

B. Control Charting Example

B.1 Background

Control charting, also known as Statistical Process Control (SPC), dates back to the 1930s where it was first used in industrial applications to control drift and variation in manufacturing standards (ANZECC & ARMCANZ (2000)). However, control charting techniques used for the last 70 years in industry have an important role to play in an environmental context. ANZECC & ARMCANZ (2000) and EPA (2005) highlight the usefulness of control charting for comparing sample data with environmental guidelines or standards: *“Regulatory agencies are moving away from the ‘command and control’ mode of water quality monitoring, and recognising that, in monitoring, the data generated from environmental sampling are inherently ‘noisy’. The data’s occasional excursion beyond a notional guideline value may be a chance occurrence or may indicate a potential problem. This is precisely the situation that control charts target. They not only provide a visual display of an evolving process, but also offer ‘early warning’ of a shift in the process level (mean) or dispersion (variability).”* When upper and lower confidence limits (around the means) are incorporated to time series data, control charts may also be used to run simple statistical tests, which in practice are equivalent to Analysis of Variance (ANOVA) and t-test procedures. For further information, refer to ANZECC & ARMCANZ (2000).

B.2 Application

Control charts are particularly useful for comparing sample data with a guideline (EQG) or standard (EQS), particularly when sample data are recorded as time series data. The advantages of control charts are that:

- minimal processing of data is required;
- they are graphical – trends, periodicities and other features are easily detected; and
- they have early warning capability – the need for remedial action can be seen at an early stage.

An example of the application of control charting to the MWADZ project is shown in Figure B.1. In this example, time series data are shown for infauna family richness. The variability in the data was generated using Monte Carlo simulation, and draws on the actual baseline data collected by DoF in 2014 and 2015. Figure B.1A shows the expected variability in the mean (or average) richness over time, up until the commencement of operation where the data were manipulated (whilst still maintaining variability) to simulate a putative impact (represented by a gradual decline in family richness). In this example, the proposed MEPA site data (red line) repeatedly overlap the reference site data until the commencement of operation, at which point the lines begin to diverge – thus simulating the beginning of a gradual decline in richness due to the predicted increase in sediment organic loading (BMT Oceanica 2015). This example demonstrates the early warning utility of the control charting procedure – where the early stages of change are observable well in advance of exceeding the environmental trigger, which in this case is represented by the EQS (see Figure B.1B).

Figure B.1B uses the same data and simulation process but shows the variability based on the upper and lower 95% confidence intervals (CI) (as opposed to the means in Figure B.1A). Comparison of upper and lower 95% CI is critical to the assessment of the EQS for infauna, LAC, TSS and Chlorophyll-a (see Sections 4.1 and 4.2). In this example, which is based on infauna, note how the MEPA lower 95% CI and the Reference upper 95% CI remain separated throughout the baseline period up until commencement of operation, when they begin to converge (and eventually overlap). What is key here, is that relative to the mean values in Figure B.1A, the upper and lower 95% confidence intervals do not overlap until later in the operational period.

This is indicative of the value in the approach, whereby divergence between means serves as early warning of an approaching exceedance, and the convergence (and eventual overlap) of the 95% CIs is representative of the exceedance (of the EQS) – which in this application is equivalent to a statistical difference between the means.

