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Dear Senate review team.

ADS team members have been working with the Tasmanian Salmon industry since 2008 (mostly in Macquarie Harbour), firstly in providing advice to Petuna Aquaculture as they looked to sell part of their company to another party and then to assist Petuna by collecting environmental data as part of an internal Environmental Monitoring Programme (EMP), which was started in 2009. Included in this program were 21 sample stations, with a number of stations inside each lease, 100m from the lease boundary and control stations 1km from the nearest farm, as well as a station at each major river mouth. We believe this is the first internal/industry related EMP program to have been undertaken within the Harbour.

Following the EMP sampling, ADS personal assisted in preparing the 2011 Environmental Impact Statement (EIS) for Petuna, Huon and Tassal aquaculture companies; this document formed the basis of the proposed Macquarie Harbour Aquaculture Expansion. Upon the completion of the EIS a monthly monitoring program was developed which is still currently ongoing. Data from this program is collected and reported to DPIPWE, and is used to monitor/assess the Harbour for environmental changes. This program has more than 20 stations including full water column profiling, a number of parameters are sampled for and these include nutrients (Nitrate and Ammonia/Ammonium), dissolved oxygen, temperature, total organic carbon, total organic nitrogen, total nitrogen, biological oxygen demand, chlorophyll-a, phytoplankton and salinity. Lab analysis is undertaken by Analytical Services Tasmania. In addition to the monthly monitoring program there are now 19 full time in-situ sensors within the harbour monitoring oxygen, salinity and temperature and a number of depths and locations. These sensors take measurements every 10m minutes and the information can be downloaded at any time.

More recently (2013-2014), ADS staff members have participated in finalising an FRDC study (a joint study involving IMAS and several other companies). This study looked at sediment nutrient releases into Macquarie Harbour and their application inside numerical models. In addition ADS staff members participated in a CFOC (Caring For Our Community), study examining the distribution of net wash from different net cleaning systems at several sites across southern Tasmania.

As far as ADS is aware most of these previous reports are in the public domain, either on the DPIPWE website (in the case of the EIS), or are kept with the TSGA or other government agencies such as the FRDC. Environmental monitoring program data is kept with DPIPWE and ADS is unsure if this data is readily available or not. Given that many of our previous studies are available to the public, we haven't included them inside this submission. We encourage the Senate review members (if they are interested), to read these online (if they haven't already been provided). Naturally we would be more than happy to answer any questions that arise from any of these reports or our EMP related work.

Over the last 6 or seven years ADS have noticed changes occurring inside Macquarie Harbour, mostly involving dissolved oxygen, river flow, salinity and climatic events.

Most recently ADS were one of the authors of the October 6th 2014 Macquarie Harbour Dissolved Oxygen Working Group study looking into dissolved oxygen levels alongside IMAS and CSIRO. ADS understands this report is now in the public domain.

Following this initial investigation ADS have since undertaken an update study looking at changes in dissolved oxygen from August 2014 until May 2015 and identifying the mechanisms behind oxygen recharge within the harbour. This study has been reviewed by IMAS (Dr Jeff Ross), CSIRO (Dr Scott Condie) and Lance Searle on behalf of the TSGA.

Below we present the main results of these studies (in the form of bullet points taken from the abstracts of these two reports rather than providing the two lengthy reports in their entirety.

Dissolved oxygen working group study (Report 1 October 2014), key points:

- There is a clear downward trend in the dissolved oxygen (DO) levels of the deep-waters (> 15m) of Macquarie Harbour over the period 2009-to July 2014.

- There have been a number of significant changes over the period from 2009-present. River flow was historically low between 2009-12 and historically high in 2013. This period also coincides with a major expansion of salmon aquaculture.

- It has been estimated that the total organic carbon load associated with river discharge into Macquarie Harbour is around 100 times that of salmon production in the harbour (ocean inputs are also expected to be small). However, the fraction of organic carbon in river discharges that is labile has not been measured in Macquarie Harbour and in other well forested catchments has been found to be small (Sun et al. 1997, Moran et al. 1999). The fractions of labile and refractory organic carbon exported to the ocean from the harbour are also unknown.

- Based on the data available from recent in situ measurements (FRDC study mentioned above) aquaculture is estimated to be responsible for between 3 and 12% of the benthic BOD in Macquarie Harbour (for sediments deeper than 15 m). The remaining benthic BOD is presumably associated with particulates in river discharge and detritus derived from biological production within the harbour.

- Previous studies have found that pelagic BOD is significantly higher than benthic BOD in many estuaries. However, pelagic BOD (it is now measured since October 2014) has not yet been measured in Macquarie Harbour.

