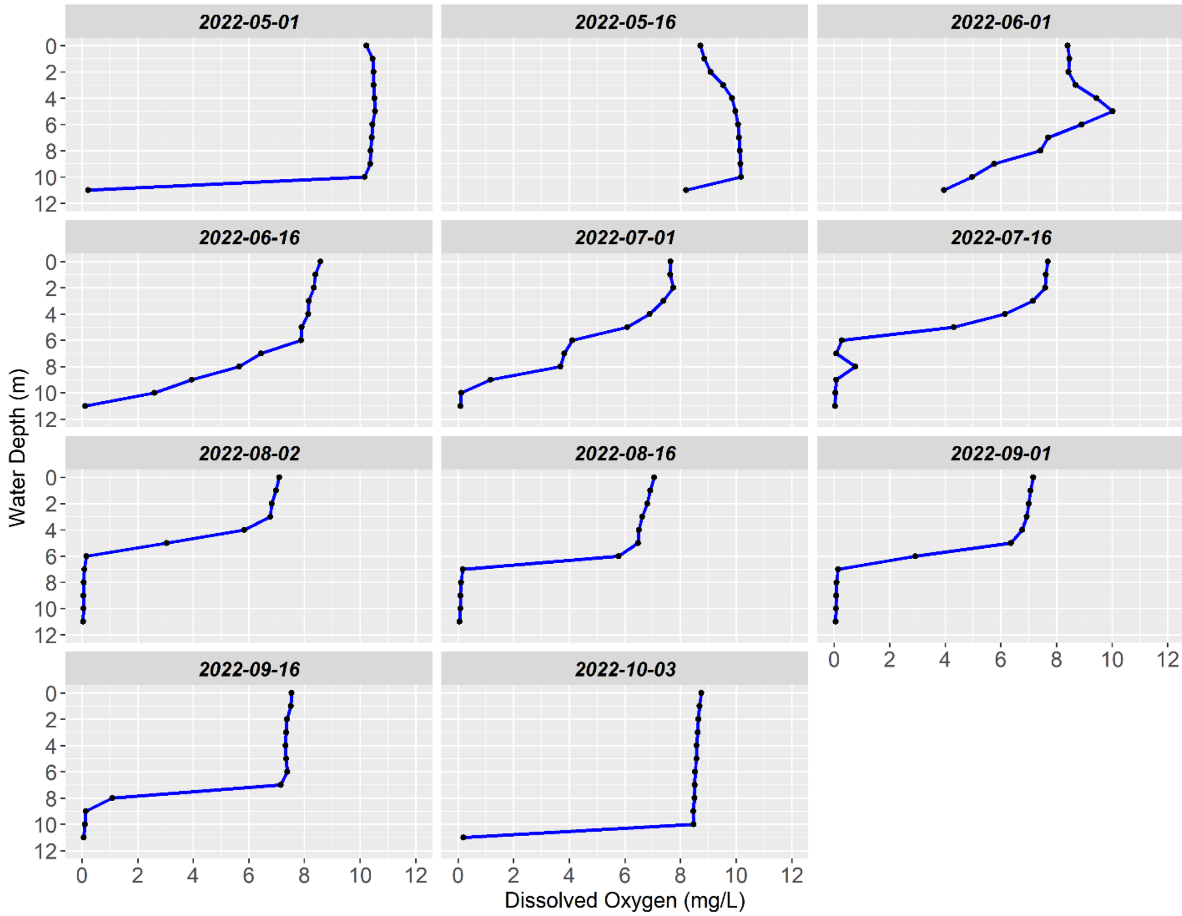


*Figure 3. Lake Hayward 2022 Station 1 dissolved oxygen concentrations.*

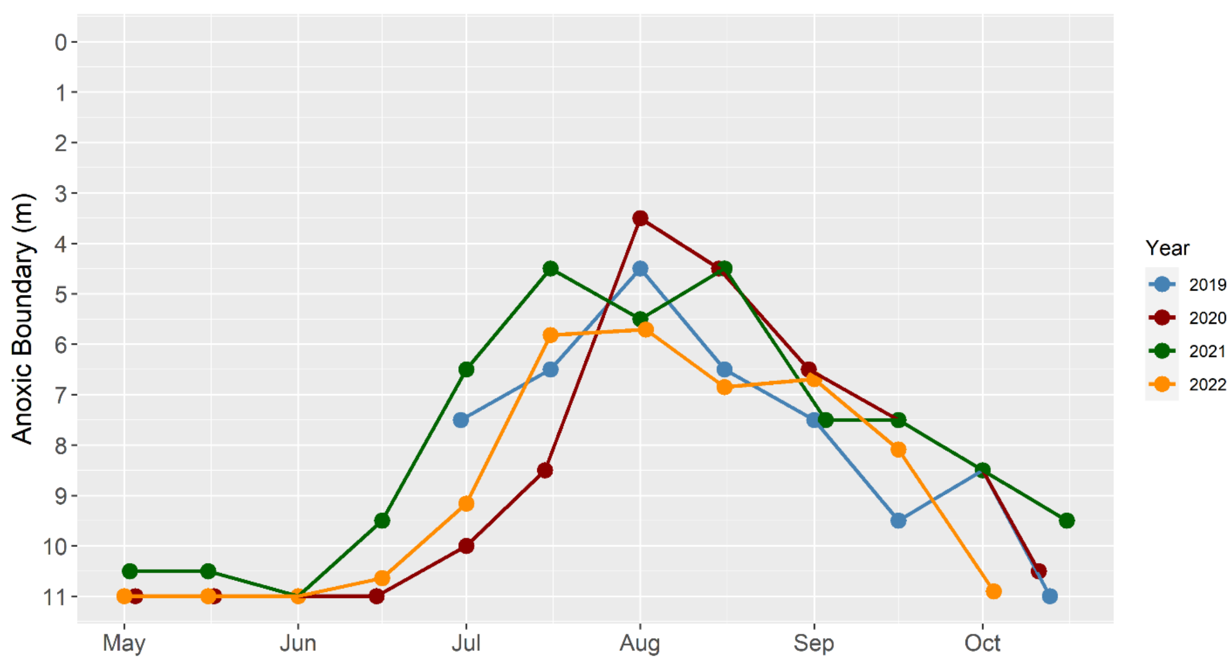


*Figure 4. Station 1 anoxic boundary, 2019-2022.*

| Date | Thermocline Depth (m) | | Anoxic Boundary (m) | |
|---|---|---|---|---|
| | Station 1 | Station 2 | Station 1 | Station 2 |
| **5/1/2022** | *NA* | *NA* | *NA* | *NA* |
| **5/16/2022** | *2.51* | *2.46* | *NA* | *NA* |
| **6/1/2022** | *4.52* | *4.95* | *NA* | *NA* |
| **6/16/2022** | *5.57* | *5.5* | *10.64* | *NA* |
| **7/1/2022** | *6.35* | *5.5* | *9.16* | *NA* |
| **7/16/2022** | *5.88* | *5.5* | *5.82* | *5.78* |
| **8/2/2022** | *5.83* | *5.5* | *5.71* | *5.33* |
| **8/16/2022** | *6.6* | *NA* | *6.85* | *NA* |
| **9/1/2022** | *7.2* | *NA* | *6.69* | *NA* |
| **9/16/2022** | *8.49* | *NA* | *8.09* | *NA* |
| **10/3/2022** | *NA* | *NA* | *10.9* | *NA* |

*Table 2. Thermocline depth and anoxic boundary in 2022 at Station 1 and Station 2. NA values indicate there was either no thermocline or anoxic conditions present.*

## Nutrients

**Total phosphorus in surface water**

Total phosphorus (TP) in the surface water should ideally remain below 15ppb at the top and middle of the water column (**Table 1**). This threshold has been exceeded each summer since 2019. In 2020, phosphorus exceeded 15 ppb in July, August, and September, with a peak Sept. 1$^{st}$ concentration of 21ppb. In 2021, TP concentration exceeded 15ppb only once, on Sept. 1$^{st}$, with a concentration of 29ppb. In 2022, TP concentration exceeded 15ppb in August and September, with a Sept. 1$^{st}$ peak concentration of 35ppb. In each of the last three years, the peak concentration occurred on September 1$^{st}$, with each succeeding year having a higher concentration than the last. These peak concentrations in September are threateningly high and should be investigated further by increasing the frequency of testing.

