Monitoring the Ecosystem Health of Estuaries on the NSW South Coast

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Abstract

Working with Councils to gain an improved understanding of the ecosystem health of estuaries is a key objective of the NSW Government Estuary Management Program, administered by the Office of Environment and Heritage (OEH). A well designed monitoring program can provide this understanding. Over the past few years both Shoalhaven City and Eurobodalla Shire Councils have embarked on additional estuary monitoring to enable them to provide baseline information on the ecosystem health of their respective estuaries. This information will also be used to help evaluate and report on the implementation of their estuary management plans (now termed coastal zone management plans), as well as inform ongoing management directions.

Shoalhaven City and Eurobodalla Shire Councils' estuary monitoring programs have historically centred on pressure indicators such as nutrients and/or bacterial sampling. Although very useful in monitoring pollution sources and recreational swimming quality, this has not provided Council with information sufficient to determine whether estuary ecosystem health is declining, being maintained or improving through initiatives such as implementation of estuary management plans. Both Councils recognised the need to modify their existing programs to fill this information gap in a scientifically robust and consistent manner. They now have two years of monitoring completed broadly in line with the monitoring and reporting protocols of the NSW Government Natural Resources Monitoring, Reporting and Evaluation (MER) Program (estuary theme).

With other Councils embarking on similar ecosystem health assessments for their estuaries, there is significant value in ensuring consistency across the State. Accordingly, this project was undertaken using the Monitoring, Evaluation and Reporting Sampling Protocols (Scanes et al., 2009) and the later Sampling, Analysis and Reporting Protocols for Estuary Ecosystem Health Assessments (OEH in prep). These protocols were followed to prepare ecosystem health report cards for both Shoalhaven and Eurobodalla Councils' estuaries. The results from these report cards are presented, along with discussion on developing and implementing ecosystem health monitoring programs for estuaries.

Background to Councils monitoring programs

Both Shoalhaven City Council (SCC) and Eurobodalla Shire Council (ESC) have a long history of involvement in the NSW Government Estuary Management Program and have completed estuary management plans (EMPs) for all their major estuaries. A component to all these plans has been to monitor water quality, with the focus in more recent plans being to monitor estuary ecosystem health. Until recently, the councils' water quality monitoring programs were centred around monitoring pressure and human health indicators. Whilst these have provided some useful information for informing EMPs and their ongoing implementation, there have been a number of limitations identified of the usefulness of the data collected.

For example, a review of water quality monitoring for the NSW South Coast (including Shoalhaven and Eurobodalla Councils) conducted by the Southern Rivers CMA (Fraser, 2008) highlighted that there is no co-ordinated, structured and standardised approach to monitoring between Councils, and that there is a lack of parameters measured that are

useful for monitoring the ecosystem health of an estuary. While SCC had some data on condition indicators such as chlorophyll a, it was patchy and not consistent over time. Other specific limitations were noted such as inconsistency in the number of sites sampled for each estuary, number of samples consistently taken, and the inconsistency of sampling throughout the year and between years. These limitations made meaningful comparisons from the data difficult (Fraser, 2008).

With these limitations in mind, and a change in focus at the State level to gain a better understanding of estuary ecosystem health, both councils applied for and gained funding under the NSW Government Estuary Management Program to modify their existing programs to focus on monitoring ecosystem health.

SCC was the first to receive funding of $50,000 in the 2008-9 financial year to set up a new ecosystem monitoring health program for the Shoalhaven River, with follow up grants of $52,000 in 2009-10 and $20,000 in 2011-12 provided to roll out and continue similar monitoring to another seven of Council's major estuaries (Lake Wollumboola, St Georges Basin, Lake Conjola, Swan Lake, Narrawallee Inlet, Burrill Lake, Tabourie Lake) (Figure 1). Monitoring occurred from September 2009 to January 2011 for the Shoalhaven River, and from January 2010 to February 2011 for the seven other estuaries. The second year of sampling occurred from September 2011 to September 2012 for all eight estuaries.

Similarly, ESC was given $60,000 in 2009-10 to modify its existing program and begin ecosystem health monitoring at six of Council's major estuaries (Clyde River, Tomaga River, Moruya River, Coila Lake, Tuross River, and Wagonga Inlet) (Figure 1). Monitoring occurred from February 2010 to January 2011, and extended for another 12 months from July 2011 to July 2012.

For both councils grant funding largely covered the costs of laboratory analysis of chlorophyll a samples, with council staff used to undertake the sampling. Both councils also used some of the grant funding for undertaking additional estuarine vegetation mapping of one or more of their estuaries.

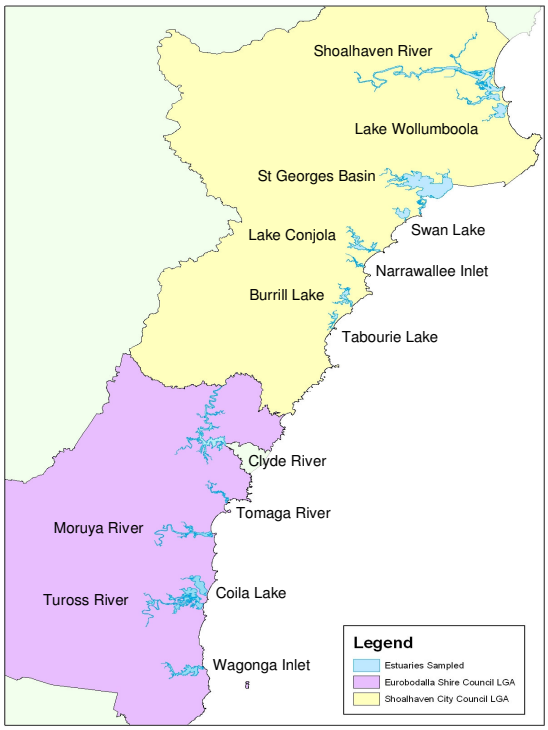


Figure 1: Map showing the 14 estuaries assessed as part of Shoalhaven City and Eurobodalla Shire Council's ecosystem health monitoring programs.

Consistency of Councils monitoring program with the Statewide MER Program

To assess and report on the health of NSW's estuaries, the NSW Government monitors a number of condition indicators as part of the Natural Resource Monitoring, Evaluation and Reporting (MER) Program (estuary theme) (DECCW, 2010a; DECCW, 2010b). It was a condition of the grant funding provided to both SCC and ESC that their ecosystem health monitoring be consistent with the MER Program as far as practical. As both Councils had active water quality monitoring programs, the intention was to build on these by incorporating key components of the MER Program. Key changes made to councils' monitoring (noting that there are some deviations from that recommended in the MER Program) included:

- Incorporating monitoring of condition indicators;
- Monitoring consistently over the year; and
- Rationalising site locations and number of sites per estuary.

Incorporating monitoring of condition indicators and monitoring consistently over the year

Chlorophyll a and turbidity

Councils' existing programs were modified to include monitoring of chlorophyll a and turbidity. These indicators were chosen as they are used in the MER Program (estuary theme) as indicators of estuary condition (DECCW, 2010a; DECCW, 2010b). The indicators represent the surface water component of the ecosystem. The MER Program, based on the findings of Scanes et al. (2007), concluded that measurement of chlorophyll a and turbidity provides an effective measure of the short term response of estuary health to certain types of pressures. In addition, chlorophyll a and turbidity could be readily incorporated into each Council's existing program of water quality sampling.

A suite of other physico-chemical water quality parameters including salinity, pH, temperature, and dissolved oxygen were also measured by both councils and provide useful information for interpreting water quality status. Additional monitoring of nutrients and/or faecal coliforms was also continued at some sites in some estuaries.

Another key recommendation for modifying each council's existing monitoring was to ensure that monitoring was undertaken consistently over a full 12 months or more to provide an adequate baseline and a minimum of 12 samples to base the analysis on. It was recommended that the Councils sample monthly for chlorophyll a and turbidity, and consider fortnightly sampling over summer. Fortnightly sampling was recommended over summer (mid November to end of March) as this is when chlorophyll a concentrations generally peak for the south coast, enabling a greater chance of capturing worse case conditions (Roper et al., 2011). As monitoring for the MER Program for south coast estuaries only occurs over mid November to the end of March to capture the annual chlorophyll a maxima (Roper et al., 2011; OEH, in prep), a bias to sampling over summer is consistent with the MER Program. Due to budget and resource limitations, only SCC incorporated fortnightly sampling.

Estuarine vegetation change

To gain a more balanced and complete understanding of ecosystem health for each of the Shoalhaven and Eurobodalla estuaries, the indicator group of estuarine vegetation change was added to the data collected by Council. The ecological health of an estuary is strongly linked to the biological diversity and integrity of estuarine vegetation (seagrasses, saltmarsh and mangroves) (Williams et al. 2003), with the MER Program noting they provide a longer-term picture of estuary health (OEH, in prep).