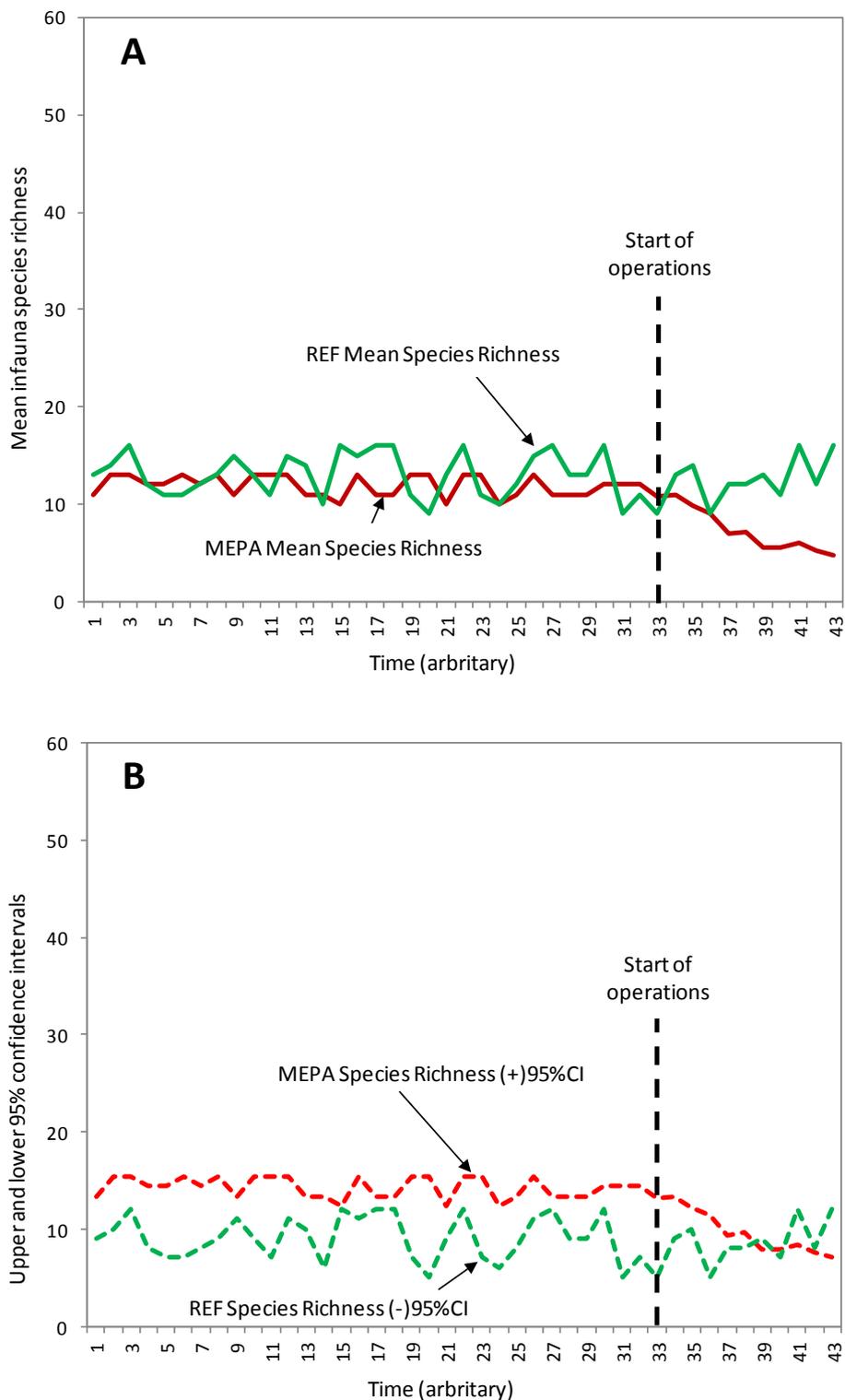


Figure B.1 Control charting example using infauna species richness

B.3 Worked example

As described above, control charts are an effective way for visually comparing the trajectories of two or more times series data, and are thus a simple but useful tool for environmental managers. Control charts can readily be developed using simple and readily available software such as MS

Excel. A worked example is provided below (the spreadsheet template used to develop this example is available from the Department of Fisheries).

The example below is based on hypothetical infauna species richness data obtained from the moderate ecological protection area (MEPA).

At the completion of each sampling period, enter the data under the appropriate MEPA distance (0 m-200 m) (Figure B.2). Means and Standard Deviations (SD) should update automatically, using the built in formulas `=average()` and `=stdev()`. The 95% confidence interval can be obtained using the formula `=CONFIDENCE(0.05,SD,n)`. Upper (+) and lower (-) 95% CI around the mean can then be calculated. These values (means and 95% CIs) are in turn captured in the Chart Template Table (see Figure B.3).

Data entered in the Chart Template Table are linked to the Control Chart plots, for mean species richness and 95%CI species richness. Once the data are entered, the plots will update automatically (Figure B.4).

MEPA											
Data	Distance					Statistics					
	0m	50m	100m	150m	200m	Mean	SD	n	95% CI	(+)95%CI	(-)95%CI
Baseline	13	12	10	11	12	11.600	1.140	5.0	CONFIDENCE(0.05	12.599	10.601
Baseline	10	11	13	12	10	11.200	1.304	5.0	1.143	12.343	10.057
Operation	13	11	11	13	11	11.800	1.095	5.0	0.960	12.760	10.840
Operation	10	11	11	13	11	11.200	1.095	5.0	0.960	12.160	10.240

Reference										
Data	Site 1				Mean	SD	n	95% CI	(+)95%CI	(-)95%CI
	Site 1	Site 2	Site 3	Site 4						
Baseline	10	13	13	12	12.000	1.414	4.0	1.386	13.386	10.614
Baseline	12	11	10	11	11.000	0.816	4.0	0.800	11.800	10.200
Operation	11	13	11	12	11.750	0.957	4.0	0.938	12.688	10.812
Operation	13	12	10	10	11.250	1.500	4.0	1.470	12.720	9.780

Figure B.2 Formula for calculating 95% confidence intervals

MEPA											
Data	Distance					Statistics					
	0m	50m	100m	150m	200m	Mean	SD	n	95% CI	(+)95%CI	(-)95%CI
Baseline	13	12	10	11	12	11.600	1.140	5.0	0.999	12.599	10.601
Baseline	10	11	13	12	10	11.200	1.304	5.0	1.143	12.343	10.057
Operation	13	11	11	13	11	11.800	1.095	5.0	0.960	12.760	10.840
Operation	10	11	11	13	11	11.200	1.095	5.0	0.960	12.160	10.240

Reference											
Data	Site 1				Mean	SD	n	95% CI	(+)95%CI	(-)95%CI	
	Site 1	Site 2	Site 3	Site 4							
Baseline	10	13	13	12	12.000	1.414	4.0	1.386	13.386	10.614	
Baseline	12	11	10	11	11.000	0.816	4.0	0.800	11.800	10.200	
Operation	11	13	11	12	11.750	0.957	4.0	0.938	12.688	10.812	
Operation	13	12	10	10	11.250	1.500	4.0	1.470	12.720	9.780	