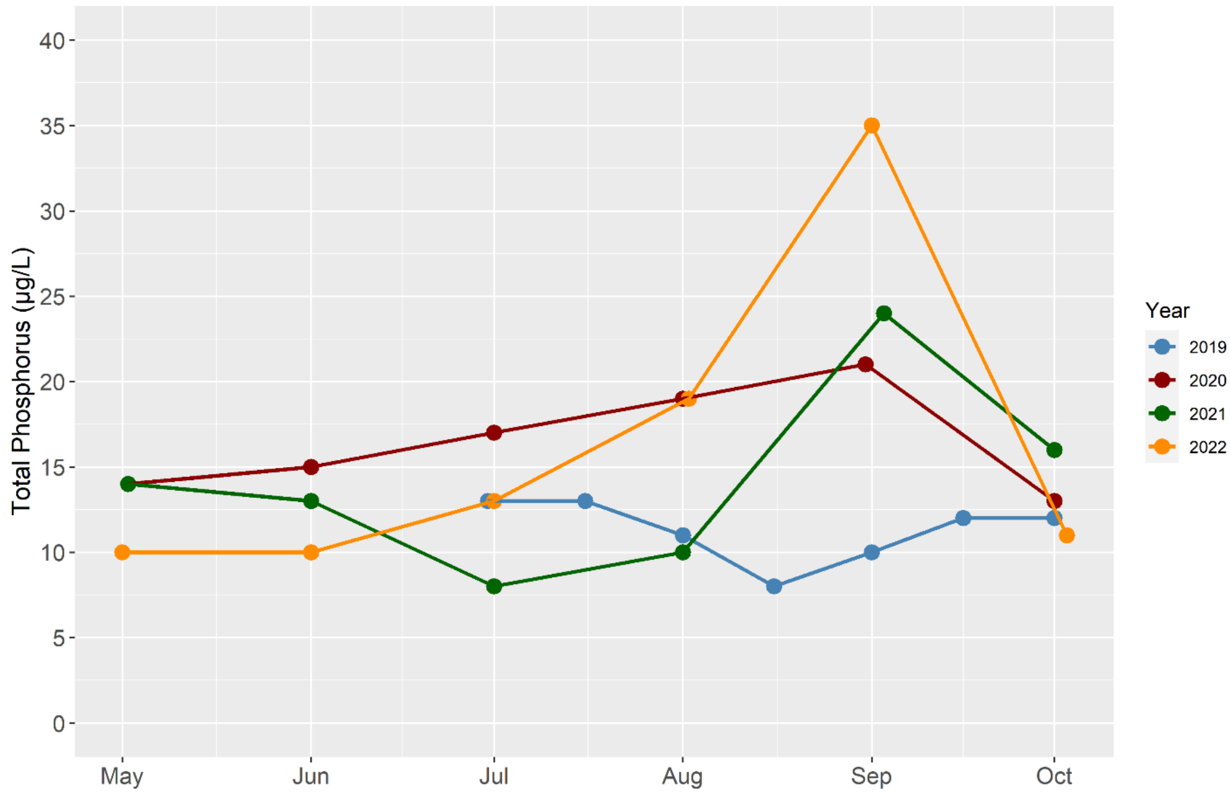

*Figure 5. Lake Hayward 2019-2022 surface total phosphorus.*

**Total phosphorus in bottom water**

In 2022, the TP concentration in the bottom water remained below 30ppb on all dates except August 2nd, when TP reached 57ppb. This corresponds with the time of maximum anoxia (see Figure 4 for the trend in anoxic boundary) and, in turn, internal loading of nutrients from the sediments at the lake bottom (**Figure 6**). However, bottom water increases in TP do not explain the large increase in TP in the surface water in September. In fact, bottom water TP was slightly lower than surface water on September 1st. This was not the case in 2020 and 2021, when bottom water TP far exceeded surface water TP.