Estuarine vegetation change data was initially taken from the NSW State of the Catchment Technical Report Series, assessing the condition of estuaries and coastal lake ecosystems in

NSW (Roper et al. 2011). The methodology used to derive change in vegetation extent is generally based around comparing the percentage change between surveys conducted in 1985 by NSW Fisheries (West et al. 1985) and 2006 by the NSW Department of Primary Industries as part of the Comprehensive Coastal Assessment (Williams et al. 2006). The comparison between West et al. (1985) and Williams et al. (2006) provides a broad indication of change that is useful for determining whether further investigation and/or action is required, noting that there are well documented limitations when comparing between the two surveys, which are acknowledged on the relevant report cards produced for both Councils.

For some of the estuaries monitored, additional data was available through time series mapping that was completed as part of other estuary specific studies (Table 7, page 11). Where this was the case, this data has been used in preference to the 1985 and 2006 survey data, as this data is considered to be more accurate and indicative of trends over time (Roper et al, 2011). This is because the vegetation mapping has been surveyed over three or more periods in time using the one consistent methodology.

Upon viewing draft report cards and the results for estuarine vegetation change, ESC indicated that they would be reluctant to release the report cards to the public using the 1985 to 2006 direct comparison. This was because some of the change was extremely large (e.g. Clyde River seagrasses increase 762%) and there was no certainty that this was accurate based on the known limitations of directly comparing between West et al (1985) and Williams et al. (2006). Instead, ESC and OEH agreed to use a portion of the grant funding and councils' matching contribution to contract the Department of Primary Industries (Fisheries) to undertake additional estuarine vegetation surveys based on the latest aerial photography for four of the estuaries where change had been the greatest. This 2012 captured data was subsequently used to compare against the 2006 data, providing greater confidence in the calculated extent changes as they were mapped using the same methodology. Similarly, this was also completed for Shoalhaven River by SCC in partnership with OEH.

Rationalising site locations and number of sites per estuary

One of the limitations that was noted by Fraser (2008) for a number of the south coast Councils' existing water quality monitoring programs was the inconsistency in the number of sites sampled for each estuary. Upon reviewing Councils' sampling sites for each of their estuaries, it was determined that some rationalisation and changes were needed. Estuaries of similar size in some cases had relatively large differences in the number of sites. In addition, many of the site locations were based on historical purposes such as monitoring known point source locations. Other estuaries had sites that were above the tidal limit for the majority of the time and hence, were not representative estuarine sites.

In general, to gain a more representative snap shot of each estuary, Councils were advised to try and have at least three sampling sites for ICOLLs, with five or more for riverine estuaries (particularly the larger rivers). This is consistent with the recommendations of Fraser (2008). However, due to budget and accessibility factors, this minimum number of sites was not achieved for all estuaries. Other site location considerations included:

- Using sites where water quality data has previously been collected to assist with comparative purposes, including MER sampling zones if the estuary had been sampled under the MER Program (Scanes et al., 2009).
- Locating sites in the lower, middle and upper portions of each estuary to get a spread over different salinity zones.
- Minimising the potential for unrepresentative impacts on water quality caused by human activities in a localised area while still ensuring safe access under all conditions. In some instances, site selection has involved a compromise between ease of access and the position of structures (e.g. stormwater pipes) that may influence water quality.

It should be noted however, due to accessibility issues, some estuaries were not adequately represented, with sample sites having to be clustered in specific regions and thus may not be representative of the estuary as a whole. In addition, not all sampling was in accordance with the MER sampling protocols due to logistics. For example, the MER protocols are based on taking integrated samples over broad zones within the estuary via boat, while councils' sampling was largely based on discreet sites (some from shore where boats were not practical). It should be noted that there are limitations with shore based sampling and both Councils are working towards integrated sampling over zones undertaken by boat/kayak.

OEH development of sampling and analysis protocols

A number of Councils in NSW have now developed, or are in the process of developing, similar estuary health monitoring programs to that of Shoalhaven and Eurobodalla. While initial progress was made by the OEH to develop and promote the use of protocols for undertaking sampling in a consistent manner to that followed under the MER Program (Scanes et al., 2009), individual Councils and groups of Councils (e.g. Georges River Councils, Great Lakes Council, Northern Rivers councils) were using different methods of data analysis and reporting. This makes comparisons between estuaries from different council areas problematic.

In recognition of a need to provide a standardised approach to all aspects of estuary health monitoring and reporting for NSW, OEH has drafted sampling, data analysis and reporting protocols for estuary health assessments (OEH, in prep). The assessment and reporting methodology contained in the protocols has been revised and updated since preparation of the SoC reports (Roper et al, 2011), however the sampling methods have remained consistent with Scanes et al (2009). Standardising monitoring and reporting based on best practice has a number of benefits, including providing consistency at a range of scales (local, regional and state-wide), allowing for the comparison of assessments and ensuring scientific validity in information provided to the community.

Data analysis and reporting

The results of Councils' ecosystem health monitoring programs have been presented in report cards (Appendix A) that grade the health of the estuaries from A (very good) to E (very poor). However, in the case of SCC's report cards the overall grade was not shown and the corresponding grade descriptor (e.g. very good) noted in the report card summary on the front page. Individual sites within each estuary were also graded. The analysis required to do this is detailed in OEH Sampling, Analysis and Reporting Protocols for Estuary Health Assessments (OEH, in prep).

Chlorophyll a and turbidity

The analysis for chlorophyll a and turbidity is largely based on two main calculations (OEH, in prep), which are combined to give each site a separate score (from 1 to 5) and corresponding grade (from A to E) for both these indicators:

1. Calculating the proportion of time that the measured values for both chlorophyll a and turbidity are above the adopted trigger values (Table 1), derived from the NSW MER Program.
2. Calculating the distance/departure from the trigger value for each indicator. The distance measure is a recognition that comparing directly to a trigger value only allows for two possible states, compliant and non-compliant. The distance measure provides for more sensitivity for ecological condition along the gradient from good to poor (Great Lakes Council, 2011).

By averaging the scores for both chlorophyll a and turbidity, a final site score is calculated and a grade assigned to each site sampled within the estuary. The same process was also

followed for each estuary as a whole by combining all the individual site data so that each estuary could also be given a score for both chlorophyll a and turbidity. The thresholds used to derive these scores and grades are standardised and based on extensive analysis of data from NSW estuaries under the MER Program, which means that if a site or estuary receives an A (very good) grade, it represents very good condition for a NSW estuary (OEH, in prep).

Table 1: Trigger values for chlorophyll a and turbidity (Roper et al., 2011).

Estuary class	Trigger values	
	Chlorophyll a (ug/L)	Turbidity (NTU)
Lake	3.6	5.7
River – lower (salinity > 25ppt)	2.3	5.0#
River – mid (salinity 10 to < 25 ppt)	2.9	8.0#
River – upper (salinity < 10ppt)	3.4	13.7#
Lagoon	2.0	3.3

#The trigger values for turbidity in rivers was reviewed consistent with recommendations made in Roper et al. (2011). The revised trigger values recommended in OEH (in prep) for turbidity are river lower – 2.8, river mid – 3.5 and river upper – 6.6 NTU.

Estuarine vegetation

In terms of applying a score and grading to the percentage loss or gain in vegetation extent between the survey years for the 2010-11 report cards, five scoring classes were used (Table 2 below) as per the MER Program for development of the SoC report cards and adopted in the OEH protocols (OEH, in prep).

Table 2: The scoring classes used for estuarine vegetation change based on percentage loss or gain (Roper et al. 2011).

Score Criteria	Rating	Grade	Score
> 10% gain	Very Good	A	5
± 10% gain	Good	B	4
-10 to -40% loss	Fair	C	3
-40 to -70% loss	Poor	D	2
-70 to -100% loss	Very Poor	E	1

Grades were only awarded for the estuary as a whole and excluded mangroves as the current understanding of what change in mangrove extent means ecologically is the subject of some debate (Roper et al. 2011). However, it should be noted that the SoC reports (Roper et al. 2011) do provide a score for mangroves, but only where change has been calculated as <10%. For the report cards generated each estuarine vegetation class was reported on unless specified otherwise. Some vegetation change was unscored due to limited extent coverage, data capturing anomalies, or where scientific studies have conveyed that natural processes are likely to be the primary cause of the change. This was the case for some estuaries including Tabourie Lake and Lake Wollumboola.

In order to provide a score for the estuarine vegetation indicator group, an average of the individual scores for saltmarsh and seagrasses was undertaken excluding mangroves. This method was applied so that estuarine vegetation as a whole would have the same overall weighting as either chlorophyll a or turbidity in the overall estuary ecosystem health grade. As the majority of estuary vegetation data initially used was the West et al (1985) to Williams et al. (2006) comparison, it was felt that the limitations with this comparison warranted a bias

to the water quality indicators in the final grade. This differs from the State of the Catchment Reports where all indicators had the same weighting.

