Theme: Water quality

Water quality is essential for maintaining the ecological, social and economic values of the Gippsland Lakes. A conceptual model that illustrates the linkages between maintaining adequate water quality and the values of the site is provided in Figure 1.

(1) **Well mixed, high oxygen, low phytoplankton, low suspended sediments** - results in clear water with high visual amenity that supports recreation and tourism for residents, visitors and local businesses.

(2) **Water quality within recreational guidelines** - allows for primary contact recreational activities such as swimming and boating.

(3) **Seagrass beds** - are good habitat for juvenile fish and support recreational and commercial fisheries.

(4) **Healthy fringing vegetation** - protects shorelines from erosion, provides habitat for fauna, enhances visual amenity and provides opportunities for passive recreation.

(5) **Ocean access** - supports commercial and recreational fishing and provides passage for migratory fish species.

Figure 1: Conceptual model of the linkages between the health of the catchment, the Gippsland Lakes and the community and economic values (GLMAC 2013).

The important water quality indicators for protecting the values of the lakes include (EPA Victoria 2015):

- Salinity – for maintaining the abundance and distribution of flora and fauna, and related recreational activities such as fishing and bird watching; and for its role in nutrient dynamics and algal blooms
- Dissolved oxygen – for its role in nutrient cycling, maintaining fish and aquatic fauna health and the flow on effects to recreational activities such as fishing
- Suspended sediments – for maintaining seagrass beds, fish habitat and visual amenity
- Dissolved and total nutrient concentrations due to their importance in phytoplankton dynamics
- Chlorophyll-a as an indicator of phytoplankton biomass – which is both a driver of primary production and food webs, but in excess can indicate algal blooms
- Phytoplankton species and abundance – as the presence of toxic algal blooms effects recreation, tourism and the regional economy
- Toxicants – for their importance in maintaining the health of aquatic biota (fish and dolphins) and human health through consumption of fish

The list above has formed the basis of the indicators selected for the State of the Gippsland Lakes Report. These have been divided further into several categories:

1. Water chemistry – salinity, dissolved oxygen, suspended sediments, nutrient concentrations.
2. Nutrient loads – total amount of nitrogen and phosphorus entering the Lakes from river flows annually
3. Phytoplankton – in terms of biomass (chlorophyll-a concentrations) and number of algal blooms
4. Toxicants – as indicated by assessments of sediments (where toxicants can accumulate and be more readily detected than in the water column).

Water chemistry

Indicators and thresholds

Thresholds for water chemistry indicators have been derived using the framework established in the Australian and New Zealand Water Quality Guidelines (ANZECC and ARMCANZ 2000). In the absence of any reference condition sites, the water quality data for the Gippsland Lakes was interrogated to find a period that could be considered to represent "good" conditions. That is, a period without algal blooms and with average rainfall conditions. The first two years of available data (1986 – 1988) was selected and thresholds have been calculated as 80th percentiles for each indicator for this period. In accordance with the prescribed method, annual 50th percentile (median) values of current conditions were compared with the thresholds.

Condition of the Gippsland Lakes, with respect to water chemistry variables has been assessed as follows:

- Good = annual median values for the past five years were consistently better than the 80th percentiles of reference years (1986-1988).
- Fair = the annual median for one year in the past five years was worse than the 80th percentiles of reference years (1986-1988).
- Poor = the annual median for two or more of the past five years was worse than the 80th percentiles of reference years (1986-1988).

Trend has been assessed using a visual assessment of indicators over the complete timeframe data is available (1986 to 2015). The control charting technique, Exponentially Weighted Moving Average (EWMA) has been used, which smooths the data and allows trends to be more easily detected (Emphron Informatics 2008).

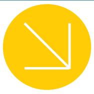
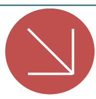
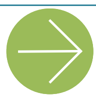
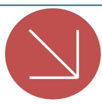
Locations

While water quality is important across all the habitats and wetlands in the Gippsland Lakes, long term data is restricted to the deep and shallow lakes of the coastal lagoons of Lakes King, Victoria and Wellington. For this reason, water chemistry in the main lakes has been assessed separately to that for the fringing wetlands.