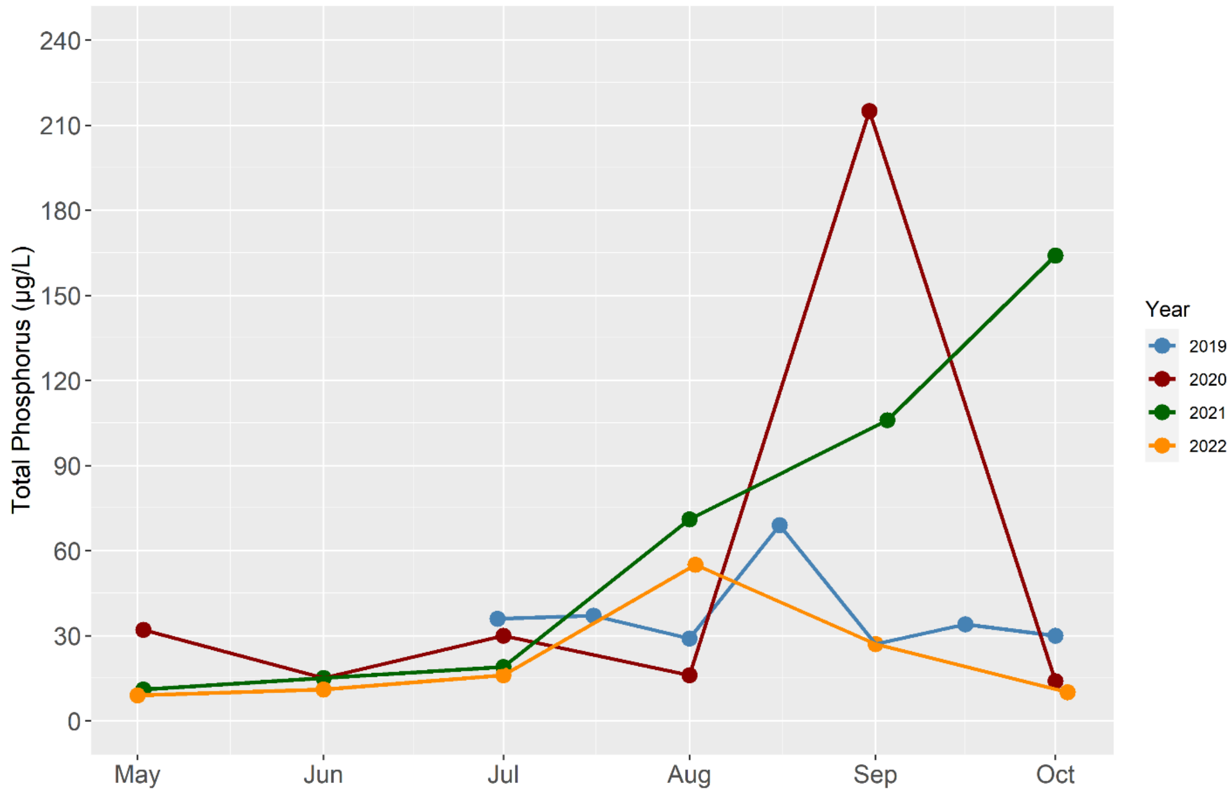


*Figure 6. Lake Hayward 2019-2022 bottom total phosphorus.*

**Total nitrogen**

Total nitrogen (TN) in the surface waters should remain below 300ppb. In 2022, TN was elevated above this threshold in May and September (**Figure 7**). The last three years of nutrient data show that TN is consistently elevated in May, the date of the first sampling. This is likely the result of septic groundwater loading.

TN in the bottom water steadily increased over the season, until reaching highest concentration in September (**Figure 8**). This is consistent with the pattern of internal loading.