Documenting key areas of estuarine vegetation change

In addition to grading estuarine vegetation change, the report cards provide a brief description about the locations within each estuary where the greatest change had occurred. This was identified by visual comparisons between the data sets. Information about likely causes of the change was also included where this was available from other information sources, including estuary management plans and associated estuary processes and other technical studies, as well as historical aerial photos.

Calculating overall estuary ecosystem health grades (condition index)

In order to calculate the overall estuary health grade (from very good to very poor) the scores (from 1 to 5) for chlorophyll a, turbidity and estuarine vegetation were firstly averaged. Once an average score from the three indicators were calculated, the grading scale adopted for the NSW MER Program (and OEH protocols) was used to assign an overall estuary grade (Table 3) (Roper et al. 2011). This grade was then reported in the first sentence of each report card for 2010-11 and represents the overall ecosystem health of the estuary as per this methodology. An additional '+' or '–' were added to final grades as per Table 3 to further differentiate between them.

Table 3: Scoring classes used to assign overall grades of very good to very poor (left box) based on Roper et al. (2011) and how a '+' or '–' were then applied (right box).

Score Criteria	Rating	Grade
4.3 to 5.0	Very Good	A
3.5 to 4.2	Good	B
2.7 to 3.4	Fair	C
1.9 to 2.6	Poor	D
< 1.8	Very Poor	E

Applying a + or -	
4.9 to 5	A +
4.5 to 4.8	A
4.3 to 4.4	A -
4.1 to 4.2	B +
3.7 to 4.0	B
3.5 to 3.6	B -
3.3 to 3.4	C +
2.9 to 3.2	C
2.6 to 2.8	C -
2.5 to 2.6	D +
2.1 to 2.4	D
1.9 to 2.0	D -
1.7 to 1.8	E +
1.3 to 1.6	E
1 to 1.2	E -

While the 2010-11 ecosystem health report cards are based on grades integrating results from chlorophyll a, turbidity, and estuarine vegetation change, for the purpose of comparing between the two years of Council sampling, only chlorophyll a and turbidity results are used. This comparison will be used as the basis for developing water quality report cards (also incorporating other indicators) for 2011-12 (currently in preparation) and future years. It is intended that incorporating estuarine vegetation change into report cards will only be done over longer timeframes (e.g. 5-10 years) when new mapping has been completed.

Results from the two years of sampling

Shoalhaven City Council - Comparison of chlorophyll a and turbidity between years

When comparing the chlorophyll a and turbidity results between the two yearly sampling periods for each estuary, it is evident there has been some improvement in chlorophyll a while turbidity has declined. This pattern is generally evident across all the estuaries, resulting in the grades calculated from combining chlorophyll a and turbidity decreasing slightly for the Shoalhaven River, Burrill Lake, Lake Wollumboola, and Lake Conjola, slightly improving for Tabourie Lake, with no change for St Georges Basin and Narrawallee Inlet (Table 4). As there was not enough samples in the first sampling year to complete an analysis for Swan Lake, no comparison can be made between years.

Table 4: Chlorophyll a and turbidity grades for each estuary for the 2010-11 and 2011-12 sampling periods.

Estuary	2010 - 2011			2011 - 2012		
	Chl-a Grade	Turbidity Grade	Chl-a & Turbidity Combined Grade	Chl-a Grade	Turbidity Grade	Chl-a & Turbidity Combined Grade
Tabourie Lake*	C	E	D-	B	E	D+
Shoalhaven River	B	B	B	B	D	C
Burrill Lake	C	B	B-	B	D	C
Lake Wollumboola*	C	D	D+	C	E	D-
St Georges Basin	A	C	B	A	C	B
Narrawallee Inlet	C	C	C	B	D	C
Lake Conjola	B	B	B	A	D	B-
Swan Lake	no data			A	D	B-

*** See explanation in text below**

From the results gathered to date, it appears that all of the Shoalhaven estuaries sampled generally had relatively low to moderate micro algae levels (as measured by chlorophyll a) over the two years of sampling. Lake Wollumboola is probably the only exception with chlorophyll a levels being moderate over both sampling years. In contrast, the majority of estuaries sampled suffered from poor water clarity (as measured by turbidity), particularly over the second year of sampling where St Georges Basin had the best overall turbidity grade of C, with all other estuaries graded D or E.

It is important to note that while some of these results would indicate water quality issues, they do not necessarily indicate human impacts. This is particularly true for estuaries like Lake Wollumboola where periods of water quality deterioration including algae blooms are a natural phenomenon and would have occurred pre European settlement (Kinhill, 2000). Similarly, estuaries like Tabourie Lake are very shallow and the poor turbidity grades would in part be associated with wind driven resuspension of the shallow lake sediments.

Eurobodalla Shire Council - Comparison of chlorophyll a and turbidity between years

When comparing the chlorophyll a and turbidity results between the two yearly sampling periods for each estuary, in general there has not been a lot of change. The Clyde River was the only estuary where both the chlorophyll a and turbidity grades decreased by a whole grade. The grades calculated from combining chlorophyll a and turbidity decreased for the Clyde River, slightly decreased for Coila Lake, and Wagonga Inlet, slightly improved for Tuross River and Tomaga River, with no change for Moruya River (Table 5).

From the results gathered to date, the majority of Eurobodalla estuaries sampled generally had relatively low micro algae levels over the two years of sampling. Coila Lake was the only estuary that had moderate micro algae levels for both sampling periods. The majority of estuaries sampled also had relatively good water clarity (low turbidity), with Tomaga River and Coila Lake the only estuaries with periods of reduced water clarity (higher turbidity).

Table 5: Chlorophyll a and turbidity grades for each estuary, as well as the grades when combining these indicators for both the 2010-11 and 2011-12 sampling periods.

Estuary	2010 - 2011			2011 - 2012		
	Chl-a Grade	Turbidity Grade	Chl-a & Turbidity Combined Grade	Chl-a Grade	Turbidity Grade	Chl-a & Turbidity Combined Grade
Clyde River	A	A	A+	B	B	B
Tomaga River	C	C	C	B	C	B-
Moruya River	A	B	A	A	B	A
Coila Lake	C	B	B-	C	C	C
Tuross River	C	B	B-	B	B	B
Wagonga Inlet	A	A	A+	A	B	A

Influence of rainfall and temperature on the chlorophyll a and turbidity results

The chlorophyll a and turbidity results need to be evaluated in the context of the climate (rainfall and temperature) experienced over the two years of sampling. Both these years were wetter than recorded averages, especially the summers, with the 2011-12 summer being particularly cooler with higher than average rainfall (Bureau of Meteorology, 2012) (see Appendix B). These factors would have an influence on the results. For example, increased rainfall and lower temperatures over the summer 2011-12 are likely to be a reason why the chlorophyll a results improved and turbidity results worsened between the two sampling periods for a number of estuaries.

In general, the wetter conditions over both summers would have resulted in more runoff and sediment being delivered to each estuary from its catchment leading to murkier waters. Murky water reduces light penetration and therefore the ability of algae to grow (Roper et al., 2011). Likewise, the lower than average temperatures experienced over the 2011-12 summer would have also contributed to lower algae growth. The cooler temperatures over the summer 2011-12 translated into water temperatures being 1-2^{0}C cooler than for the summer of 2010-11 for a subset of estuaries where this data was analysed. Studies have shown good correlation between increasing water temperature and increasing chlorophyll a (Roper et al., 2012).

As the chlorophyll maxima (when algae growth is greatest) occurs over the warmer summer months, which is mid November to the end of March for the south coast region (OEH, in prep), the combined effects of increased turbidity and cooler temperatures over summer 2011-12 would have likely contributed to chlorophyll a levels improving between the 2010-11 and 2011-12 sampling periods.

Ecosystem health results incorporating estuarine vegetation change for the 2010-11 report cards

The overall grades presented for each estuary for the 2010-11 ecosystem health report cards are based on integrating results from the different indicators of chlorophyll a, turbidity, and estuarine vegetation (seagrass and saltmarsh) change. This provides a more balanced and complete assessment of ecosystem health that will be useful for identifying longer term change.

For SCC, five out of the seven estuaries assessed had an overall health grade of good (B), with the other two estuaries graded fair (C). For ESC, two out of six estuaries were graded very good (A), three graded good (B), with one graded fair (C) (Table 6).

Table 6: Final estuary grades as reported on the 2010-11 ecosystem health report cards integrating estuarine vegetation.