Results

Summary

Indicator	Status and trends				Summary
	Unknown	Poor	Fair	Good	
Salinity		Lake Wellington		L. Victoria & King	Salinity in the Gippsland Lakes is influenced by rainfall, river flow and tidal exchange. During periods of drought, when freshwater inflows are low, salinity rises across the system. Conversely during flood periods, salinity across all surface waters drops to near fresh. Salinity in Lakes King and Victoria was assessed as good, while salinity in Lake Wellington was assessed as poor (see Appendix 2). The EWMA plotted over time illustrates that while there have been patterns of variability in response to rainfall events, there has been no sustained change in salinity in Lakes King and Victoria. The salinity in Lake Wellington, however, has continued to increase over time, largely in response to reductions in freshwater inflows, but also influenced by rising sea levels (EPA Victoria 2013, 2015).
	Data quality: Fair **Data custodian:** EPA Victoria				
Dissolved oxygen		Lake Victoria		Lakes King & Wellington	Dissolved oxygen is influenced by temperature, salinity and biological activity and can vary considerably over short periods of time. In most aquatic systems dissolved oxygen follows a diurnal cycle. Aquatic

Indicator	Status and trends Unknown Poor Fair Good	Summary
	Data quality: Fair **Data custodian:** EPA Victoria	plants, including phytoplankton are net producers of oxygen during the day (as a by-product of photosynthesis) and consumers of oxygen during darkness (when respiratory consumption exceeds photosynthetic production). Wind can also play a large factor in dissolved oxygen concentrations, particularly in the shallow waters of Lake Wellington. Dissolved oxygen was assessed as “good” in Lakes King and Wellington and “poor” in the surface waters of Lake Victoria. There is some evidence of a declining trend in dissolved oxygen levels in the surface waters of all three lakes (see Appendix 2).
Suspended sediments	 Lake Victoria  Lakes King & Wellington **Data quality:** Good **Data custodian:** EPA Victoria	Suspended sediments in the Gippsland Lakes are from inflowing waters from catchments and resuspension of bottom sediments, particularly in shallow areas (Harris et al. 1998, Holland et al. 2009). Lakes King and Victoria are largely clear, with salinity induced flocculation of sediments occurring. Lake Wellington is mostly turbid as a result of catchment derived sediments, wind generated resuspension of bottom sediments and the actions of European carp (Harris et al. 1998). All lakes were assessed as “good”. Lake Wellington is turbid, but this step change occurred over half a century ago, well before the site was recognised as a wetland of international importance (see Text Box below).
Total nitrogen	 L. Victoria & Wellington  Lake King **Data quality:** Good **Data custodian:** EPA Victoria	The combination of catchment inputs and nutrient recycling processes within Lakes Victoria and King, result in a gradient of nutrient concentrations in the water column which are higher at the western end of Lake Victoria (closest to catchment and sediment nutrient sources) and lowest at the eastern end of Lake King, near Lakes Entrance (Ladson and Tilleard 2011, EPA Victoria 2013). Nitrogen concentrations in Lake Wellington are higher again and have been classified as eutrophic by OECD standards (Harris et al. 1998). The annual median total nitrogen concentrations in Lakes Victoria and Wellington were above the threshold values for all recent years with sufficient data, while that in Lake King remained within the threshold value. There is some evidence of an increasing trend in total nitrogen in Lake Wellington, and to a lesser extent, Lake Victoria (Appendix 2).
Dissolved inorganic nitrogen	 Lakes King, Victoria and Wellington	Dissolved inorganic nitrogen comprises nitrate, nitrite and ammonium, all of which are readily available for plant (including algal) uptake. The shallow, well oxygenated environment of Lake Wellington provides

Indicator	Status and trends	Summary
	Unknown Poor Fair Good	
	Data quality: Good **Data custodian:** EPA Victoria	ideal conditions for nitrification/denitrification within the lake sediments, which results in large losses of nitrogen to the atmosphere as nitrogen gas (Longmore and Roberts 2006). The marine stratified environments of Lakes Victoria and King have more complex nitrogen cycles. Dissolved inorganic nitrogen concentrations in all Lakes have exceeded their respective thresholds and are assessed as "poor". There is some evidence of an increase in dissolved inorganic nitrogen over time (Appendix 2).
Total Phosphorus	Lake Wellington L. Victoria & King **Data quality:** Good **Data custodian:** EPA Victoria	Similar to total nitrogen, there is a gradient of total phosphorus concentrations from Lake Wellington to Lake King. Lake Wellington acts as a net exporter of total phosphorus to Lakes Victoria and King (Monbet et al. 2007). There were large peaks in nutrient concentrations in all three main lakes in 2006/7, which were linked to a large bushfire in the catchment. While total phosphorus concentrations in Lakes King and Victoria returned to "good" levels, they were above the threshold value for all recent years with sufficient data in Lake Wellington, with some evidence of an increasing trend (Appendix 2).
Dissolved inorganic phosphorus	Lakes King, Victoria and Wellington **Data quality:** Good **Data custodian:** EPA Victoria	Dissolved organic phosphorus is mostly in the form of phosphate and is readily available for uptake by macrophytes and phytoplankton. Concentrations of phosphate in all three lakes was assessed as good, with some evidence of improvements over the historical record (Appendix 2).
Chlorophyll-a	Lake Wellington L. Victoria & King **Data quality:** Good **Data custodian:** EPA Victoria	Chlorophyll-a is the green photosynthetic pigment in plants and is used as an indicator of phytoplankton biomass. Median concentrations of chlorophyll-a were below the threshold in Lakes Victoria and King from 2015 to 2020 indicating "good" condition. In Lake Wellington the threshold was exceeded in 2019/20 which is assessed overall as "fair". There is little evidence of a trend in chlorophyll-a in Lakes Victoria and King. There appeared to be a trend of increasing phytoplankton in Lake Wellington from 2007 to 2013, a decline from 2013 to 2016, then an increasing trend again since 2016 (Appendix 2). Whether this is evidence of a sustained trend remains unknown.