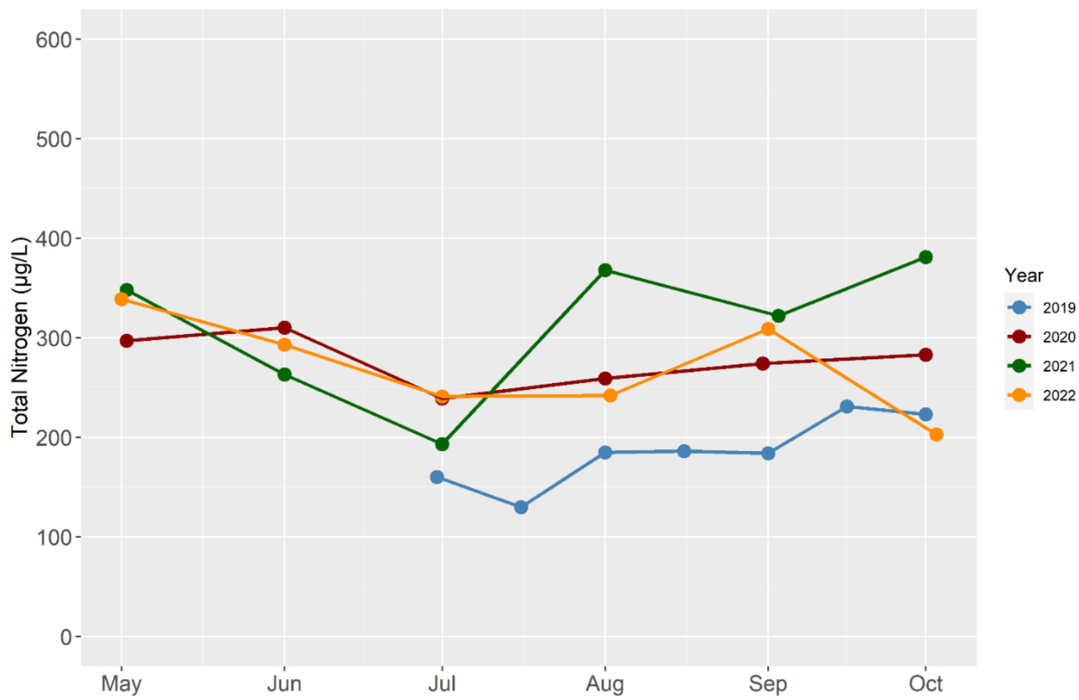


*Figure 7. Lake Hayward 2019-2022 surface total nitrogen.*

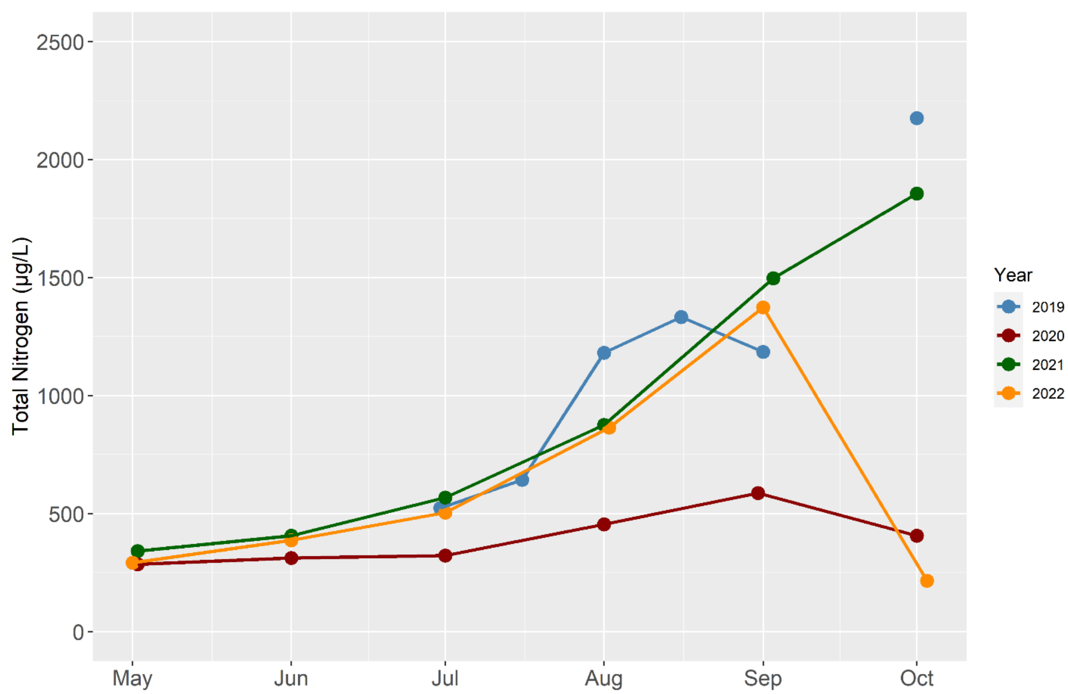


*Figure 8. Lake Hayward 2019-2022 bottom total nitrogen.*

*Table 3. Nutrient Results from 2022 Sampling. TP = Total Phosphorus, TN = Total Nitrogen, $NH_3$ = Ammonia-Nitrogen, NOx = Nitrate-Nitrogen, Fe = Total Iron.*