Estuary	2010 - 2011				
	Chl-a Grade	Turbidity Grade	Seagrass Grade	Saltmarsh Grade	Estuary Grade (Chl-a, Turbidity, Seagrass, Saltmarsh Combined)
Tabourie Lake	C	E	nc	A	C
Shoalhaven River	B	B	A	B	B+
Burrill Lake	C	B	A	C	B
Lake Wollumboola	C	D	A	nc	C+
St Georges Basin	A	C	C	A	B
Narrawallee Inlet	C	C	A	A	B
Lake Conjola	B	B	D	A	B
Swan Lake	no data		D	na	Not calculated
Clyde River	A	A	A	A	A+
Tomaga River	C	C	A	B	B-
Moruya River	A	B	B	B	A-
Coila Lake	C	B	C	B	B-
Tuross River	C	B	D	B	C+
Wagonga Inlet	A	A	C	D	B+

na = not applicable as one or both surveys recorded nil area

nc = not calculated due to mapping issues or where natural variation has been documented as the primary cause of change

Estuarine vegetation change

In terms of the estuaries where additional time series mapping or recently completed mapping is available (Table 7), the results show some interesting trends. In estuaries where mangroves are present, they have increased between the survey years except for Tuross River. Similar trends of mangroves increasing in estuaries have been reported from a number of other NSW estuaries (Roper et al., 2011). In all the river estuaries, saltmarsh has increased, while for the ICOLLs (Burrill Lake and Tuross River) saltmarsh has decreased. Saltmarsh has also decreased in Wagonga Inlet. Loss of saltmarsh in Wagonga Inlet has been attributed to direct human impacts such as reclamation as well as expansion of mangroves (Burrell, 2012). Similarly, reclamation for development was also identified as the primary cause of saltmarsh loss for Burrill Lake (Meehan, 2007).

The results for estuaries that only use the 1985 – 2006 comparison are not discussed here as they have been reported on in the SoC reports and accompanying technical report (Roper et al. 2011). However, the calculated percentage change for seagrasses, mangroves and

saltmarsh and corresponding grades assigned for all estuaries that was used to inform the report cards is shown in Table 8.

Supplementing the data from the 1985 to 2006 comparison with more detailed time series mapping and/or new mapping has resulted in grades changing for some of the estuaries (Table 7). In some cases this is likely to be the result of errors and limitations associated with the original 1985 mapping, which is the case for estuaries like Wagonga Inlet and Burrill Lake where time series mapping shows a consistent trend in contrast to the original mapping for one or more vegetation types. For some of the other estuaries, the difference may also be partly due to more recent factors that have influenced the health of the estuary over the last 5 to 10 years, including climatic and management factors. This could be the case for estuaries like the Tuross River. As the original comparison spans more than 20 years, subsequent more recent comparisons are less likely to show large percentage changes, which have an influence on the grades. This is likely to be the case for estuaries like the Tomaga River and the Shoalhaven River where the same increasing trend is identified in both the original and subsequent comparisons.

Table 7: Comparison of estuarine vegetation percentage change results and grades between the 1985 to 2006 surveys (left box), and surveys based on detailed time series mapping and/or new mapping (right box).

Estuary	Change % (between 1985 and 2006)			Grade		Percentage Change (Used for Report Cards)			Grade	
	Seagrasses	Mangroves	Saltmarsh	Seagrasses	Saltmarsh	Seagrasses	Mangroves	Saltmarsh	Seagrasses	Saltmarsh
Clyde River*	762%	43%	-49%	A	D	95%	3%	77%	A	A
Tomaga River*	536%	67%	31%	A	A	34%	27%	3%	A	B
Moruya River*	86%	25%	17%	A	A	9%	25%	1%	B	B
Tuross River*	381%	17%	100%	A	A	-52%	-35%	-2%	D	B
Wagonga Inlet#	-45%	-21%	-58%	D	D	-10%	41%	-49%	C	D
Shoalhaven River^	316%	20%	33%	A	A	27%	7%	3%	A	B
St Georges Basin$	-63%	9%	315%	D	A	-23%	9%	315%	C	A
Burrill Lake#	50%	na	51%	A	A	17%	na	-14%	A	C

Note: Grades that are shaded highlight where they have changed between the 1985-2006 comparison to the comparison used from either more detailed time series mapping or more recent mapping, which were used to inform the report cards

* Percentage change based on comparison between 2006 CCA data and 2012 DPI data

Percentage change based on detailed time series mapping

^ Percentage change based on comparison between 2006 CCA data and 2010 DPI data

$ Percentage change based on detailed time series mapping (for seagrasses only)

Table 8: The calculated percentage change for seagrasses, mangroves and saltmarsh and corresponding grades assigned for all estuaries that was used to inform the 2010-11 report cards. This incorporates comparisons from time series and new mapping and supplemented with data from the 1985 – 2006 comparison where this does not exist.

Estuary	Percentage Change			Grade	
	Seagrasses	Mangroves	Saltmarsh	Seagrasses	Saltmarsh
Shoalhaven River	27%	7%	3%	A	B
Lake Wollumboola	17%	na	nc	A	nc
St Georges Basin	-23%	9%	315%	C	A
Swan Lake	-55%	na	na	D	na
Lake Conjola	-68%	na	108%	D	A
Narawallee Inlet	518%	10%	93%	A	A
Burrill Lake	17%	na	-14%	A	C
Tabourie Lake	-82%	na	295%	nc	A
Clyde River	95%	3%	77%	A	A
Tomaga River	34%	27%	3%	A	B
Moruya River	9%	25%	1%	B	B
Coila Lake	-27%	na	8%	C	B
Tuross River	-52%	-35%	-2%	D	B
Wagonga Inlet	-10%	41%	-49%	C	D

na = not applicable as one or both surveys recorded nil area
nc = not calculated due to mapping issues or where natural variation has been documented as the primary cause of change

Conclusions and Recommendations

Both Councils now have a baseline of ecosystem health data for their major estuaries from which to compare to over time. In summary, estuaries in Eurobodalla were found to be generally in very good to good condition and estuaries in Shoalhaven generally in good to fair condition. This baseline is broadly consistent with State Government monitoring and across each Council. This will assist in evaluating the ongoing management of each estuary through initiatives such as implementing estuary management plans. Once the final report cards are released to the public (only Shoalhaven City Council to date), they will also provide a useful educational tool on the health of each estuary.

To provide greater confidence in the overall estuary ecosystem health assessments that include estuarine vegetation change, it is recommended that both Councils continue to undertake additional mapping of estuarine vegetation in estuaries where only the two major surveys have been completed. In addition, it is also recommended that councils fully align their sampling methodology with that used by OEH (OEH in prep). To aid in more detailed interpretation of results, additional pressure indicators should be considered for future monitoring.

References

Bureau of Meteorology (2012). Climate data online. Bureau of Meteorology website - http://reg.bom.gov.au/climate/data/

Burrell, A. (2012). Mapping Changes of Saltmarsh and Mangrove Vegetation Communities in Wagonga Inlet, NSW South Coast. Honours Thesis, Environmental Science, Faculty of Science, University of Wollongong.

DECCW (2010a). *New South Wales Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015.* Department of Environment, Climate Change and Water, December, 2010. Viewed 15th August 2011 from: http://www.environment.nsw.gov.au/resources/soc/10977nrmmerstrat1015.pdf

DECCW (2010b). *State of the Catchments 2010, Estuaries and Coastal Lakes - Southern Rivers region*. Department of Environment, Climate Change and Water, November, 2010. Viewed 15th August 2011 from: http://www.environment.nsw.gov.au/resources/soc/southernrivers/10603SRestuarine.pdf

Fraser, M. (2008). The development of an ecosystem health monitoring program for the estuaries and coastal lakes in the Southern Rivers Catchment Management Authority region. Southern Rivers Catchment Management Authority, Wollongong.

Great Lakes Council (2011). 2011 State of the Environment Report. Viewed 31st January 2012 from: http://www.greatlakes.nsw.gov.au/files/13e416da-b80a-4b21-85e5-9fa600a3de87/2011_GLC_SoE.pdf

Kinhill (2000). Lake Wollumboola Estuary Management Plan. Prepared for Shoalhaven City Council

OEH (in prep). OEH Sampling, Analysis and Reporting Protocols for Estuary Ecosystem Health Assessments. NSW Office of Environment and Heritage, Sydney.

Meehan, A.J. (2007). Long term changes in seagrass and saltmarsh of Burrill Lake. Department of Natural Resources, Internal report, 6 pp.

Roper, T. Creese, B. Scanes, P. Stephens, K. Williams, R. Dela-Cruz, J. Coade, G. & Coates, B. (2011). *Assessing the condition of estuaries and coastal lake ecosystems in NSW Technical Report - NSW State of the Catchments 2010*. NSW Office of Environment and Heritage, Sydney. Viewed 15th January 2012 from: http://www.environment.nsw.gov.au/resources/soc/20110717EstuariesTRS.pdf

Scanes P., Coade, G., Doherty, M. and Hill, R. (2007). Evaluation of the utility of water quality based indicators of estuarine lagoon condition in NSW, Australia. *Estuarine, Coastal and Shelf Science* 74 (2007) 306 to 319.

