Possum Kingdom Lake Project

Source: Texas Parks & Wildlife

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Abstract

This report is a survey of temperature, salinity, dissolved oxygen, and Secchi disk depth in the subtropical reservoir Possum Kingdom Lake, Texas. The study plots the survey data together with the determined density, stability, and the Brunt Väisälä Frequency. The study also provides tables that contain average and standard deviation with depth for all lake data, as well as the Secchi disk depth, attenuation coefficient of light, and depth of euphotic zone for the surveys. The report utilized and compared data from four locations from two previous field trip surveys. The first field trip took place on the 18th of May 2015, and the second on the 17th of May 2018. Measured lake temperatures ranged from 10.33°C to 26.54°C in 2015, and from 11.48°C to 25.69°C in 2018. In 2015 the average salinity of Possum Kingdom Lake increased with depth whereas in 2018 it remained uniform throughout all depths. The dissolved oxygen levels were not measured in 2015, but the data for 2018 showed that it decreased with depth from 100.21% to 0.45%. For 2015 the average water density was mostly larger for all depths and was also more varied than that recorded in 2018. Both the Stability and Brunt-Väisälä frequency showed large variations between station locations as well as between both years. The estimations presented an inverse relationship between the two years up to 7m depth, below which they followed a similar trend. The Secchi depth and turbidity varied significantly between 2015 and 2018 which implies that the turbidity varies with time in our case study area. However, in each year at different stations, the Secchi depth and turbidity are almost the same which shows that turbidity does not change in different areas of the Possum Kingdom Lake. Furthermore, the data in this report suggest that during 2018 that the summer warming processes and fresher high flows in the lake occurred later than that of 2015.

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Introduction

Purpose

Reservoirs provide many services such as municipal water, flood control, and hydroelectricity (Allen et al. 2008), as well as ecological services to surrounding natural habitats it is therefore vital that they are effectively managed (Tundisi, 2018). Changes to the physical and biogeochemical composition of reservoirs could have serious economic and environmental implications. Towards better management, the various factors that influence the physical and biogeochemical states of reservoirs must be understood. In line with this directive, this report is to supplement the information available on the physical quality of Possum Kingdom Lake as well as to obtain additional information concerning the reservoir's stratification. The specific goals of the report are: 1) to provide an analysis of the data collected by UTA students from the two respective field trips, 2) to compare the physical state of the reservoir for two different years ' given data.

Reservoir Description

Possum Kingdom Reservoir is a well-known lake in Northern Texas for its recreational offering and is one of the only three major reservoirs on the primary stream of the Brazos River. Construction of the reservoir began as an expansion of Morris Sheppard Dam in May 1983 and was impounded in March 1941 to offer water to municipalities, industries, resource mining, farms, and hydropower facilities situated in the bordering Jack, Pinto, Stephens, and Young counties. The stretched-out, meandering reservoir is located at Latitude 32°52'20", Longitude 98°25'32" in Palo Pinto County, 2.6 mi upstream from Loving Creek, and 11.3 mi southwest of Graford (USGS 2020). Furthermore, the lake encompasses an area of 26.56 mi², has a drainage area of 23,596 mi², a storage capacity of 570,200acre-feet, a max depth of 30 meters, a mean operating elevation of 1000 ft above mean sea level (USGS 2020), and annual average evaporation of 62 inches (Fransworth, 1982). The location of the reservoir and the relevant data collection station points are shown in Figure 1 below.

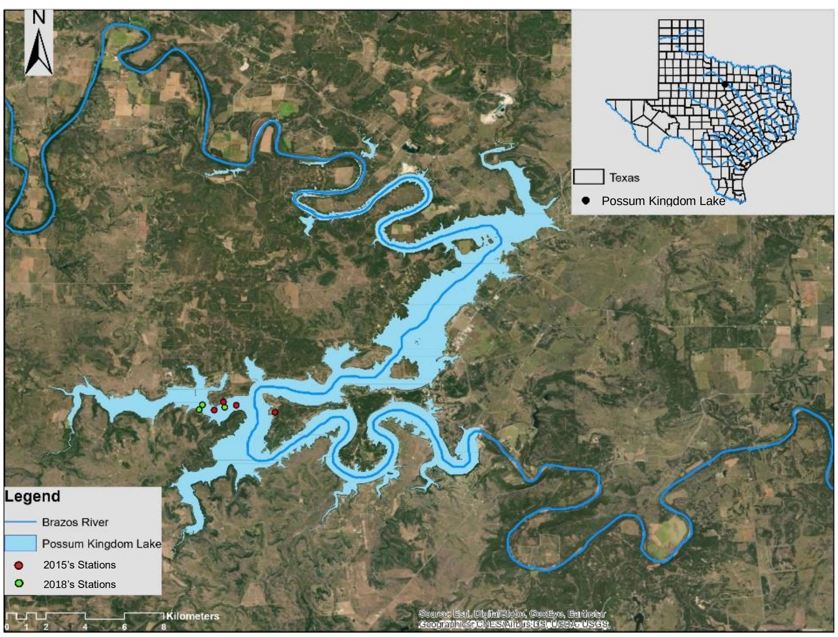

Figure 1: Map of Possum Kingdom Reservoir with approximate locations of field collection sites. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and Site (32°52.871'N;98°33.308'W) are symbolized by red circles. For the year 2018 station A. For 2018 station A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D(32°52,803'N;31°866'W) are symbolized green circles.