Status

The data for each individual indicator of water chemistry is provided in Appendix 2. The median values over the past five years (July 2015 to June 2020) are provided in Tables 1, 2 and 3 to illustrate the current status of each parameter in three locations (Lake Wellington;

Lake Victoria and Lake King). This illustrates the gradients of salinity (lowest in Lake Wellington, to highest in Lake King (closest to marine influences) and the opposite gradient of nutrients (highest in Lake Wellington and lowest in Lake King). The pattern of dissolved inorganic nitrogen and phosphorus is more complex, with nutrient recycling between the sediments and the water column playing a major role.

Table 1: Median values for each indicator in Lake Wellington (data from EPA Victoria). Shading indicates exceedance of the threshold.

Indicator	Threshold	2015/6	2016/7	2017/8	2018/9	2019/20	Rating
Chlorophyll-a	20	15	15	N/A	15	20	Fair
DO	95-110	95	98	N/A	100	104	Good
DIN	2	12	13	N/A	18	24	Poor
TN	624	800	735	N/A	950	1100	Poor
DIP	11	6	4.5	N/A	8	3	Good
TP	62	100	90	N/A	130	110	Poor
TSS	30	25	23	N/A	22.5	26	Good
Salinity	6	10	7	N/A	17	14	Poor

Table 2: Median values for each indicator in Lake Victoria (data from EPA Victoria). Shading indicates exceedance of the threshold.

Indicator	Threshold	2015/6	2016/7	2017/8	2018/9	2019/20	Rating
Chlorophyll-a	10	7	6	N/A	6	9	Good
DO (surface)	100-120	97	99	N/A	N/A	105	Poor
DO (bottom)	70-110	89	84	N/A	N/A	104	Good
DIN	3	8	8	N/A	11	10	Poor
TN	450	570	580	N/A	700	735	Poor
DIP	15	8	5	N/A	5	2	Good
TP	75	60	70	N/A	70	70	Good
TSS	14	9	9	N/A	9	15	Fair
Salinity (surface)	23	23	19	N/A	N/A	23	Good
Salinity (bottom)	28	24	22	N/A	N/A	25	Good

Table 3: Median values for each indicator in Lake King (data from EPA Victoria). Shading indicates exceedance of the threshold.

Indicator	Threshold	2015/6	2016/7	2017/8	2018/9	2019/20	Rating
Chlorophyll-a	5	3	5	N/A	2	1	Good
DO (surface)	100-120	104	107	N/A	N/A	106	Good
DO (bottom)	70-110	87	74	N/A	N/A	98	Good
DIN	7	7	8	N/A	8	7	Poor
TN	450	400	420	N/A	440	405	Good
DIP	12	7	4	N/A	3	3	Good
TP	50	30	40	N/A	40	20	Good
TSS	10	3	5	N/A	3	3	Good
Salinity (surface)	26	26	21	N/A	N/A	26	Good

Salinity (bottom)	30	29	26	N/A	N/A	30	Good

Median chlorophyll-a concentrations from 2015 to 2020 in Lakes Wellington, Victoria and King were 16, 7 and 3 μg/L, respectively, illustrating the gradient in phytoplankton biomass across the main lakes. Chlorophyll-a concentrations are generally higher in wet years (e.g. 2011/12) but have largely remained below average over the past five years indicating a return to “good” condition. Average chlorophyll-a concentrations are presented in Figure 2 and indicate that the highest concentrations occurred during spring.

