Reviewer 1

The manuscript by Cook et al. is very interesting and addresses the causes of cyanobacteria blooms in a temperate lagoon system. The study is well done and uses dated sediment cores with the analysis of proxies related to eutrophication and algal production. The sediment data are combined with historical archives on settlement and development of the basin. The authors describe the environmental history of the basin and the impact of humans. The manuscript will make an important contribution and supports previous related work on the occurrence of cyanobacteria in low salinity coastal marine ecosystems.

I have no large concerns regarding the significance of the contribution or the scientific quality, however, the paper needs some organization of the discussion to add structure, but more important to increase its readability and impact. The manuscript needs topical headings instead of one large discussion section. Perhaps the sections could be at the start of discussion (Impact of settlement), top of page 18841 (Eutrophication and cyanobacteria blooms), and then page 18842 line 1 regarding 3 key factors – this section is the key to the discussion. With this revision the manuscript will become a valuable contribution to the literature.

We thank the reviewer for their very positive comments. We agree the discussion needs to be broken up, and have re-written the discussion with the sub headings 'impact of settlement', 'cyanobacteria and eutrophication' and finally 'Did nitrogen play a key role in the re-emergence of cyanobacteria blooms?

Specific comments

Sediment dating – It is not clear how the CIC model was "modified" (page 18834, line 21). Why not use a CRS model? It seems like it might be more appropriate given the changes in sedimentation rates. I don't think the dates will change significantly enough to change the interpretation, but it will be more correct.

We believe this is a matter of semantics. The model has been modified from its original formulation, but is as described by Appleby 2001. To avoid confusion, we have simply refer to it as a CIC model in the revised manuscript.

However, my other concern with sedimentation rates are changes in sediment mixing through time. The most serious potential change in sedimentation rates could occur with the appearance of large sediment mixing polychaetes with increases in salinity, or the contrary e.g. the loss of organisms with oxygen depletion.

We agree, this cant be ruled out, particularly below the depth of 210Pb activity. We do however believe that large scale mixing of the core can be ruled out, leaving our broad interpretation of the 3 zones unchanged. Firstly, zone LK-1, which is prior to the opening of the artificial entrance consistently has the highest count of *Cyclotella* and lowest concentration of Thalassic diatoms. Second many of the proxies measured at high resolution showed abrupt changes throughout the core. If there was significant sediment mixing, such abrupt changes would be smeared out. The following has now been added as a final paragraph in the results section

'Although there is a possibility of mixing below the depth of ^{210}Pb activity cannot be ruled out, we believe that large scale mixing of the core below this depth can be ruled out, leaving our broad interpretation of the 3 zones unchanged. Firstly, zone LK-1, which is prior to the opening of the artificial entrance consistently has the highest count of *Cyclotella* and lowest concentration of Thalassic diatoms. Second many of the proxies

measured at high resolution showed abrupt changes throughout the core. If there was significant sediment mixing, such abrupt changes would be smeared out.'

Pigments – Were samples shielded from light during the freeze-drying process or han- dling prior to pigment analysis? Studies have clearly shown the importance of protec- tion from light (L&O Methods, 2005, 3:477–487).

We are aware of the extreme sensitivity of pigments to light and great care was taken to avoid this during the sampling and all extraction steps. Upon sampling, the cores were placed in black plastic bags, and upon slicing this were gradually peeled back and rapidly placed bags wrapped in aluminium foil. Similarly, during the extraction and analysis steps, pigments were shielded from light. These details have been added to the manuscript.

Section 3.2 – How were the three broad zones determined? What program (C2, R) or what procedure was used to delineate the zones?

The zones were delineated by eye based on a combination of the abrupt changes in the geochemistry and the DCA axes. These periods also corresponded well with pre-european, the period of early settlement and modern times as covered in the discussion. This has now been outlined at the start of the sediment chronology section of the manuscript.