Chart template							
Monitoring occasion		Mean		(+) 95% CI		(-) 95% CI	
		MEPA	Ref	MEPA	Ref	MEPA	Ref
Baseline	1	=I4	12.000	12.599	13.386	10.601	10.614
Baseline	2	11.200	11.000	12.343	11.800	10.057	10.200
Operation	3	11.800	11.750	12.760	12.688	10.840	10.812
Operation	4	11.200	11.250	12.160	12.720	10.240	9.780
	5						
	6						

Figure B.3 Approach for linking the raw data to the Chart Template Table

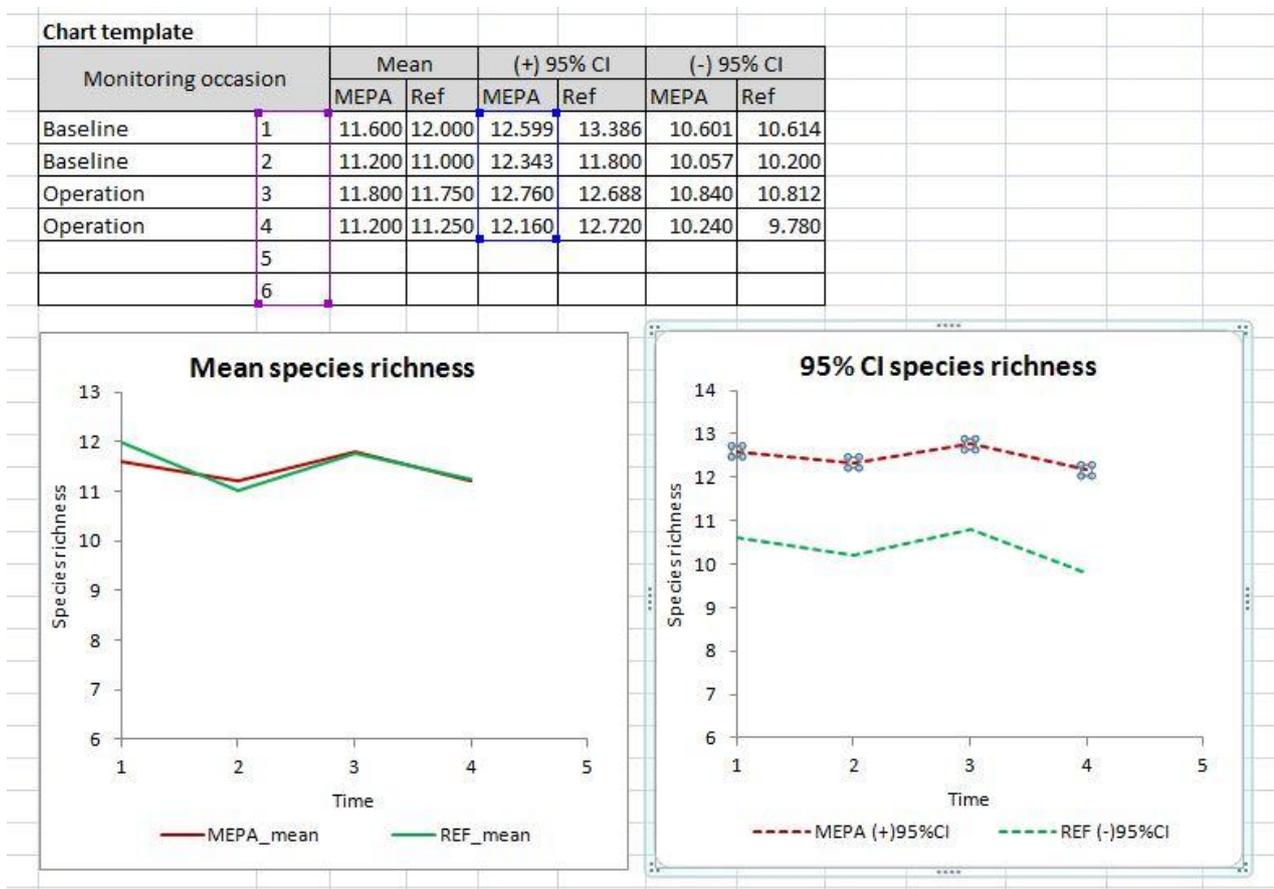


Figure B.4 Link between the Chart Template Table and the Control Charts

B.4 References

- ANZECC & ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4. Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australian Capital Territory
- BMT Oceanica (2015) Modelling and Technical Studies in Support of the Mid-West Aquaculture Development Zone. Prepared for Western Australian Department of Fisheries by BMT Oceanica Pty Ltd, BMT WBM, and AED UWA, Report No. 1051_009/1_Rev0, Perth, Western Australia, September 2015
- EPA (2005) Manual of Standard Operating Procedures for Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003-2004) – A supporting document to the State Environmental (Cockburn Sound) Policy 2005. Environmental Protection Authority Report 21, January 2005