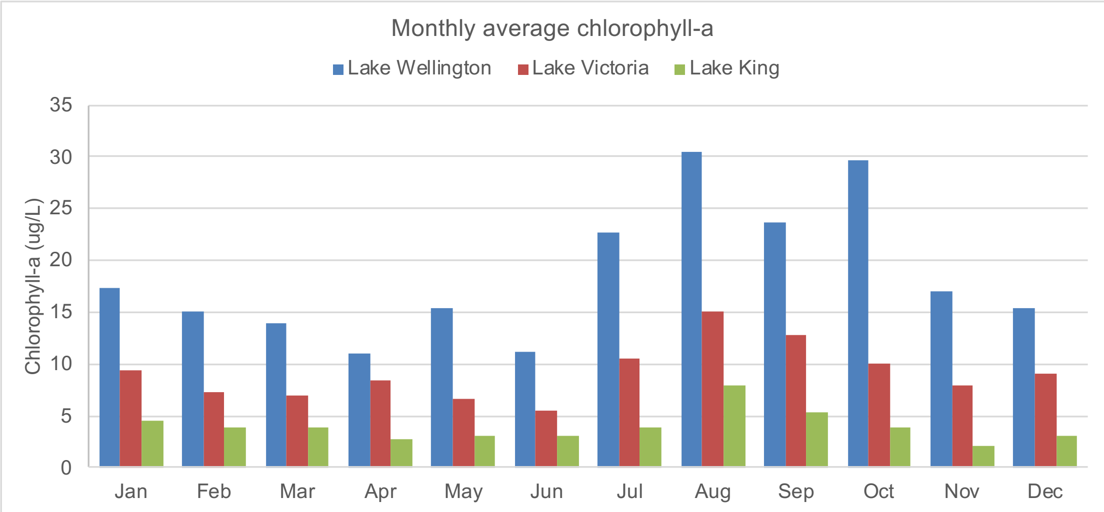


Figure 2: Average monthly chlorophyll-a concentrations in the surface waters of Lakes Wellington, Victoria and King 2017 - 2020 (data from EPA Victoria).

Trend

Exponentially Weighted Moving Averages are provided for each location and indicator in Appendix 2 and these have been used to visually express trends in water chemistry. For example, the EWMA of salinity is provided in Figure 3 for Lakes King and Wellington. This shows the clear step change in salinity in Lake Wellington, while the salinity in Lake King has remained largely the same over the past three decades. The EWMAs in Appendix 2, largely indicate that while water quality in Lakes King and Victoria have remained stable, there has been a decline in water quality in Lake Wellington.