Page 18841, line 5. "calibrate" – not sure that is what you mean. Please rewrite.

We agree, validate is a better term that has now been used.

"Cyanobacterial" is used several times. I think the more correct form is simply "cyanobacteria"

Cyanobacterial seems to be the commonly used genitive case, as indicated by the title of two references cited. This has been left as is.

Reviewer 2

General Comments: This is a good and thorough study which looks at a variety of biomarkers in sediment cores, located in Lake King, to investigate the occurrence of cyanobacteria from the past to the present and compare it to historical archives. The structure and organization of the paper is hard to follow, in particular the discussion which jumps from different time periods without fully explaining and supporting their idea until later. Suggestions for better organizing the discussion are found below. This is an interesting study with many supporting biomarkers. However I found the conclu- sion to be unoriginal. With some reorganization of the discussion and a more thought out conclusion this can be a great paper.

We thank the reviewer for their positive and thoughtful review.

Specific Comments:

Abstract: Not clear why this study was conducted or why it is important. I suggest putting in a sentence similar to 18831 line 18.

The opening sentence of the abstract now reads

'Blooms of noxious N_2 fixing cyanobacteria such as *Nodularia spumigena* are a recurring problem in some estuaries, however, however, the historic occurrence of such blooms in unclear in many cases'

Lines 11- 13: Not very convinced that "Gippsland Lakes provide an ideal case study" expand on explanation more.

Upon reflection this sentence is superfluous and has been deleted

18831 Lines 21-24: Great importance sentence.

18832 Line 24: Why did you choose this particular spot to sample? Is it representative of the whole Gippsland Lakes?

We stated on line 19 pg 18833, that previous studies have shown blooms are centred on this area. We have now restated this at the end of the first sentence under 'sampling site'

18833 Line 1 18835 Line 20: LKN1 core was exposed to light and heat, which would have degraded pigment biomakers. Then I see that you only used LKN2 for pigment analysis. How did you get pigment data for the earlier years?

This was carefully shielded from light during sampling, which is now stated.

'During sectioning, the core was placed in a black plastic bag and once sectioned, samples were rapidly placed in the dark.'

18838 Lines 15-16: Pheophytin-a is only mentioned once here. Refer back to this biomarker in the discussion. Explain what this biomarker is used for.

We agree this has not been discussed enough. Pheophytin a is typically a maker for total productivity. We have now added two references to pheophytin a, which support the other proxies showing eutrophication prior to entrance opening as well as more recently.

Results: I suggest organizing the methods and materials in the same order you explain the results for the different proxies.

The methods have now been re-ordered to match the order mentioned in the results

Dating, isotopes/total C and N, pigments, diatoms and charcoal

Discussion: I suggest rearranging the discussion following the same order as the re- sults with the three different sections (i.e LK1-3) where each section you include the "factor controlling the incidence of cyanobacteria bloom" (18841 line 1 through 18842 line18). I believe it would be easier to follow.

We believe this would interrupt the flow of some of the key ideas in the discussion. We have now added the sub headings as suggested by reviewer 1, which we believe has helped make the discussion clearer.

18840 Lines 18-21. This sentence makes it seem as if the reference is for a study done in Gippsland Lakes. Rewrite to: " . . .within Gippsland Lakes and this is comparable with previous studies done in the Baltic Sea (i.e. Bianchi et al., 2000 and Funkey et al., 2014).

Clarified as suggested

18842 Line 7 11: Firstly and Secondly should be First and Second C8797

Amended as suggested

8842 Line 26-28: Can you provide a reference for this?

We believe the reviewer is referring tip g 8843, and the requested reference is for the quantity of water diverted.

This is based on the following consultancy report which will be referenced in the revised MS

Moroka (2010). 'Understanding the Environmental Water Requirements of the Gippsland Lakes Systems. Stage 2: Input to the Gippsland region Sustainable Water Strategy.' Report to East and West Gippsland Catchment Management Authorities, Traralgon. (Moroka: Melbourne.)