Previous Studies

Numerous physical and biological surveys have been performed since the construction of Possum Kingdom Reservoir, with additional water quality sampling activities along the Brazos River dating back to 1906 (Doyle & Byars, 2009). Apart from the typical surveys conducted and maintained by the USGS, such as water supply, water storage capacity, and drainage area, Doyle & Byars 2009 points out that most studies along the river and in the related reservoirs focused on better understanding and managing natural salt pollution that originated in the upper Brazos basin (Doyle & Byars, 2009). Studies proved that the primary source of the salinity came from the Slat Fork Brazos River watershed, as well as portions of the boarding Double Mountain Fork Brazos River and North Croton Creek watershed (Doyle & Byars, 2009; Wurbs, 2002) and that the salinity decrease in the lower basins (Wurbs et al., 1993). Kingdom Possum Lake is located relatively higher up compared to the other reservoirs and is, therefore, more saline. Nine months after the construction of Possum Kingdom Reservoir Hasting (1994) found that chemical stratification was already clearly evident. Adding to this point Leifeste & Popkin (1968) in their study, which ranged from 1962 to May 1965, found that the winter low-flows into the reservoir are much more saline than the higher flows of spring and summer. Their data also showed that the arrangement of temperature and chemical stratification is directly related to seasonal changes in weather and river inflow. In 1982 a report by Haysmith et al. (1983) more specifically found that, in addition to the chemical stratification, that thermal stratification spans from February through September. Their report also found that during this period the levels of dissolved oxygen (DO) are often below 1 milligram per liter (mg/l) in the deeper parts of the reservoir. Their study recorded that the saline inflow causes a salinity gradient in the reservoir with fresher water on the surface and denser saline water on the bottom. Furthermore, an environmental impact assessment conducted as part of a hydropower license acquisition for the Morris Sheppard Project pointed found the velocity of the discharge during peak operation is vital in preventing salt accumulation as it breaks down the above-mentioned gradient and causes mixing through the water column (FERC, 1988). Despite this, the assessment points out that the low DO levels in the reservoir did not comply with the state water quality standards. Numerous reports were followed to assess the influence of dissolved solids on the fish populations in the in and around the lake. Following reports also reported similar trends of low DO levels as well as periodic increases in chloride levels (BRA, 2007; McFarland, 2002; TSUSM, 2010).

Building on this literature and previous reports this report aims to identify and differentiate variations in physical elements in the lake between the two different years. This will be achieved by analyzing and discussing the similarities and differences of the lake temperature, density, stability, Brunt Väisälä Frequency, salinity, dissolved oxygen, as well as the Secchi disk depth.

Methods

For this survey, the project utilized previously captured data taken at eight different sample points at various depths in two different years. The first sampling took place on the 17th of May 2015 and data was collected from three offshore sample points and one other sample point with an unidentified location (shown by red circles shown in Fig 2). The second sampling took place on the 18th of May 2018 at three offshore sample points and one onshore sample point (shown in green circles in Fig 1). Data were collected at each station by two groups, each group's respective data was used to derive a combined average for all measured parameters at each station for both years.

Based on the material provided in the field instructions document and the data sheets provided that listed utilized instruments, we envision that the following field instruments were utilized in the following manner. A GPS was used to capture the absolute locations of the sample points. The 2015 field trip utilized the YSI 55 and the YSI 2030 meters to measure the water temperature, and salinity for each descending meter of the lake, while the 2018 fields trip only utilized the YSI2030 and additionally included dissolved oxygen measurements. A Secchi Disk was used to measure the turbidity. The disk would be lowered into the water and the maximum depth that the disk is visible is regarded as the Secchi depth.

The depth, temperature, and density measurements were further utilized to estimate the density (RHO), stability (E), Brunt Väisälä Frequency (N) for each depth at each station. RHO defined as ρ = Mass/Volume was approximated using the equation of state utilizing an internet tool (http://www.phys.ocean.dal.ca/~kelley/seawater/ density.html). E was estimated with $E = 1/\rho \, d\rho/dz$, whereas N was calculated using $N = \sqrt{gE}$. The mean and standard deviation (SD) for all measurements and estimations where also derived and subsequently summarized in tables for each year by using Mean: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$; Standard Deviation ($s$): $\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{i=n}(x_i - \bar{x})^2$. Finally, the Secchi depth was used to compute the attenuation coefficient by $k=(1.6\pm0.6)/SD$, where SD is the depth at which the Secchi disk was last seen. Subsequently, k was used to compute the light penetrating to a specific depth $I(z)= I(z=0)\, e^{-kz}$, which in turn is used to determine the euphotic zone. The higher the Secchi depth, the lower the turbidity would be.