- Dissolved oxygen in the deep waters of Macquarie Harbour is mainly replenished through (i) mixing with higher DO surface waters; and (ii) higher DO ocean waters overflowing the sill at the mouth of the harbour and descending as a dense plume that recharges DO near the bottom.

- There are a number of limitations in our knowledge about the biogeochemical processes in Macquarie Harbour that preclude any definitive attribution of the recent decline in deep-water DO. Primary among these are the absence of reliable estimates of labile organic carbon fluxes associated with river discharge and export to the ocean, and levels of pelagic BOD.

- Historically low and high river discharge and associated organic carbon loads are likely to have influenced both the physical resupply of oxygen and the BOD of bottom waters.

- Historically, DO levels appear to have been maintained by a combination of regular (bottom-up) recharge and (surface-down) mixing events driven by highly variable river discharge. However, for 2009-present rainfall and river discharge conditions may have altered the frequency of these events. Detailed hydrodynamic modelling and continuous monitoring are required to quantify this relationship.

- The rapid transition to high river discharge (2013) after a prolonged period of low discharge (2009-2012) is likely to have delivered an accompanying influx of accumulated organic carbon from the catchment. However, the influence of this influx on BOD in bottom waters is unclear. Measurements of labile and refractory loads and modelling to estimate retention verses export to the ocean are required to assess the role of river organic carbon loads on bottom water BOD.

As stated above, the May 2015 report updates the information in the October 2014 report and examines recently collected data. A better understanding of the processes operating within Macquarie Harbour and the physical forces driving oxygen recharge has been gained from this consideration of updated data. Although a full understanding of attribution is still elusive the current update clearly identifies some of the causes for the historic DO depressions, oxygen recharges and the expected outcomes under a range of conditions both natural and farm/Hydro driven.

A study was also undertaken to examine the potential impacts if any (on dissolved oxygen) of a hydro shutdown within the Gordon River catchment (October 2015) during a one month Hydro shutdown that occurred within the Gordon Catchment. The results of this study were also provided in this report.

Dissolved oxygen working group study (Report 2 May 2015), update key points:

- During the October 2014 Gordon River hydro shutdown there appeared to be little or no change in Dissolved Oxygen within the Harbour. After the shutdown there was a drop in DO in the mid to upper parts of the water column but this mostly related to an increase in sea surface temperature due to the onset of summer and doesn't appear to be directly related to the shutdown itself.

- One potential hypothesis is that during the shutdown low river flows may adversely impact DO levels by reducing the volume of high oxygenated waters entering the harbour (generally river water dissolved oxygen levels are between 9-10mg/L). Flow records indicate that there were at least six minor floods (below the dam) during the shutdown period. The 24-year historical

perspective on seasonal variability provides a convincing case that the shutdown conditions were not at all anomalous for October.

- Given the naturally high levels of flow discharging into the Gordon River below the dam during October there is little likelihood that October shutdowns would cause lower DO conditions in the harbour and the deployment of equipment over the October 2014 period indicates this. However, for two years of the 24 on record, there was low flow (likely caused by drought). During such periods or if the shutdown was to occur during the height of summer there may be more risk.

- At many depths, DO levels appear to have recovered to nearly the same levels as those observed at the start of the monthly monitoring program in late 2011 (based on May 2015 dissolved oxygen data). However, in the mid water column we can observe some oxygen depletion especially at 15-25m. While current evidence (i.e. mixing curves from the original DO report) points at biochemical cycling involving dissolved oxygen consumption (nitrification, pelagic and benthic respiration, etc.), the exact mechanisms behind this consumption and their relative contribution are still unidentified and need further investigation. Part of this may also involve the migration of lower DO concentration bottom water towards the surface through mixing and vertical density driven forcing from bottom recharge rather than any actual sudden depletion.

- Analysis of water level records revealed it as a one of the key drivers in determining Harbour dynamics. Given its irregular nature, water level elevation is a result of a number of factors. These factors include, air pressure, tide, river flow, and a number of other processes. The key driver of water level elevation in Macquarie harbour was found to be air pressure (responsible for more than >40%), followed by tide approximately 20%, then river flow. Low air pressure is strongly linked to changes in current flow in the harbour (as observed when comparing air pressure and ADCP measurements) and recharge. During the first report the drivers behind water level elevation were barely discussed (though they were acknowledged), further analysis has shown that it is one of the key requirements in promoting DO rich waters to enter Macquarie harbour through Hells Gate.

- Two recent bottom water dissolved oxygen recharges (August 2014 and May 2015) within Macquarie Harbour appear to have been caused by a combination of strong winds in a NW-N direction (directly down the harbour towards the Gordon River), combined with a low pressure system.