| Depth | Date | $NH_3$ (µg/L) | NOx (µg/L) | TN (µg/L) | TP (µg/L) | Fe (mg/L) |
|---|---|---|---|---|---|---|
| **1** | 5/1/2022 | 18 | 150 | 339 | 10 | - |
| **6** | | *2* | 151 | 317 | *11* | - |
| **8** | | *2* | 149 | 302 | 9 | - |
| **10** | | *2* | 153 | 292 | 9 | 0.050 |
| **1** | 6/1/2022 | 15 | 65 | 293 | 10 | - |
| **6** | | 7 | - | 259 | 8 | - |
| **8** | | 34 | - | 293 | 13 | - |
| **10** | | 128 | - | 387 | 11 | 0.254 |
| **1** | 7/1/2022 | - | - | 241 | *13* | - |
| **6** | | - | - | 256 | *12* | - |
| **8** | | - | - | 275 | 13 | - |
| **10** | | - | - | 504 | 16 | 1.527 |
| **1** | 8/2/2022 | 3 | 2 | 242 | *19* | - |
| **6** | | 42 | 2 | 331 | 24 | - |
| **8** | | 175 | 2 | 292 | 16 | - |
| **10** | | 936 | 2 | 864 | 55 | 7.401 |
| **1** | 9/1/2022 | 30 | 4 | 309 | 35 | - |
| **6** | | 104 | - | 291 | 20 | - |
| **8** | | 359 | - | 495 | 15 | - |
| **10** | | 1,245 | - | 1374 | 27 | 11.630 |
| **1** | 10/3/2022 | 27 | 22 | 203 | 11 | - |
| **6** | | 27 | - | 222 | 11 | - |
| **8** | | 27 | - | 240 | 13 | - |
| **10** | | 28 | - | 215 | 10 | 0.141 |

## Phytoplankton

Four phytoplankton groups were observed in Lake Hayward in 2022: chrysophytes, cyanobacteria, diatoms, and greens (**Figure 9**). Of these, diatoms were generally the most abundant group, present in all collected samples.

Cyanobacteria were present in the August, September, and October samples. While cyanobacteria can be a cause for concern due to the ability of certain species to produce toxins, the group totaled just over 6,000 cells/mL at its most abundant, in October (**Figure 10**). Based on World Health Organization guidelines, this is considered low in terms of the probably of acute health effects (**Table 4**).

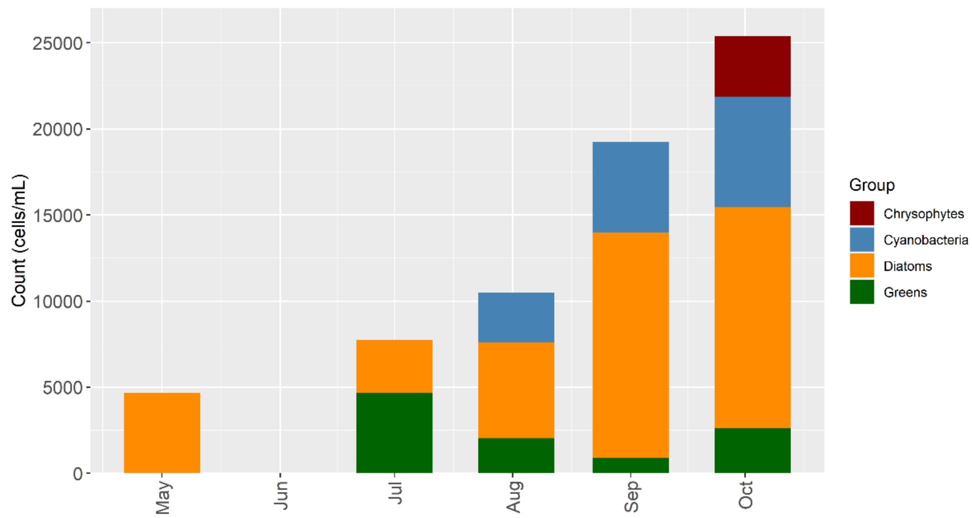


*Figure 9. Major phytoplankton groups observed in Lake Hayward open-water samples.*