Results

Physical Measurements: Temperature, Salinity, and Dissolved Oxygen

Table 1 and 2 below summarizes the Mean and SD for temperature, DO, and RHO at various depths of Possum Kingdom Reservoir in 2015 and 2018, respectively.

Table 1: Mean and standard deviation (SD) for temperature (T), and density (RHO) at depth of Possum Kingdom Reservoir in 2015

Depth (m)	T mean(°C)	T SD	Salinity mean (psu)	Salinity SD	RHO mean (kg/m3)	RHO SD
0	26.54	0.88	1.58	0.10	997.82	0.31
1	24.96	0.71	1.63	0.05	998.29	0.21
2	23.56	0.25	1.70	0.00	998.70	0.05
3	22.76	0.09	1.79	0.03	998.97	0.02
4	22.58	0.05	1.94	0.08	999.13	0.07
5	22.45	0.07	2.09	0.10	999.28	0.09
6	22.33	0.16	2.24	0.07	999.42	0.04
7	22.05	0.00	2.39	0.02	999.60	0.02
8	21.66	0.16	2.49	0.02	999.77	0.06
9	21.20	0.11	2.59	0.03	999.96	0.04
10	20.15	0.32	2.69	0.03	1000.27	0.09
11	18.05	0.95	2.86	0.08	1000.83	0.24
12	15.51	1.07	2.89	0.02	1001.30	0.20
13	13.36	0.76	2.86	0.05	1001.61	0.12
14	12.01	0.49	2.85	0.06	1001.78	0.07
15	10.94	0.31	2.83	0.05	1001.89	0.05
16	10.33	0.12	2.80	0.00	1001.94	0.01

Table 2: Mean and standard deviation (SD) for temperature (T), dissolved oxygen (DO), and density (RHO) at depth of Possum Kingdom Reservoir in 2018

Depth (m)	T mean(°C)	T SD	Salinity mean (psu)	Salinity SD	RHO mean (kg/m3)	RHO SD	DO mean (%)	DO SD
0	25.69	0.23	1.10	0.00	997.70	0.06	100.21	3.34
1	25.61	0.20	1.10	0.00	997.72	0.05	99.09	1.29
2	25.36	0.10	1.10	0.00	997.81	0.02	87.06	21.64
3	25.09	0.20	1.10	0.00	997.87	0.05	97.11	1.78
4	24.88	0.35	1.10	0.00	997.93	0.09	96.25	1.97
5	24.25	0.25	1.10	0.00	998.09	0.06	91.39	2.82
6	23.66	0.23	1.10	0.00	998.24	0.06	90.13	2.83
7	23.23	0.23	1.10	0.00	998.35	0.06	88.51	4.42
8	22.65	0.47	1.10	0.00	998.49	0.11	78.66	5.72
9	21.50	0.30	1.10	0.00	998.76	0.07	64.18	7.42
10	19.60	0.34	1.10	0.00	999.17	0.07	36.76	2.02
11	18.10	0.26	1.10	0.00	999.47	0.05	36.30	6.32
12	17.19	0.25	1.10	0.00	999.65	0.04	33.96	6.37
13	16.38	0.17	1.10	0.00	999.79	0.03	30.08	5.60
14	15.49	0.09	1.10	0.00	999.94	0.01	17.11	8.18
15	14.73	0.14	1.10	0.00	1000.06	0.02	9.43	8.17
16	13.83	0.31	1.10	0.00	1000.20	0.04	4.13	5.76
17	13.05	0.47	1.10	0.00	1000.31	0.06	1.43	1.48
18	12.43	0.23	1.10	0.00	1000.39	0.03	0.70	0.05
19	11.88	0.10	1.10	0.00	1000.46	0.01	0.62	0.03
20	11.48	0.25	1.10	0.00	1000.51	0.03	0.45	0.30

The overall mean temperature gradient for 2015 data ranges from 10.33°C to 26.54°C with a standard deviation that ranges from 0 to 0.88 (Table 1). The temperature measurement is taken in 2018 ranges from 11.48°C to 25.69°C with a standard deviation that ranges from 0.09 to 0.47 (Table 2). Figure 2 shows the temperature with depth for both recorded years.