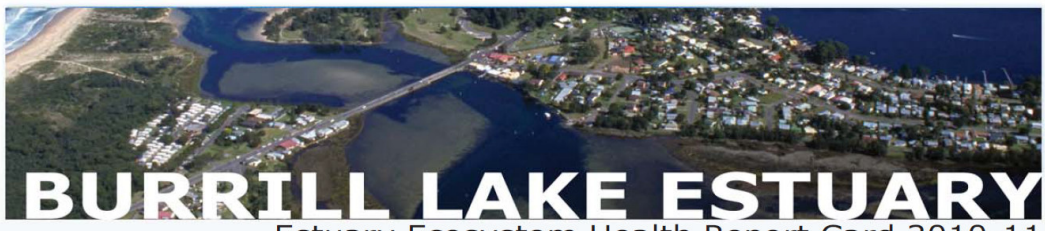
Scanes, P. Coade, G. & Dela-Cruz, J. (2009). *Monitoring, Evaluation and Reporting Sampling Protocols*. NSW Department of Environment, Climate Change and Water, Sydney.

West, R. J., Thorgood, C., Walford, T. and Williams, R.J. (1985). An estuarine inventory of New South Wales, Australia. Fisheries Bulletin 2, Department of Agriculture New South Wales.

Williams, R. J., A. Meehan, et al. (2003). Status and trend mapping of aquatic vegetation in NSW estuaries. Coastal GIS 2003: an integrated approach to Australian coastal issues. C. D.

Williams, R. J. West, G, Morrison, D. and Creese, R.G. (2006). Estuarine resources of NSW, prepared for the Comprehensive Coastal Assessment. NSW Department of Primary Industries. Port Stephens.

Appendix A – Example of Ecosystem Health Report Cards produced for 2010-11



BURRILL LAKE ESTUARY

Estuary Ecosystem Health Report Card 2010-11

Ecosystem Health

Based on the indicators assessed, the health of Burrill Lake is good. For most of the time water clarity was high and algae levels were relatively low. While an increase in the important habitat of seagrass was identified, a moderate decline in saltmarsh occurred.

This assessment is based on chlorophyll a and turbidity collected by Council between January 2010 to February 2011, and estuarine vegetation change between 1944 and 2002 calculated by the NSW Office of Environment and Heritage. While this assessment is a snapshot in time, it provides a baseline against which future sampling can be compared, allowing us to track how well we are managing this important estuary.

For more detailed information about Council's sampling program and the methodology for analysing data, please refer to the accompanying technical report located on Council's website.

Estuary Information

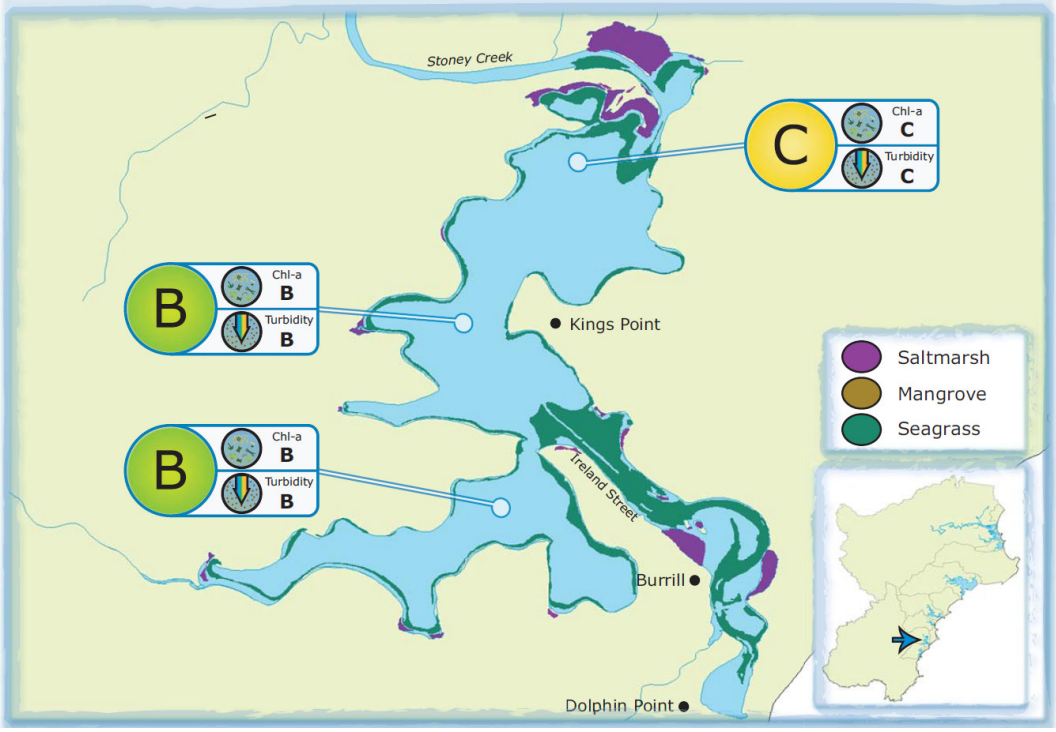
Catchment area (km^2):	60.7
Estuary area (km^2):	4.4
Estuary volume (Ml):	17652.7
Estuary type:	Youthful barrier estuary
Entrance:	Intermittently open
Major tributary:	Stoney Creek

Average Yearly Rainfall: 1044.9mm
(Stn No:69138) 2010: 1309.8mm (total)

Land Use (Area): Urban: 7.5% Forest: 45.3%
(2005 data) Rural: 45.2% Other: 2%

Burrill Lake Estuarine Vegetation

Saltmarsh	Mangroves	Seagrass
C	(unscored)	A



Water Quality Indicators (Grades based on OEH Estuary Health Assessment Methodology)

Chlorophyll a *indicates the amount of microscopic algae, called phytoplankton, growing in the water. Excessive input of nutrients from catchment runoff (urban stormwater, agricultural runoff, and sewage overflows) can increase chlorophyll a levels and lead to algal blooms and detrimental effects on estuarine plants and animals.*

For 2010/11 Burrill Lake overall received a good rating for chlorophyll a with 47% of total samples exceeding guideline values, with these samples barely exceeding the guideline. The site at the confluence of Stoney Creek and Burrill Lake had the greatest number of exceedances with 63%, indicating possible excessive nutrient input from the upstream catchment. As a comparison, chlorophyll a data collected by the State Government between 2008 and 2009 had 74% of samples exceeding guideline values, but was based on a different sampling regime.

Turbidity *is a measure of light scattered by suspended particles such as sediment, algae and dissolved material in the water which affect its colour or murkiness. Turbidity can increase from sediments transported in catchment runoff (particularly after heavy rainfall), shoreline erosion and increased microscopic algae. Increased turbidity can have negative impacts on seagrasses and fish.*

For 2010/11 Burrill Lake overall received a good rating for turbidity with only 8% of total samples exceeding guideline values, with these samples barely exceeding the guideline. Similarly, the site at the confluence of Stoney Creek and Burrill Lake had the greatest number of exceedances with 13%. As a comparison, turbidity data collected by the State Government between 2008 and 2009 all complied with guideline values, but was based on a different sampling regime.

Grades

A — *Very Good*

B — *Good*

C — *Fair*

D — *Poor*

E — *Very Poor*

Estuarine Vegetation Indicators (Grades based on % gain or loss in extent)

Seagrasses *are aquatic flowering plants that form meadows near shore. They are highly productive, provide nursery and foraging habitat (for fish, crustaceans and molluscs), bind sediments against erosion and help regulate nutrient cycling. They are very sensitive to changes in water clarity.*

Seagrasses in Burrill Lake increased by 17% between 1944 and 2002, receiving a grade of very good. This increase has primarily occurred at the confluence of Stoney Creek and Burrill Lake, and around the general perimeter of the lake. An increase in this valuable habitat is extremely positive.

Mangroves *grow between mid and high tide levels. They are an important food source, provide habitat for a number of species such as crabs and juvenile fish, protect shorelines and cycle nutrients and carbon. While an increase in mangroves can be a positive outcome where they are recolonising in areas previously removed, increases in mangrove distribution can sometimes be at the expense of other important habitat types such as saltmarsh, which could be viewed as a negative outcome.*

There is a very limited area of mangroves in Burrill Lake so no comparison can be made.