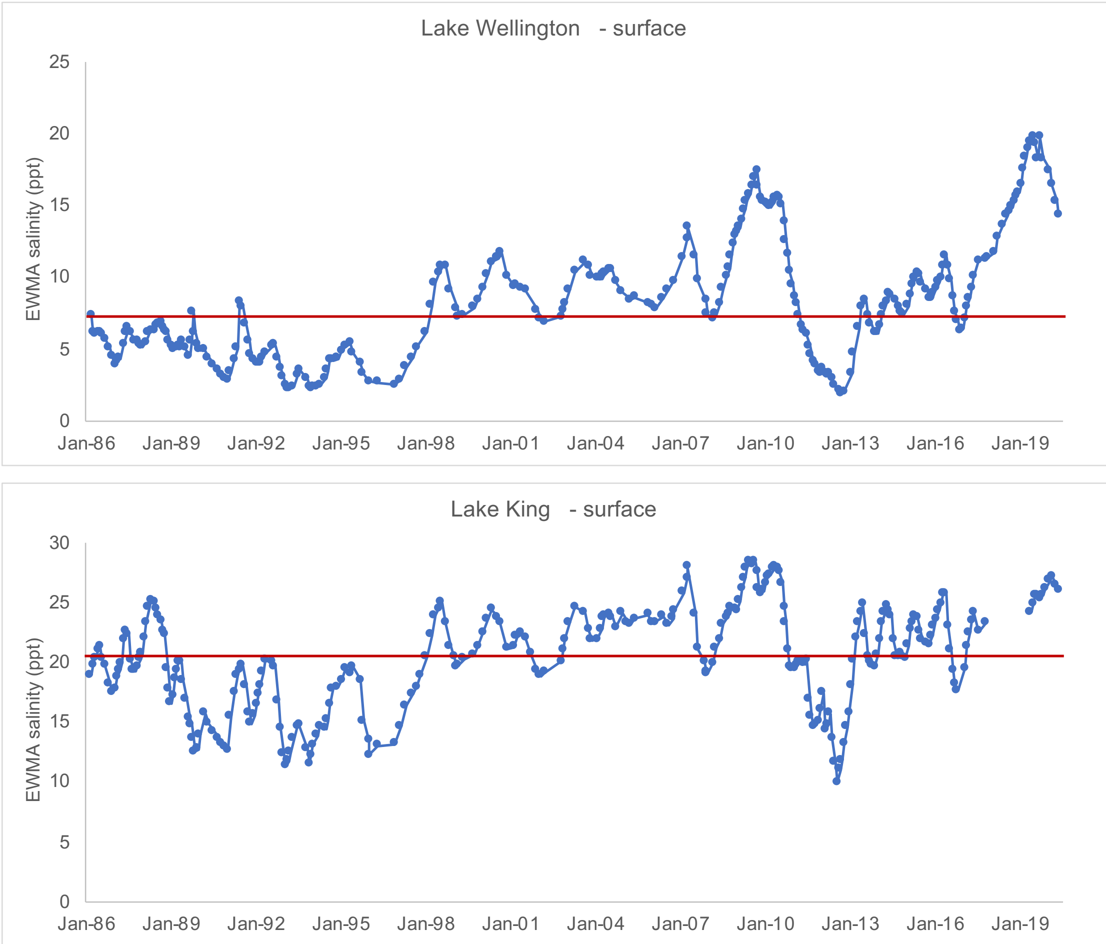


Figure 3: Exponentially weighted moving averages (EWMA) of salinity in Lakes Wellington and King, red lines indicate long term median values (data from EPA Victoria).

There is little evidence of a trend in chlorophyll-a concentrations in Lakes King and Victoria (see Appendix 2). The EWMA for chlorophyll-a concentration in Lake Wellington indicates a potential trend of increasing concentration from 2007 to 2013, but a return to average conditions in recent years (Figure 4).

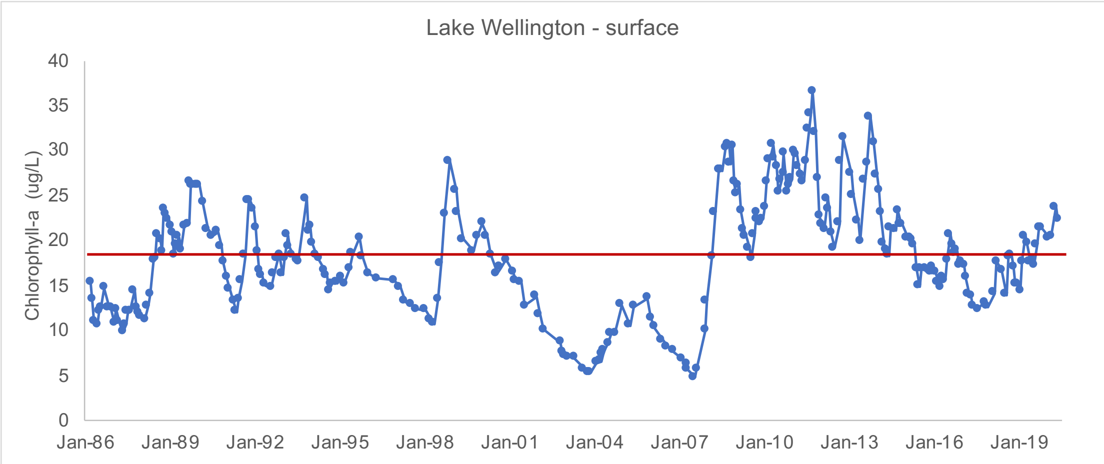


Figure 4: Exponentially weighted moving averages (EWMA) of chlorophyll-a in Lake Wellington (data from EPA Victoria). Red line indicates long term average.

Water chemistry – fringing wetlands

Indicators and thresholds

Data for water chemistry in the fringing wetlands is limited, with no consistent historical data upon which site-based thresholds can be calculated. Thresholds for salinity at Dowd and Heart Morass have been derived based on historic data.

Condition thresholds for salinity in Heart and Dowd Morass are as follows:

- Good = median salinity of < 4 ppt in all five years
- Fair = median salinity of < 4 ppt in two or more of the past five years
- Poor = median salinity > 4ppt in all five years.

Trend has been assessed in two ways. A statistical assessment of trend using seasonal Mann-Kendell trend test ($p < 0.05$) over the complete timeframe data is available (2017 to 2021.

Results

Summary

Indicator	Status and trends				Summary
	Unknown	Poor	Fair	Good	
Salinity			Dowd Morass	Heart Morass	Salinity in Dowd and Heart Morass is influenced by inundation and water source. Inflows of water from the Latrobe River result in reduced salinity, but when river flows are low, more saline water can enter the wetlands from Lake Wellington. Annual median salinity was below the threshold each year (2017/18 to 2020/21) with the exception of 2018/19 in Dowd Morass. This results in a rating of "good" for Heart Morass and "fair" for Dowd Morass. There is some evidence of decreasing salinity (improved condition) in recent years, but more data are required.
	Data quality: Good **Data custodian:** Victorian Water Measurement Information System data.water.vic.gov.au/monitoring.htm				

Status

Annual median salinity in Heart and Dowd Morass have been below the 4 ppt threshold each year since 2017 with the exception of Dowd Morass in 2019, when the median was 6.2 ppt (Table 4). Salinity in the two wetlands is highly dependent on inundation and water source, with freshwater inflows from the Latrobe River contributing to decreased salinity. When water levels in the wetlands are low, there can be movement of more saline water from Lake Wellington, particularly into Dowd Morass, which then leads to increased salinity. The beds of both wetlands are lower than the Latrobe River, meaning that large floods are required to fully flush salts out of the system.