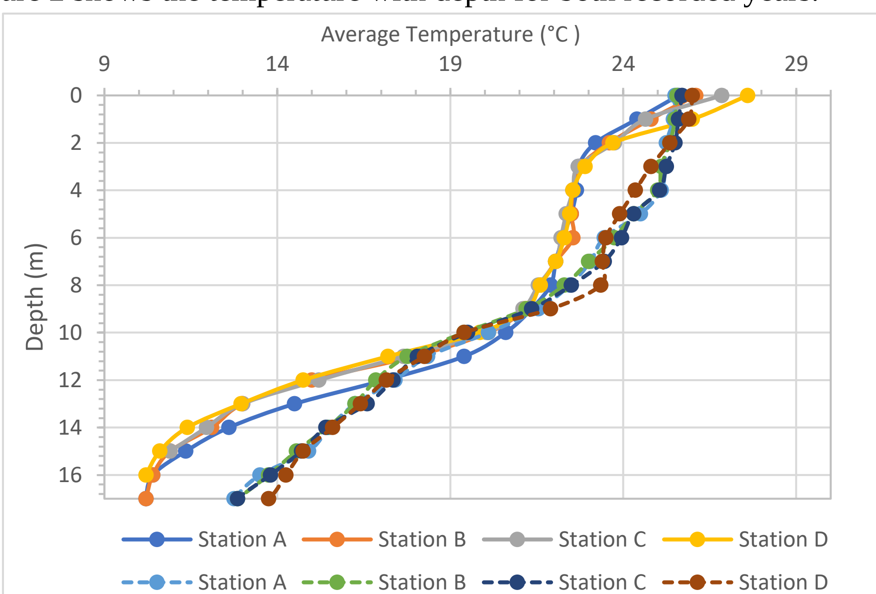

Figure 2: Average temperature (°C) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and D (32°52.871'N;98°33.308'W) are symbolized by solid lines. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by dashed lines. Refer to Figure 1 for topographic locations of stations.

The amount of dissolved material is measured in water through salinity. In 2015 the average salinity of Possum Kingdom Lake increased with depth, ranging from 1.5 psu to 1.7 psu. However, for 2018's field remained uniform through all depths and was measured at 1.1 psu (Figure 9).

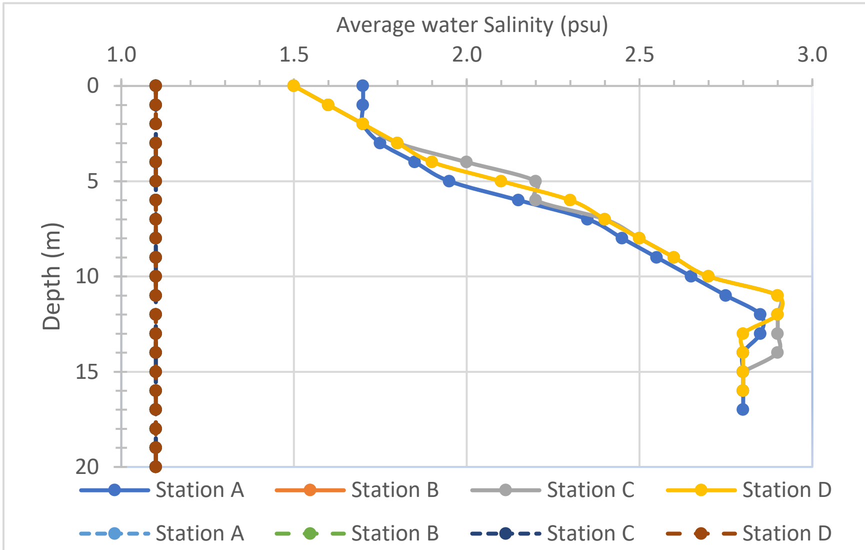

Figure 3: Average salinity (psu) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and D (32°52.871'N;98°33.308'W) are symbolized by solid lines. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by the dashed straight line. Refer to Figure 1 for topographic locations of stations.

The rate at which oxygen dissolves in water bodies is mostly regulated by salinity, atmospheric pressure, and temperature. The DO levels were not measured in 2015, but the measurement for 2018 shows the mean DO gradient ranged from 0.45 % to 100.21 % with its SD ranging from 0.05 to 21.64 (Table 2). Figure 4 below shows the DO with depth for 2018.