Saltmarsh *is a community of plants and animals that grows above the mangroves at the highest tidal levels. Saltmarsh is important in estuarine food webs, providing a site for invertebrate breeding and a feeding area for economically important fish and shorebirds. Saltmarsh decline is a worrying trend from a number of estuaries in NSW and has led to saltmarsh being listed as an endangered ecological community under the Threatened Species Conservation Act 1995. Declines in recent years have been linked to both increased sedimentation from catchment land use pressures and sea level rise.*

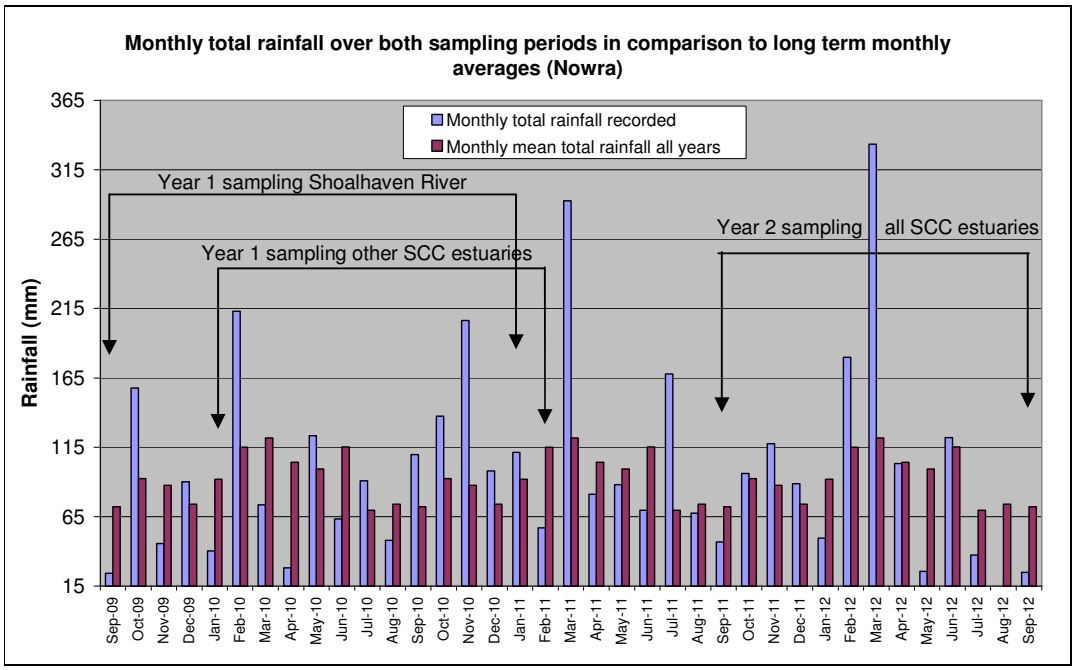
Saltmarsh in Burrill Lake has decreased by 14% between 1944 and 2002 and therefore received a grade of fair. This decrease has primarily occurred adjacent to and north west of Ireland Street, attributed to the residential development that occurred after 1972.

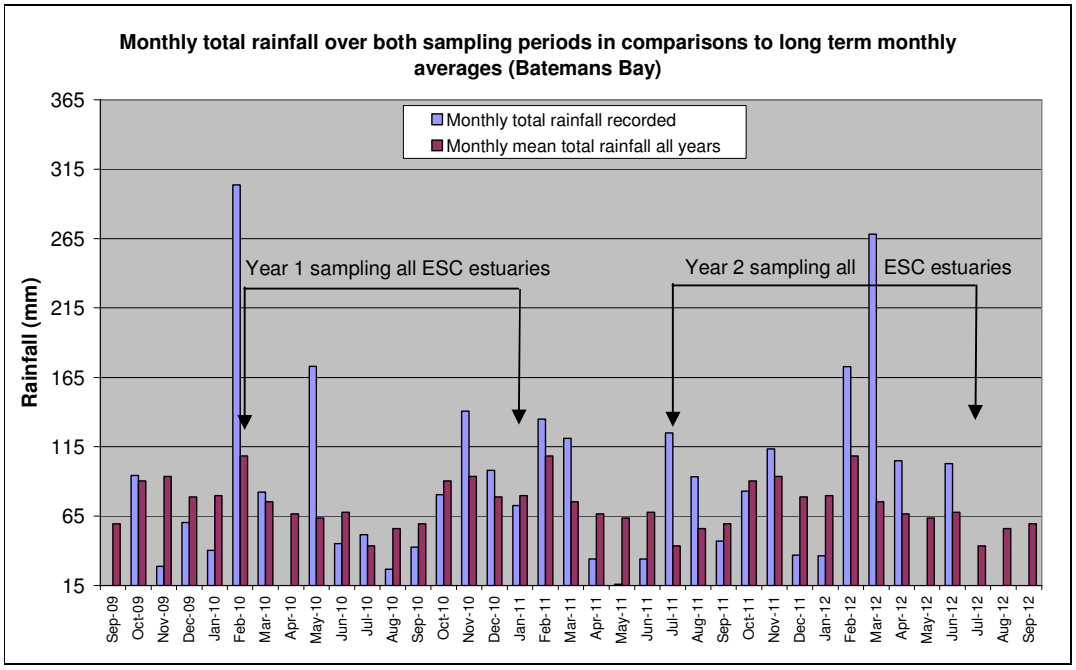
This report card is an initiative of Shoalhaven City Council, with financial and technical support from the NSW Government Estuary Management Program

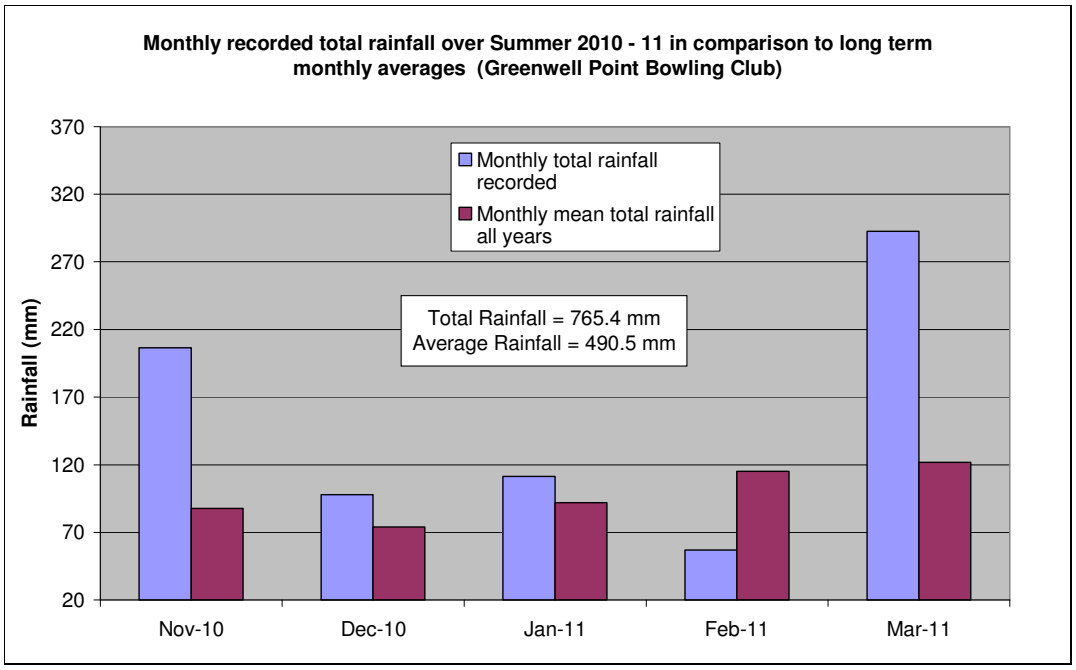
NSW GOVERNMENT Office of Environment & Heritage