Table 4: Median salinity from Dowd and Heart Morass (data from Victorian Water Measurement Information System). Shading indicates exceedance of the threshold.

Locations	Threshold	2017/8	2018/9	2019/20	2020/21	Rating
Dowd Morass	4	3.1	6.2	3.2	1.0	Fair
Heart Morass	4	3.9	3.3	3.0	1.9	Good

Trend

Exponentially Weighted Moving Averages for salinity in Dowd and Heart Morass suggest that there has been an improvement (reduction) in salinity in recent years (Figure 5 and Figure 6). Whether this is indicative of a long tern trend or just a reflection of wetter conditions in 2020 and 2021, is not yet known.

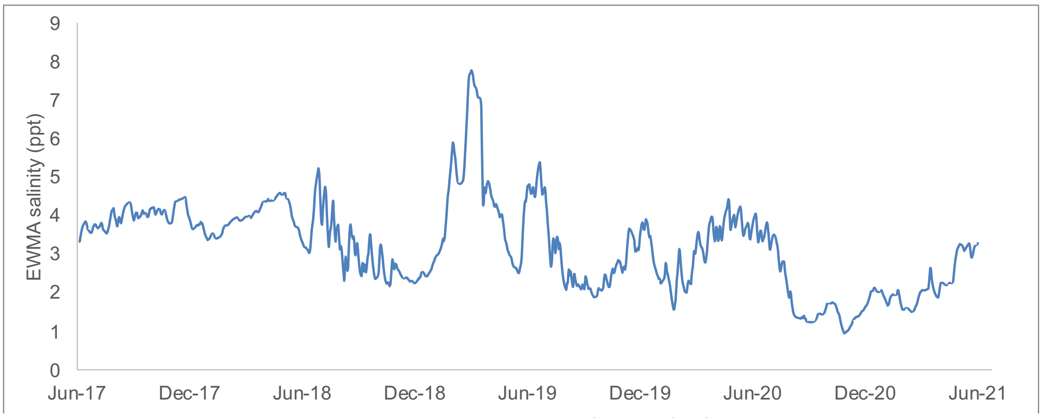


Figure 5: Exponentially weighted moving averages (EWMA) of salinity in Heart Morass.

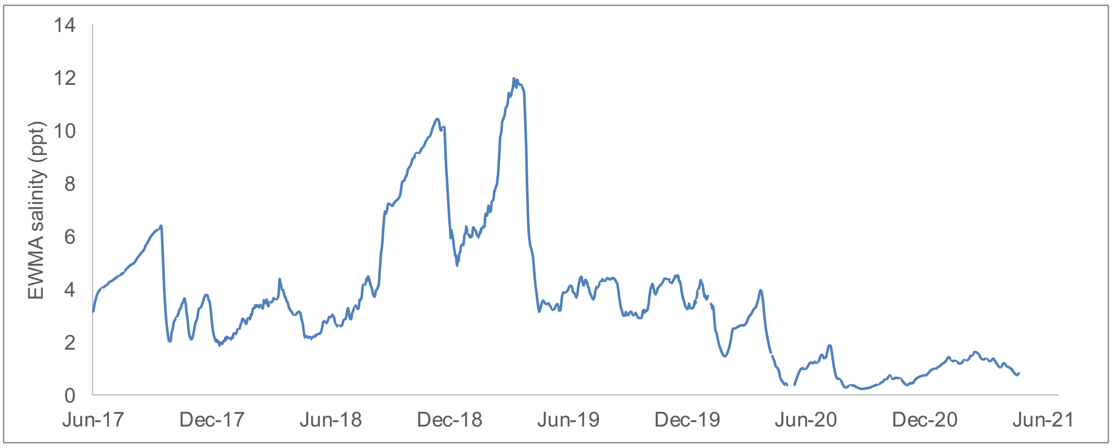


Figure 6: Exponentially weighted moving averages (EWMA) of salinity in Dowd Morass.

Toxicants

Indicators and thresholds

Toxicants include heavy metals as well as pesticides, herbicides and other chemicals that may cause harm to biota and humans. Toxicants from the catchment are transported through rivers and streams into the Gippsland Lakes and most will be bound to sediment particles and deposited in the sediments of receiving waters. For this reason, many studies focus on measuring toxicant concentrations in sediments.

Condition with respect to toxicants has been assessed based on sediment quality guidelines (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000) as follows:

- Good = meets ANZECC low sediment quality guidelines
- Fair = between low and high sediment quality guidelines
- Poor = exceeds high sediment quality guidelines.