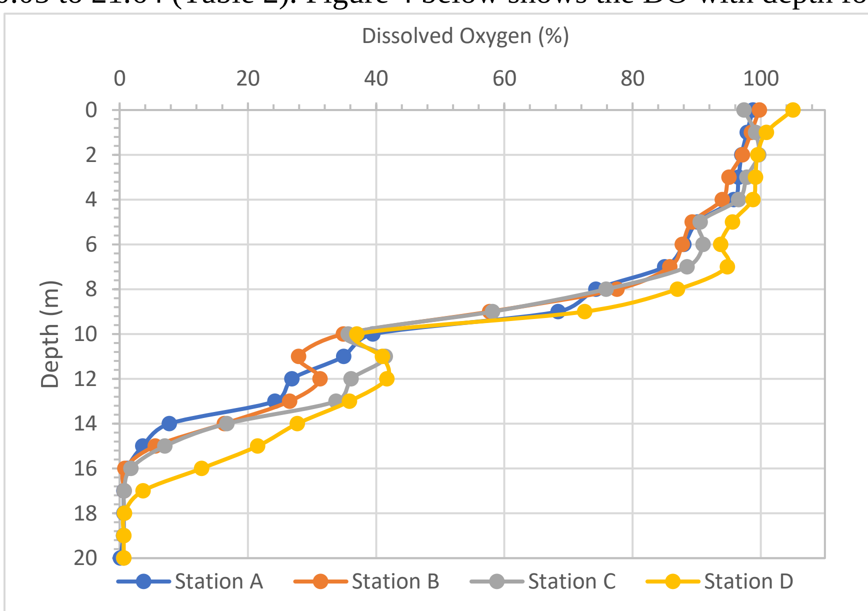

Figure 4: Average dissolved oxygen (%) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 dissolved oxygen was not measured. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by dashed lines. Refer to Figure 1 for topographic locations of stations.

Variances in water density are caused by differences in temperature and salinity. The average water density for 2015 ranged from 997.82 kg/m^3 to 1001.94 kg/m^3 with a SD ranging from 0.01 to 0.31. For 2018 it ranged from 997.7 kg/m^3 to 1001.51 kg/m^3 with a SD ranging from 0.11 to 0.01. Figure 5 below shows the density measurements for each measured depth for both years.

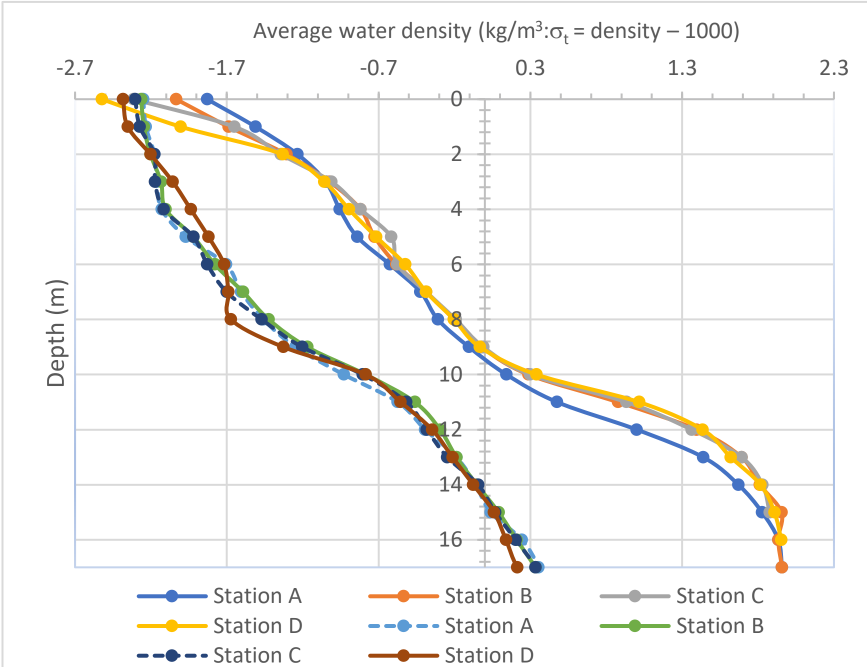

Figure 5: Average water density (kg/m^3) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and D (32°52.871'N;98°33.308'W) are symbolized by solid lines. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by dashed lines. Refer to Figure 1 for topographic locations of stations.

Water Stability, And Brunt-Väisälä Frequency Estimations

Estimations of water stability gradients through depth for all stations recorded in 2015 ranged from -0.0208 m^{-3} to 0.676 m^{-3}. For 2018 water stability for all stations ranged from 0.004 m^{-3} to 0.558 m^{-3}. Water stability with depth for all stations is presented in figure 6. To clarify trends the mean water stability for each of the two years was computed from all respective stations to derive a reservoir mean water mass stability as seen in Figure 7 below. For 2015 the mean reservoir water mass stability gradient ranged from 0.024 m^{-3} to 0.558 m^{-3}, whereas for 2018 it ranged from 0.024 m^{-3} to 0.412 m^{-3}.