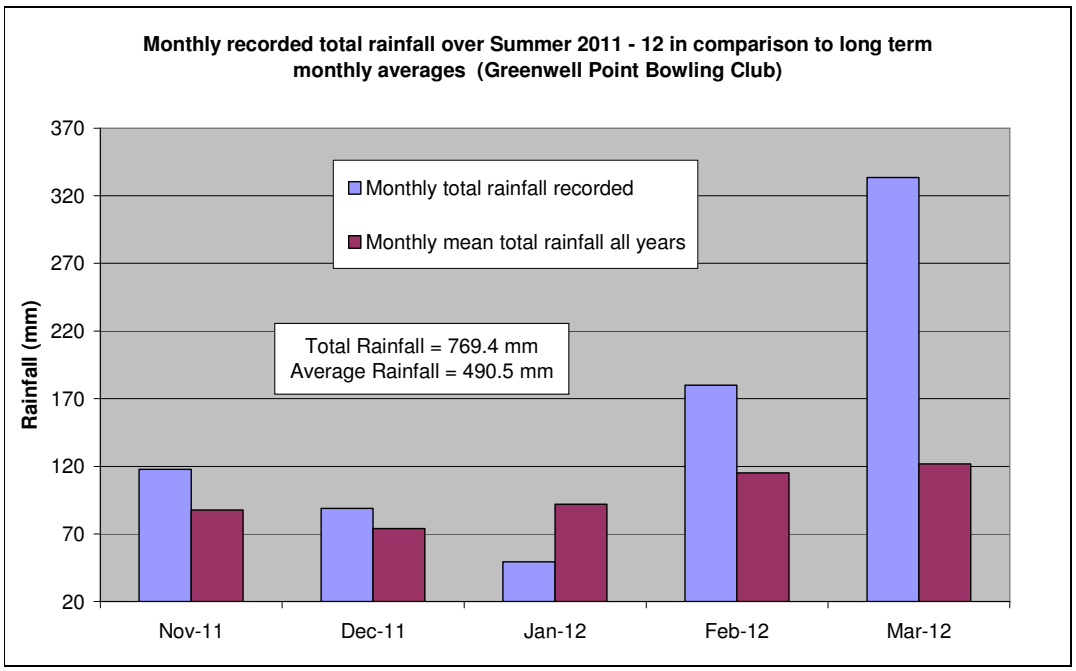
Shoalhaven City Council

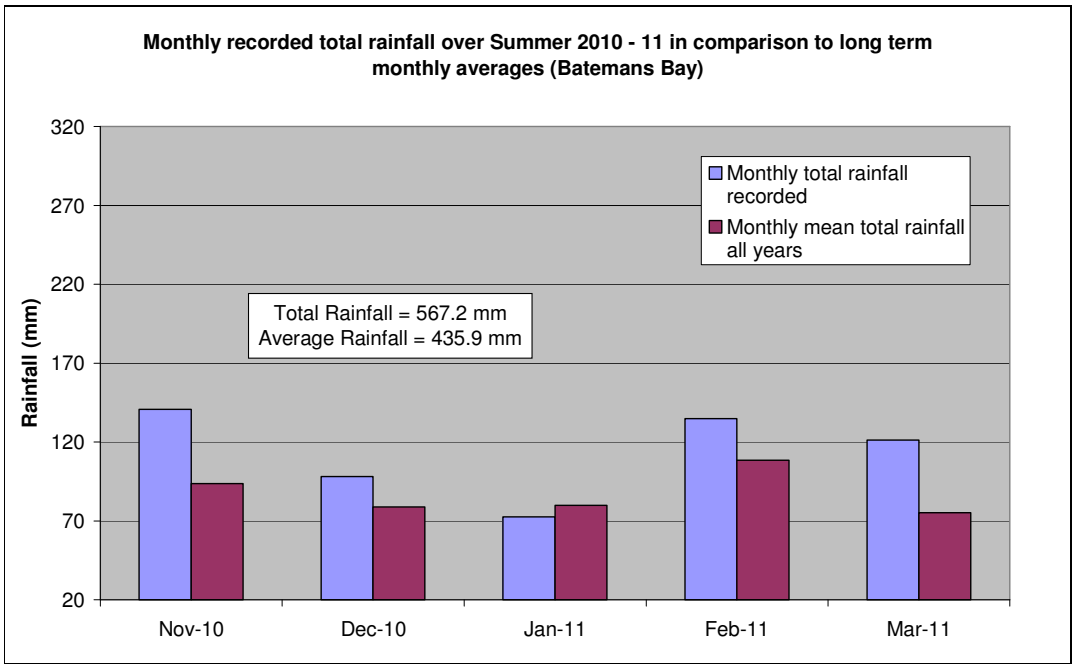
Appendix B – Rainfall and Temperature Graphs

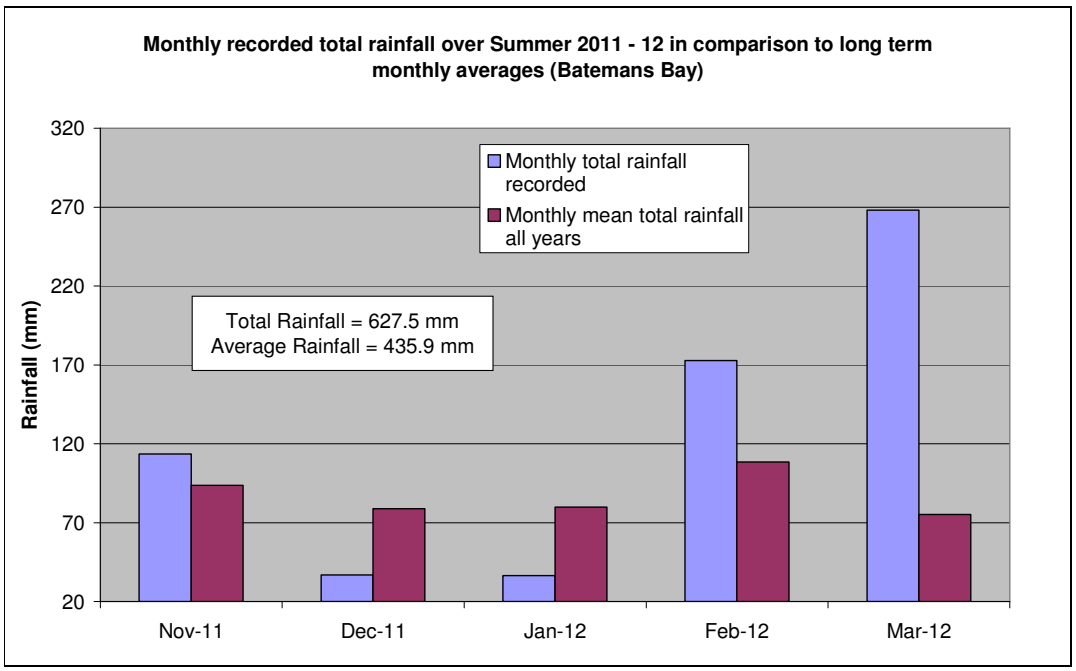


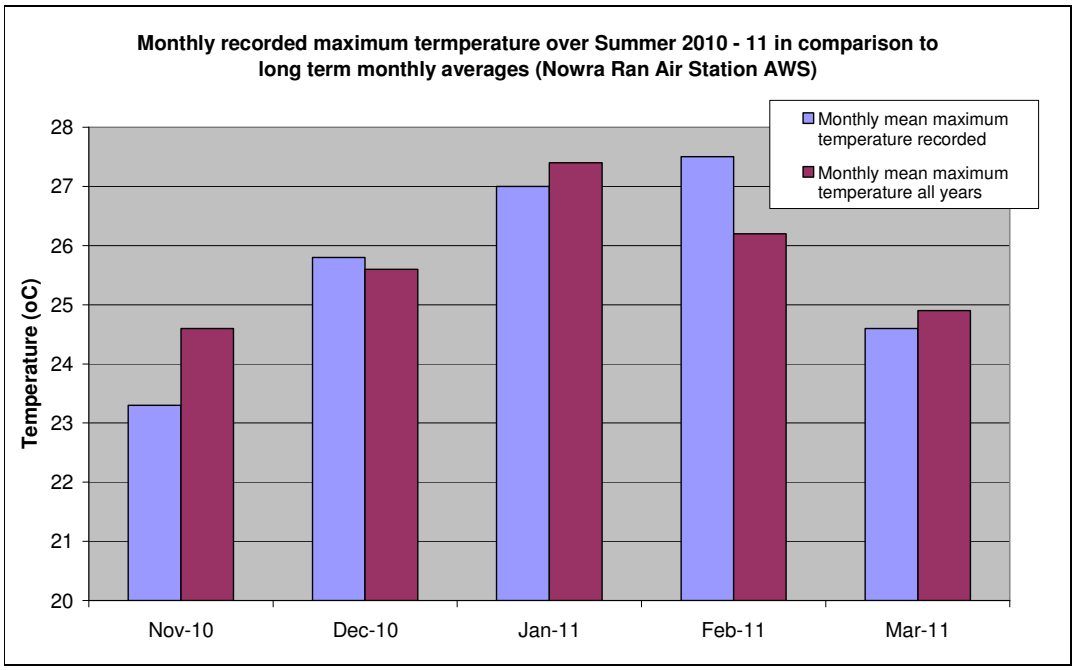



Monthly recorded total rainfall over Summer 2010 - 11 in comparison to long term monthly averages (Greenwell Point Bowling Club)
Rainfall (mm)
370
320
270
220
170
120
70
20
Monthly total rainfall recorded
Monthly mean total rainfall all years
Total Rainfall = 765.4 mm
Average Rainfall = 490.5 mm
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11


Monthly recorded total rainfall over Summer 2011 - 12 in comparison to long term monthly averages (Greenwell Point Bowling Club)
Rainfall (mm)
370
320
270
220
170
120
70
20
Monthly total rainfall recorded
Monthly mean total rainfall all years
Total Rainfall = 769.4 mm
Average Rainfall = 490.5 mm
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12