18843 Lines 1-3: Can you provide a reference for the 1939 wildfires?

Australian Broadcasting Corporation. 2016 [cited 2016 Jan 15]; Available from: http://www.abc.net.au/blackfriday/story/default.htm.

18844 Line 10: change to- World War II
Amended

18844 Line 10: Where is the "increased nitrogen inputs" coming from?

As documented in the previous paragraph, hydrological modelling has estimated that nitrogen loads have increased by a factor of 1.8, and this most likely originates from agriculture.

18844: Lines 13-17: I'm not convinced this is the right conclusion for this paper. From your explanation in 18842 Line 3-18 cyanobacteria blooms have occurred in Gippsland Lakes even when there was low nitrogen and phosphorus inputs. Definitely reducing N and P will help alleviate the gravity of the spring and cyanobacteria blooms.

Our argument is that there were large cyanobacteria blooms prior to European settlement and increased nutrient loads due to recycling of phosphorus in anoxic bottom waters. This being the case, there was sufficient phosphorus within the system in pre-European times to drive algal blooms. During this period the phosphorus release was driven by strong stratification and lack of hydrodynamic flushing leading to bottom water anoxia. The opening of the entrance increased ventilation (increased flushing and decreased stratification) reducing anoxia. In the absence of any hydrodynamic changes in the past 50 years, we argue that it is increased nitrogen loads that have lead to the re-emergence of anoxia and associated phosphorus release and the re-emergence of blooms.

We have now been a little more circumspect in our conclusion, by stating that blooms may have been amplified by increased nitrogen inputs.

Figure 1: Add coordinates of sampling site.

Now added to the caption

Figure 1. The Gippsland Lakes, south-eastern Australia. The cores were collected at in Northern Lake King marked with the solid circle (37.875620° S, 147.757280° E).

Figures 2-4: The graphs are well done and clear. The captions however need to be expanded to describe all parameters and units.

Further details added to the captions as requested

Fig 2. Unsupported ^{210}Pb activities (Bq/Kg sed) versus depth (a), ^{137}Cs activities (Bq/Kg sed) versus depth (b) and the age depth model based on unsupported ^{210}Pb values using the CIC (constant initial concentration) model (c). The star in (c) refers to the depth of the ^{137}Cs peak activity.

Fig 3. Depth profiles for the site Lake King North of diatom salinity indicator species (See Fig 4 for classification of species) and geochemical proxies including: Pigments chlorophyll a (Chl-*a*), pheophytin *a*, and total cyanobacteria (the sum of the pigments, zeaxanthin, canthaxanthin and echineone) normalised to sediment organic carbon content; Sediment organic carbon and nitrogen isotope isotope ratios (δ^{13}C and δ^{15}N respectively); Sediment organic carbon and total nitrogen content (% sediment mass) and their ratio (C_{org}, N, C/N respectively); Charcoal content of the sediment expressed in particles per mL. The zones LK-1 to LK-3, are 3 region of the profile corresponding to inflections in DCA axis 1 (See Fig. 4) and also abrupt changes in the carbon and nitrogen isotope and concentration proxies.

Fig 4. Profiles of diatom species abundance (% of total species count) grouped based on water salinity (fresh, saline, thalassic and other). Fresh indicates diatoms found at <5 PSU, saline indicates species expected to grow at high salinity within estuaries, and thalassic species are expected to be found exclusively in the coastal ocean. Other refers to species typical of intermediate salinity within estuaries and lagoons. Detrended Correspondence Analysis (DCA) axes 1 and 2 are also shown with depth.

Figure 34: What are LK1-3?

The three zones will now be indicated in the caption

'The zones LK-1 to LK-3, are 3 region of the profile corresponding to inflections in DCA axis 1 (See Fig. 4) and also abrupt changes in the carbon and nitrogen isotope and concentration proxies.'