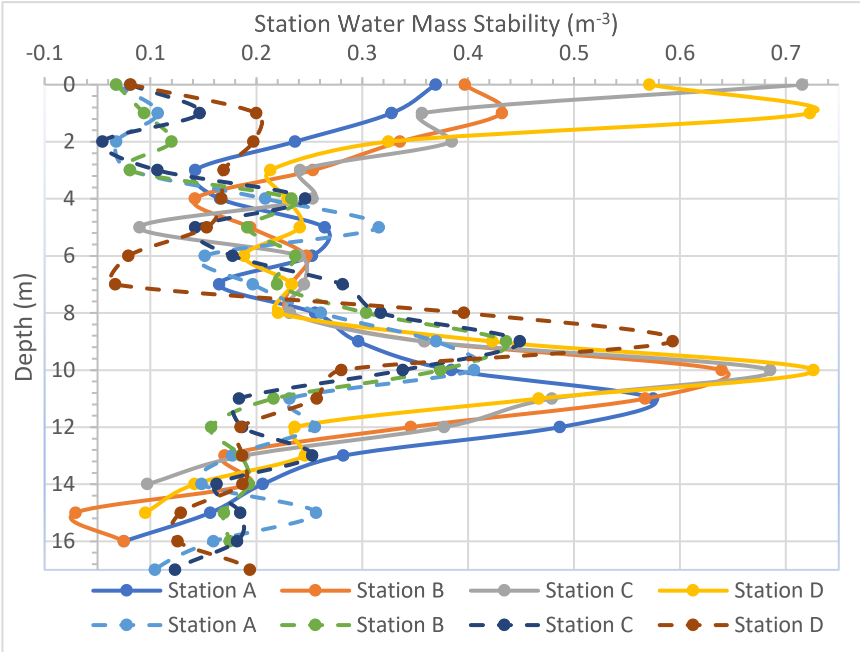

Figure 6: Station water mass stability (E) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and D (32°52.871'N;98°33.308'W) are symbolized by solid lines. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by dashed lines. Refer to Figure 1 for topographic locations of stations.

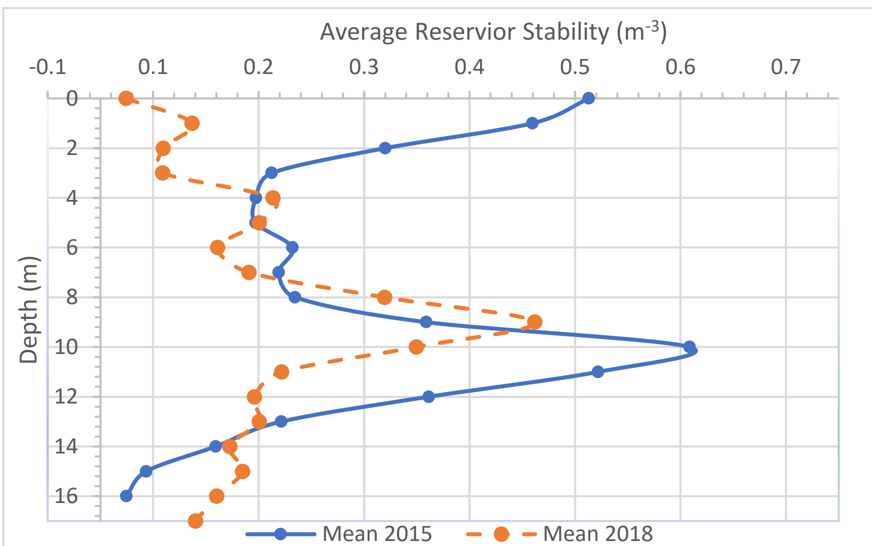

Figure 7: Mean water mass stability (E) with depth (m) for all stations for each recorded year at Possum Kingdom Reservoir. 2015 is represented by a solid blue line, and 2018 is represented by an orange dashed line. Refer to Figure 1 for topographic locations of stations.

The Brunt-Väisälä frequency (N) is the angular frequency at which a vertically displaced parcel will oscillate within a statically stable layer. Estimations of N for all stations in 2015 ranged from 0.067 s^{-1} to 0.21 s^{-1} whereas in 2018's recording it ranged from 0.132 s^{-1} to 0.808 s^{-1}. Figure 8 below presents each station N with depth. Similarly, to the stability assessment, the mean for each of the two years was computed from all respective stations to derive a reservoir mean N as seen in Figure 9 below.