Monthly recorded total rainfall over Summer 2010 - 11 in comparison to long term monthly averages (Batemans Bay)
Rainfall (mm)
320
270
220
170
120
70
20
Monthly total rainfall recorded
Monthly mean total rainfall all years
Total Rainfall = 567.2 mm
Average Rainfall = 435.9 mm
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11


Monthly recorded total rainfall over Summer 2011 - 12 in comparison to long term monthly averages (Batemans Bay)
Rainfall (mm)
320
270
220
170
120
70
20
Monthly total rainfall recorded
Monthly mean total rainfall all years
Total Rainfall = 627.5 mm
Average Rainfall = 435.9 mm
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12


Monthly recorded maximum termperature over Summer 2010 - 11 in comparison to long term monthly averages (Nowra Ran Air Station AWS)
Monthly mean maximum temperature recorded
Monthly mean maximum temperature all years
Temperature (oC)
28
27
26
25
24
23
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21
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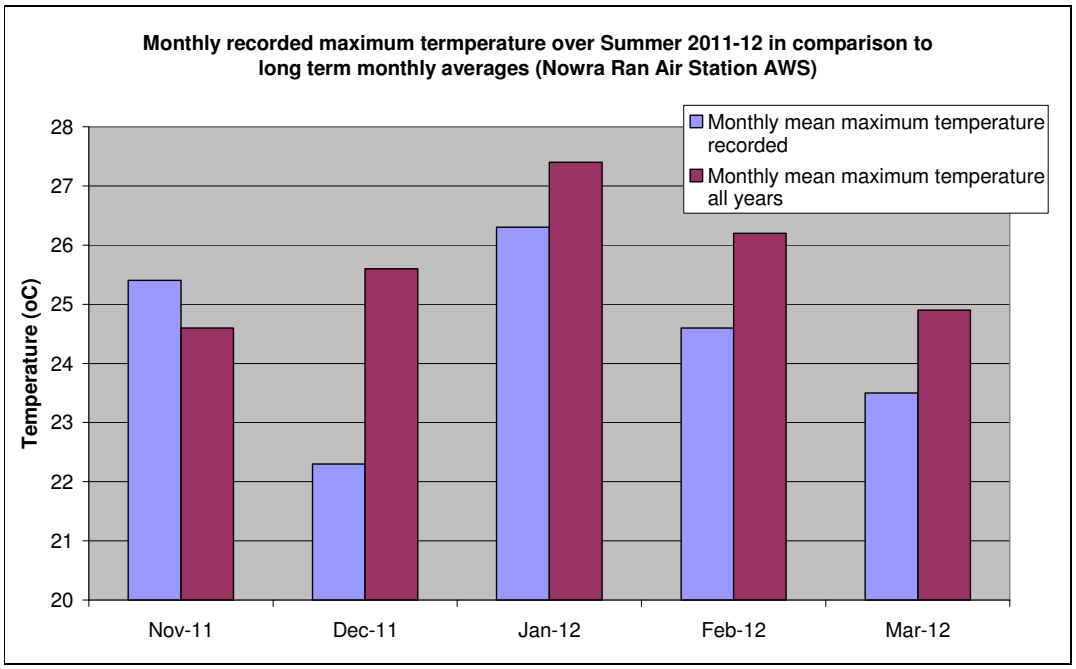
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11


Monthly recorded maximum termperature over Summer 2011-12 in comparison to long term monthly averages (Nowra Ran Air Station AWS)
Monthly mean maximum temperature recorded
Monthly mean maximum temperature all years
Temperature (oC)
28
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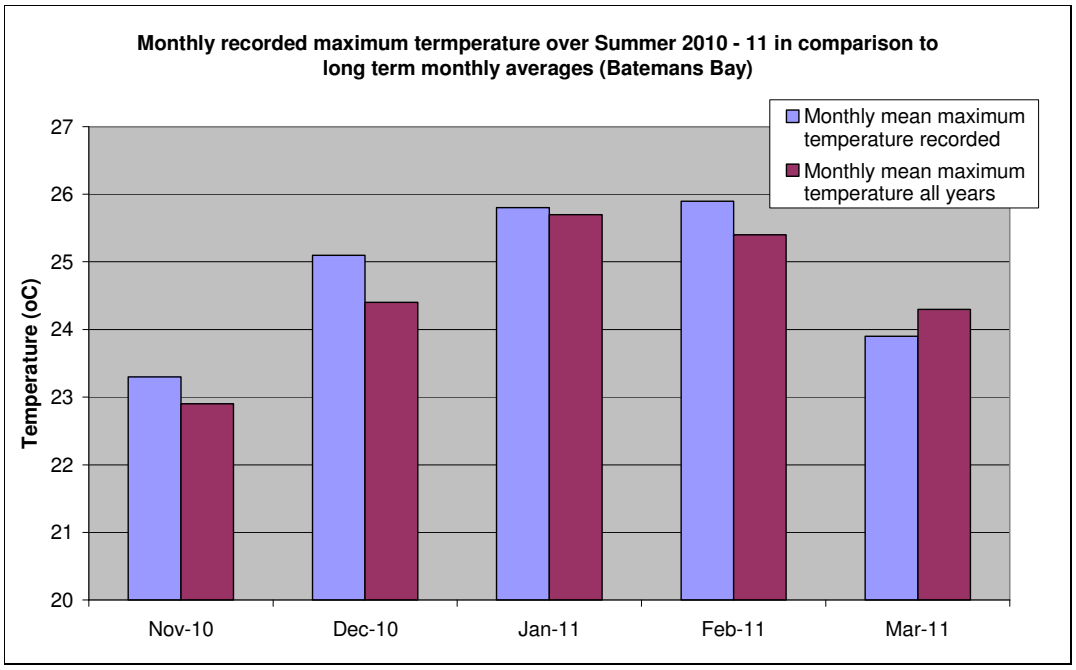
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12


Monthly recorded maximum termperature over Summer 2010 - 11 in comparison to long term monthly averages (Batemans Bay)
Monthly mean maximum temperature recorded
Monthly mean maximum temperature all years
Temperature (oC)
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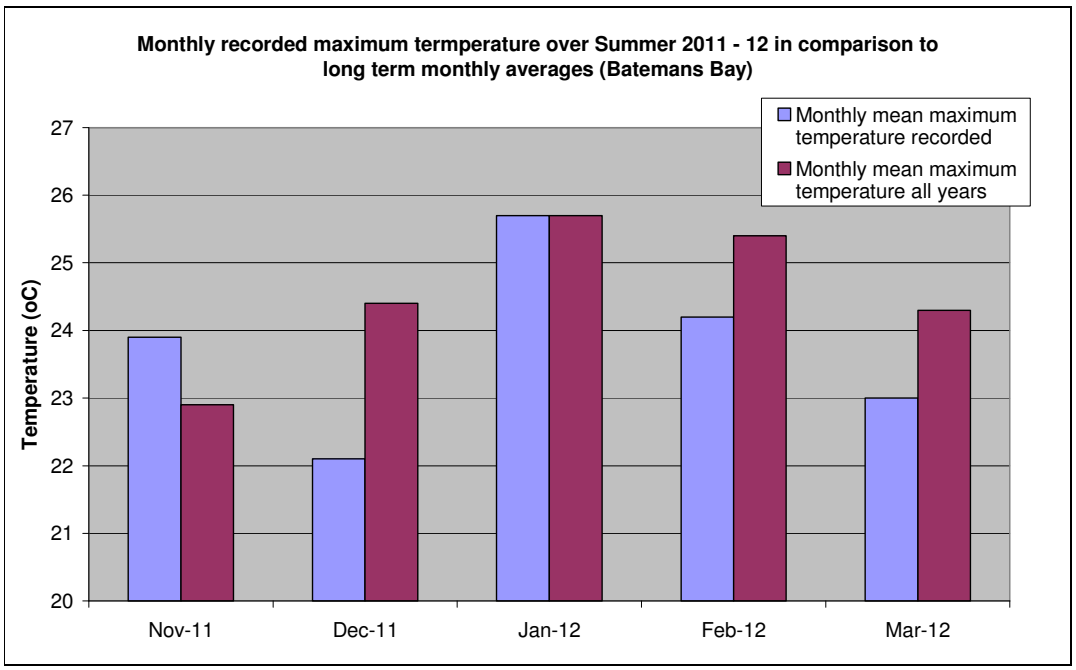
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11


Monthly recorded maximum termperature over Summer 2011 - 12 in comparison to long term monthly averages (Batemans Bay)
Monthly mean maximum temperature recorded
Monthly mean maximum temperature all years
Temperature (oC)
27
26
25
24
23
22
21
20
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12