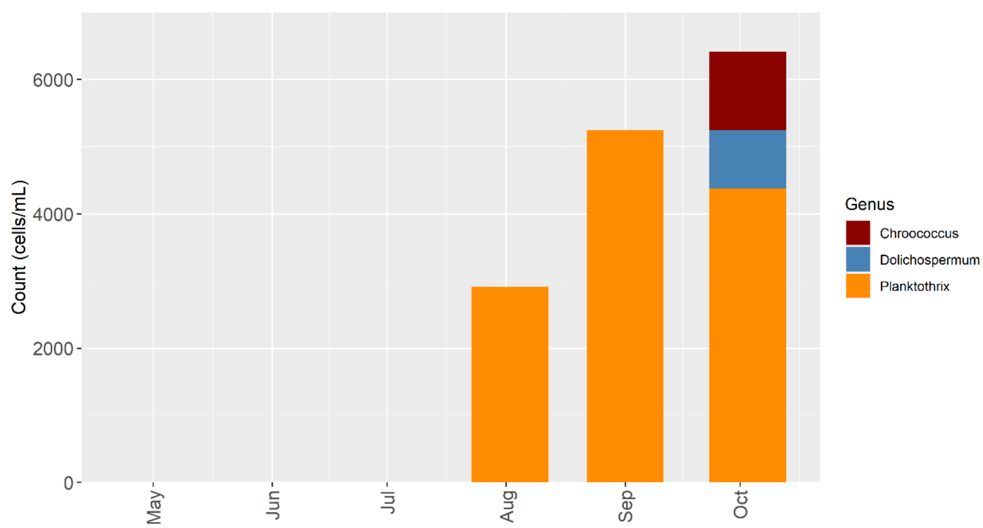


*Figure 10. Cyanobacteria algae observed in Lake Hayward open-water samples.*

*Table 4. WHO guidance values for the relative probability of health effects resulting from exposure to cyanobacteria.*

| **Relative Probability of Acute Health Effects** | **Cyanobacteria Density (Cells/mL)** |
|---|---|
| Low | < 20,000 |
| Moderate | 20,000-100,000 |
| High | 100,000-10,000,000 |
| Very High | > 10,000,000 |

## Stream Nutrient Concentrations

Volunteers collected water samples from seven of the lake's twelve inlets on eight occasions between April and September 2022. A few inlets had multiple sampling locations upstream from the lake (W1, W2, and W3) The samples were analyzed for total phosphorus and total nitrogen concentrations.

Several of the inlets that were sampled in 2022 contained elevated total phosphorus exceeding 100ppb (**Table 5**). Two inlets had concentrations greater than 200ppb (Inlet W2-HFLDUSDS and Inlet W2-BBO). While 2022 concentrations were elevated, they were overall better than 2021, when inlet concentrations exceeded 200ppb on multiple occasions, with some inlets containing TP concentrations ranging from ~350-850ppb.

The highest concentrations of total nitrogen were documented at Inlets E3, E5, and E6 (**Table 6**). These inlets had concentrations eight to nine times that of the in-lake surface water.

*Table 5. Total phosphorus concentrations in the lake's inlets in 2022.*

| **Site** | **Total Phosphorus (µg/L)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **4/1** | **4/8** | **4/19** | **5/2** | **6/7** | **8/22** | **8/23** | **9/6** | **Average** |
| W1 (total area 65 ac) | | | | 40 | 94 | | | 98 | *77* |
| W1-Lookout (Drains to W1) | 50 | 61 | | 39 | 122 | | | 116 | *78* |
| W2 (total area 49ac) | | | | | | | | | |
| W2-USD (Drains to W2) | | | | | | | | | |
| W2-BBO (Drains to W2-USD) | | | | | | | 224 | 66 | *145* |
| W2-U (Drains to W2-BBO) | 19 | 39 | | | 14 | | 147 | 77 | *59* |
| W2-U HFLD31 (Drains to W2-U) | | | | | 8 | | | | *8* |
| W2-HFDUSDS (Drains to W2-USD) | 106 | 147 | | | | | | 242 | *165* |
| W3 (total area 63ac) | | | | 8 | 42 | 70 | | 86 | *52* |
| W3 LNGWD (Drains to W3) | | | | | 55 | | | 118 | *87* |
| W3-BCLFUSD (Drains to W3 LNGWD) | | | 114 | 34 | | | | 123 | *90* |
| E3 (total area 189 ac) | | | | | 12 | | | 47 | *30* |
| E5 (total area 160ac) | | | | | 9 | 55 | | 42 | *35* |
| E6 (total area 104ac) | | | | | 13 | 53 | | 31 | *32* |
| N1 (total area 432ac) | | | | | 28 | | | 37 | *33* |