Locations

The most recent assessment of sediment toxicants was conducted in 2015 and 2016 across the main lakes and also included sampling in two fringing wetlands: Heart Morass and Dowd Morass (Reeves and Trewarn 2016).

Results

Summary

Indicator	Status and trends				Summary
	Unknown	Poor	Fair	Good	

Indicator	Status and trends	Summary
	Unknown / Poor / Fair / Good	
Toxicants	Fair: L. Victoria, Wellington **Data quality:** Fair **Data custodian:** DELWP	There is some evidence of concentrations of mercury in sediments exceeding sediment quality guideline low trigger values in Heart Morass, Lake Wellington and Lake Victoria (Reeves and Trewarn 2016). In addition, there are high concentrations of nickel throughout the system, although this is a result of underlying geology and common in aquatic ecosystems in Victoria. Other metals were below guideline levels and overall the risk to the environment and human health from toxicants in the Gippsland Lakes is considered to be low. There is insufficient data to indicate trends.

Status

Concentrations of heavy metals in the sediments of the Gippsland Lakes (Table 5) indicate levels of nickel, mercury and arsenic above ANZECC low sediment quality guideline values.

Concentrations of nickel are not considered to be of concern as they reflect broader background levels of nickel in sediments and soils across Victoria as a result of underlying geology (Fabris et al. 1999b).

Concentrations of arsenic in sediments were elevated in Lake Wellington at depth (rather than the surface) which may indicate that deposition was related to historical activities in the catchment such as mining. The generally low levels and the presence of this toxicant only at depth indicates a low level of risk to ecology and human health (Reeves and Trewarn 2016).

The most recent study correlates with historical investigations with respect to mercury. Over the past 30 years, there have been several studies that have indicated that mercury may be of concern in the main lakes (Glover et al. 1980, Harris et al. 1998, Fabris et al. 1999a).

There are a number of possible sources of mercury in the Gippsland Lakes catchment. This includes:

1. Gold mining in the 19th and 20th Centuries - mercury was used to extract the gold from the crushed ore. The waste crushed rock, containing small amounts of mercury, was often discharged directly to waterways. This mercury could have remained in stream sediments, but a portion could have been washed into the Gippsland Lakes and deposited in the sediments.
2. Coal-fired power stations - coal-fired power stations are the single largest known source of mercury emissions globally (US EPA 2008). Although the amount of mercury in coal is very small, the large amount of coal burned each year (currently over 30 million tonnes annually in the Latrobe Valley) could mean the release of a significant amount of mercury into the atmosphere. This can be washed into the Lakes with rain. Interestingly the most recent investigation indicated a correlation between mercury and selenium concentrations in the Lower Latrobe River, pointing to power station fly-ash as the source
3. Mercury may naturally occur in bedrocks and sediments of the catchment.

Elevated concentrations of mercury in the sediment does not necessarily mean that there is an impact on human health or the health of plants and animals that live in the Gippsland Lakes. Most of the mercury in the sediment will be in solid form, bound to sediment particles. In this form, mercury is not readily bio-available. Under certain conditions (like low oxygen levels) bacteria in the sediment can convert the mercury from the solid form to methyl mercury, which is very fat soluble and can be absorbed by animal cells. In addition, mercury is known to bioaccumulate, with concentrations increasing as animals up the food chain consume animals containing mercury. A recent investigation of the concentrations of mercury in fish in the Gippsland Lakes however, indicated they were well within food safety guidelines (Department of Health and Human Services 2017).

Table 5: Concentrations of metals at depth, exceedances of ANZECC low guideline values shaded (Reeves and Trewarn 2016; BD = below detection).

		Toxicant (mg/kg)						
Location	Depth	Chromium	Nickel	Copper	Arsenic	Cadmium	Mercury	Lead
Heart Morass	0-5	41.86	37.53	38.44	11.63	0.40	0.31	40.38
	5-10	42.43	39.33	39.29	12.55	0.12	0.15	42.54
	10-15	43.76	40.03	39.78	13.83	0.10	0.17	43.25
	15-20	44.34	41.23	39.79	19.95	0.12	0.17	43.52
Dowd Morass	0-5	31.05	18.15	17.96	5.20	0.01	0.07	17.51
	5-10	24.34	13.97	22.79	7.50	0.03	0.13	12.12
	10-15	24.55	16.67	27.82	6.95	0.04	0.09	9.36
	15-20	21.33	17.04	30.96	7.83	0.04	0.11	9.08
Lake Wellington	0-5	35.95	21.99	15.55	9.27	0.04	0.06	11.17
	5-10	41.56	25.53	20.88	22.00	0.04	0.06	13.67
	10-15	44.81	27.87	23.35	20.11	0.04	0.06	16.01
	15-20	45.23	28.14	22.86	13.67	0.04	0.06	16.19
Lake Victoria West	0-5	32.15	24.33	21.98	7.76	0.05	0.39	17.77
	5-10	24.18	18.55	15.94	5.86	0.03	0.41	14.82
	10-15	30.62	23.46	20.78	8.99	0.05	0.56	18.64
	15-20	27.61	21.30	20.25	9.02	0.05	0.62	17.84
Lake King	0-5	4.72	20.58	1.92	10.40	0.06	BD	15.10
	5-10	4.19	21.77	1.50	10.76	0.05	BD	17.40
	10-15	4.25	23.74	1.55	12.48	0.05	BD	18.08
	15-20	4.74	23.31	1.79	5.90	0.07	BD	12.09