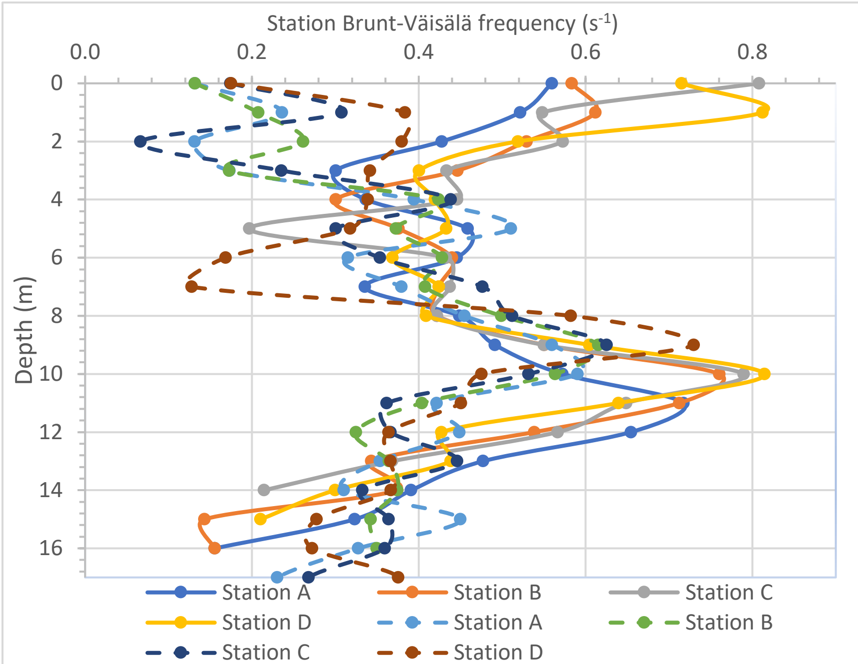

Figure 8: Brunt-Väisälä frequency (s^{-1}) with depth (m) for all stations at Possum Kingdom Reservoir. For the year 2015 station A (32°53.003'N;98°33.221'W), B (location not defined), C (32°62.882'N;98°32.609'W), and D (32°52.871'N;98°33.308'W) are symbolized by solid lines. For the year 2018 site A (32°52.824N;98°32.887W), B (32°52.921'N;98°32.514'W), C (32°52.97'N;98°32.73'W), and D (32°52,803'N;31°866'W) are represented by dashed lines. Refer to Figure 1 for topographic locations of stations.

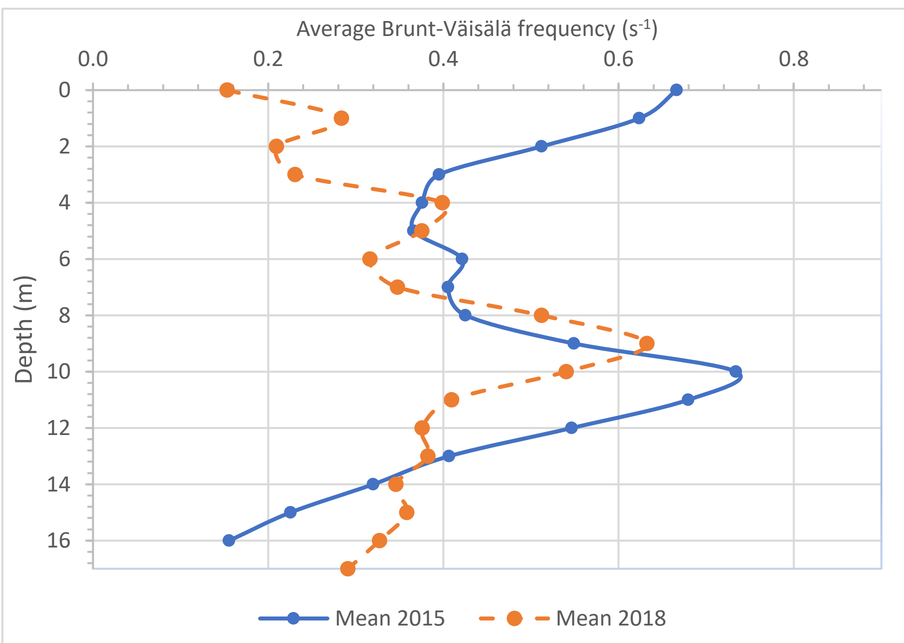

Figure 9: Average Brunt-Väisälä frequency (s^{-1}) with depth (m) for all stations for each recorded year at Possum Kingdom Reservoir. 2015 is represented by a solid blue line, and 2018 is represented by an orange dashed line. Refer to Figure 1 for topographic locations of stations.

Radiation and Optics: Light and Secchi Disk

Table 3 shows that the Secchi depth is not varying a lot with space. However, it varies a lot from 2015 to 2018. Regarding Table 4, the Secchi depth and turbidity of water is so high in 2018 while it is so low in 2015. So, the turbidity in 2018 is high while it is low in 2015. Figure 10 shows the relative light intensity in different depths. For the same depth the lower the k is the higher the relative light intensity. For the year 2015, the k (low, high) is 1.356 and 2.98 which makes relative light intensity drastically approach zero in lower depths compared to the k (low, high) of 2018 which is 0.172,0.378 which decreases less radically.