*Table 6. Total nitrogen in the lake's inlets in 2022.*

| Site | Total Nitrogen (µg/L) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **4/1** | **4/8** | **4/19** | **5/2** | **6/7** | **8/22** | **8/23** | **9/6** | **Average** |
| W1 (total area 65 ac) | | | | 330 | 347 | | | 761 | *479* |
| W1-Lookout (Drains to W1) | 310 | 308 | | 295 | 364 | | | 625 | *380* |
| W2 (total area 49ac) | | | | | | | | | |
| W2-USD (Drains to W2) | | | | | | | | | |
| W2-BBO (Drains to W2-USD) | | | | | | | 2,283 | 4,017 | *3,150* |
| W2-U (Drains to W2-BBO) | 3,981 | 3,728 | | | 3,658 | | 2,216 | 4,138 | *3,544* |
| W2-U HFLD31 (Drains to W2-U) | | | | | 3,788 | | | | *3,788* |
| W2-HFDUSDS (Drains to W2-USD) | 416 | 404 | | | | | | 2,914 | *1,245* |
| W3 (total area 63ac) | | | | 893 | 1,049 | 1,184 | | 2,225 | *1,338* |
| W3 LNGWD (Drains to W3) | | | | | 104 | | | 1,133 | *619* |
| W3-BCLFUSD (Drains to W3 LNGWD) | | | 915 | 222 | | | | 1,677 | *938* |
| E3 (total area 189 ac) | | | | | 738 | | | 762 | *750* |
| E5 (total area 160ac) | | | | | 839 | 1,625 | | 840 | *1,101* |
| E6 (total area 104ac) | | | | | 286 | 2,095 | | 734 | *1,038* |
| N1 (total area 432ac) | | | | | 600 | | | 607 | *604* |

## Conclusions

Water clarity in Lake Hayward is generally good in May but declines in June and July. Typical May clarity is between 5 and 6 meters, while typical August and September clarity is 2 to 4 meters. Clarity tends to improve in October to between 4 and 6 meters. In 2022, water clarity was very good on September 1st, reaching slightly better than 6 meters.

The lake thermally stratifies in May and remains stratified until October. There tends to be thermocline located at 6 meters, with a metalimnion generally between 4 and 8 meters. The lake formed a true hypolimnion below 8 meters. The metalimnion deepened to 8 meters in late September.

Dissolved oxygen remains well saturated in water between the surface and 4-6 meters but declines with depth in the deeper water. The bottom water became fully anoxic in July, with an anoxic boundary at 6 meters. This was better than the prior three years, when the boundary reached 3.5-4.5 meters below the surface. Dissolved oxygen remained depleted in water deeper than 8 meters in late September, roughly the same depth as the metalimnion, suggesting entrainment into mixing waters at 8 meters.

Phosphorus in surface water was low in May (10 ppb) but increased during the season to reach 35ppb on September 1st. Seasonal high TP concentrations have occurred on Sept 1st in 2020, 2021, and 2022. Phosphorus in the bottom water in 2022 remained below 30ppb through May and into July. TP at the bottom reached a peak concentration of 55ppb. This is considerably lower than the 165ppb peak in 2021 and the 230ppb peak in 2020 but is similar to the maximum of 70ppb in 2019.

Total nitrogen in the surface water remains low during most of the season; all values from 2019 to 2022 have been <400ppb, and most values have been less than 300 ppb. Of interest are the considerably lower concentrations of nitrogen in 2019, when most values were <200ppb.

Bottom water nitrogen has shown large increases in August and September, with maximum concentrations between 1300 and 2200ppb. 2020 stands out as having a September maximum concentration of 550ppb.

Cyanobacteria were present at relatively low numbers in August, September, and October. The dominant genera, Planktothrix, are deep water types that rarely form surface blooms. Dolichospermum, which can form surface blooms, was present in very low numbers only in October.

The inlets have been shown to carry large amounts of phosphorus and nitrogen into the lake. Very few of the stream samples collected have acceptable levels of phosphorus and nitrogen, while some have extremely high levels.

## Recommendations

The lake is showing signs of enrichment and approaching eutrophic conditions. Continued water quality monitoring is critical to maintaining a close eye on all the trends detailed above, and to develop a database necessary for feasibility analysis. Lake water quality monitoring should begin in April, and possibly extend into November. Watershed contribution seems to be excessive in many cases. Continued stream chemistry sampling is necessary to track sources of loading, testing should include nitrate at all sites, and ammonia should be tested at sites with very high total nitrogen: W2-BBO, W2-U, W2-HFLD31, and W3. Testing could also include ortho-phosphorus where total phosphorus is over 100ppb. At least once in a season, all the inlets should be sampled during one event. Consider obtaining a flow meter to measure the water flows at the time of sampling to allow for calculation of mass load.