Trend

Information on toxicant concentrations in the waters and sediments of the Gippsland Lakes is limited. There are a handful of historical studies (Glover et al. 1980, Harris et al. 1998, Fabris et al. 1999a) some isolated one off investigations (Boon et al. 2007) and the recent investigation (Reeves and Trewarn 2016). This is insufficient to determine trends.

Knowledge gaps

The water quality of the main lakes is to a large extent well studied and the monthly EPA Victoria monitoring program provides a good long-term record for this part of the site. Water quality in the fringing wetlands is less well studied and while spot water quality measures are often taken when other studies on biota are being conducted, these rarely provide anything more than isolated snapshots. This is particularly problematic for wetlands with fluctuating hydrology. There will be strong dilution effects as wetlands fill and then a slow concentration of salts, nutrients and other elements in the residual pool as water evaporates. This means that spot measures taken at random intervals provide very little useful information for understanding condition and trends.

While a comprehensive water quality monitoring program is probably not warranted at every fringing wetland in the Gippsland Lakes system, a program that identifies some key indicator sites and instigates regular water quality monitoring would be valuable. Matched hydrological information (such as water depth or extent of inundation) would be essential to interpret water quality measures and it would take several years of drought and flood to establish patterns and trends.

The sediment investigation in 2015 / 2016 provides a good pilot study of toxicants across the system. The elevated concentrations of mercury and arsenic warrant further investigation and the project, completed in 2016, recommended that bioavailability of these metals should be tested (Reeves and Trewarn 2016).

Influencing factors and threats

Water chemistry in the Gippsland Lakes is influenced by a wide range of internal and catchment based factors. In particular, water resource use, inflows from the catchment and the influences of a changing climate have been identified as threats to the current and future water quality of the Gippsland Lakes (EPA Victoria 2015).

Approximately 20% of the total average freshwater inflow to the Gippsland Lakes is extracted for a number of consumptive purposes, including the major extractions of the Macalister Irrigation District (Tilleard and Ladson 2010). Water resource use is not even distributed across the catchment, and is significantly higher in the western rivers than the east. The combined effects of extraction and storage result in an average reduction of freshwater inflow into Lake Wellington of more than one third (O'Connor et al. 2009). This reduction in freshwater inflows has been identified as the critical factor affecting salinity (and the rise of salinity) in Lake Wellington (Tilleard et al. 2009, Ladson et al. 2011). The reduction in freshwater inflows lowers water levels and results in increased saline water flowing from Lake Victoria through McLennan Strait into Lake Wellington (Tilleard et al. 2009, SKM 2010). This then has follow-on effects of the back flow of saline water from Lake Wellington into many of the fringing wetlands (Boon et al. 2007). Under a future climate with higher sea levels and a reduction in rainfall and run-off, salinity in Lake Wellington and the fringing wetlands could be expected to increase.

Increased nutrient and sediment loads from the catchment have been identified as significant drivers of water quality decline in the system, leading to eutrophication, algal blooms and impacts to the beneficial uses and values of the Gippsland Lakes. Riverine nutrient loads are the dominant input of nutrients to the system, except under the right (algal bloom) conditions when direct fixation from the atmosphere by nitrogen fixing cyanobacteria can exceed catchment inputs (Cook et al. 2008).

As stated above, events such as bushfires in the catchment, result in the mobilisation of large amounts of sediment and nutrients into the system. For example, it was estimated that the combined effects of bushfires and floods in 2007 resulted in an addition 4000 tonnes of nitrogen entering the system (Ladson 2012). Climate change projections also suggest that fire weather, one of the risk factors for bushfires, will become more severe; indicating an increase in the frequency and intensity of bushfires (Hennessy et al. 2006). An increase in fires, together with increased intensity and frequency of storm events could lead to a repeat of the 2007 events which saw a major decline in water quality in the Gippsland Lakes.

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