Table 3: Mean value for Secchi depth, attenuation coefficient, and depth of euphotic zone for Possum Kingdom Lake in 2015 and 2018

Secchi depth	**2015**	**2018**
station 1	0.80	5.56
station 2	0.80	6.00
station 3	0.65	6.50
station 4	0.70	5.20
Mean	0.74	5.82

Table 4: Mean value for Secchi depth, attenuation coefficient, and depth of euphotic zone for Possum Kingdom Lake in 2015 and 2018

Possum Kingdom Lake	**2015**	**2018**
Mean Secchi depth (m)	0.738	5.815
K (low)	1.356	0.172
k(high)	2.983	0.378
Depth of Euphotic zone(low)	1.544	12.172
Depth of Euphotic zone(high)	3.396	26.778

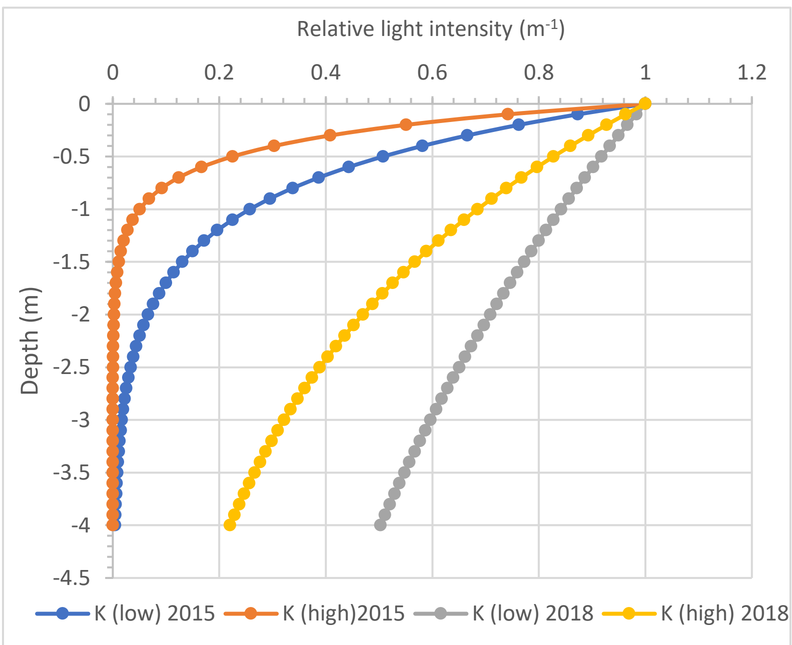

Figure 10: Average relative light intensity (m^{-1}) with depth at Possum Kingdom Lake in 2015, and 2018

Discussion/Conclusion

The SD of temperature, salinity, and density for both years were relatively low. The thermal stratification of Possum Kingdom Lake follows that of one typically associated with deep lakes during spring, with temperature decreasing with depth. The heated incoming water causes a decrease in density, subsequently, the warmer water at the surface is seen overlaying the colder water at the bottom. Although relatively similar, the measurements for both the actual temperature and the standard deviation of the temperature of 2018 is slightly less varied than that of 2015 as seen in table 1 & 2. This corresponds to the slightly smaller thermal gradient of 2018 compared to that of 2015 as seen in figure 2. Similarly, the salinity gradients were larger during 2015. For 2018 the salinity appeared uniform at 1.1 psu. For 2015 the average water density was mostly larger for all depths and was also more varied than that recorded in 2018. It can be expected that the decreased density gradient in 2018 implies that the depth to which wind could cause mixing was larger than that of 2015. The three strata layers namely the epilimnion, the metalimnion, and the hypolimnion were more distinct in 2015 data. 2018's data shows DO decrease with depth throughout the reservoir with all stations showing a similar trend. Although the DO levels were not taken for 2015 it can be expected that due to increased thermal stratification and decreased mixing the DO levels would be less.

Both the Stability and Brunt-Väisälä frequency (N) estimations follow similar trends. Both showed large variations between station locations as well as between both years. However, the data presented a clear inverse relationship between the two years up to 7m depth, below which they followed a similar trend. In 2018 the stability and internal wave oscillations increased with depth up 7m, whereas in 2015 it decreases with depth up to 7m.

Since we have very different Secchi depth and turbidity for the same Lake for different years, it implies that the turbidity is varying with time in our case study area. However, in each year in different stations, Secchi depth and turbidity are almost the same which shows that at specific time turbidity does not change in different areas of the Possum Kingdom Lake. The average relative light intensity diagram showed the higher k remaining above the lower k, showing that the relative light intensity goes to zero in shallower depths.

The data in this report suggest that during 2018 that the summer warming processes and fresher high flows in the lake occurred later than that of 2015. This suggestion is based on the expectation that winter waters in deep reservoirs being generally isothermal and circulate more freely; the Leifste & Popkin's (1968) study showed that for Possum kingdom Lake uniformity in temperature and salinity is expected to occur during the winter months, and the differences observed in the above mention gradients and SD's between the two different year's data. Overall, the data presents clear seasonal trends and variation in annual climate variations as seen in the difference in measurements with depth. Therefore, as the climate changes these trends might also change, warranting further research to investigate changes beyond spring.

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