- More specifically: The strong NW-N winds appear to push surface water down towards the southern end of the harbour or at the very least stops it from flowing out through Hells Gate. This may induce a slight gradient where water elevation at the southern end of the harbour is higher (Figure 1) than the northern end (also known as set up, though no measurements have been taken to support this). The rise in water elevation due to the low pressure system raises the water level outside of Hells Gate and inside the gate itself making it easier for oceanic water to flow across the sill and into the harbour. Based on the recharge observed in the bottom

waters near the sill (from in-situ instruments deployed near there). Several days later, as these NW-N winds died down all three growers reported a strong surface current (several knots), as water discharged from the southern end of the harbour out through Hell's Gate (pers. coms).

- In the October DO 2014 report the likely mechanisms for DO recharge via Hell's Gate were wind, tide, and pressure and low river flow. This report has taken this understanding a step further by highlighting the actual combination of processes required and how they interact with one another to create a significant dissolved oxygen recharge within the harbour.

- There appears to be a link between decreasing salinity, river flow and decreasing Dissolved Oxygen in Macquarie Harbour deep waters. Over the last four years salinity has dropped several PPT at the same time Dissolved oxygen has also been decreasing. This drop in salinity would indicate that there have been a lack of oceanic recharge events within the harbour which we can partly associate with changes in river flow, wind and pressure (i.e. no favourable NW winds with low pressure). Though this certainly needs more investigation. Such a link was not identified in the October 2014 MHDOWG report and hence this examination of salinity again provides new insight into Macquarie Harbour dynamics.

- When salinity stabilised during 2014, an increase or at the very least a stabilisation of dissolved oxygen levels was observed within the harbour.

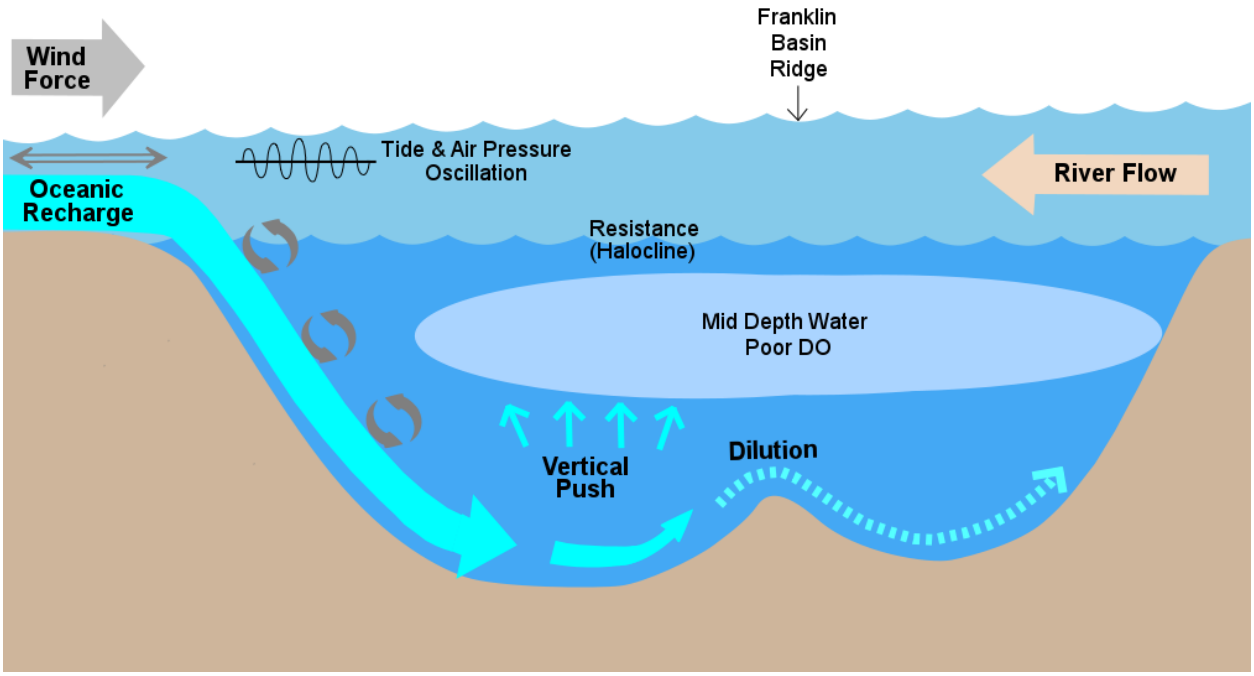

Figure 1 Conceptual diagram highlighting the processes and interactions in a dissolved oxygen recharge event in Macquarie Harbour.

Based on the two reports we made the following recommendations.

- Existing monitoring, including recently incorporated TOC, DOC and TN sampling, should be continued and supplemented by a strategic field campaign aimed at measuring the influence of organic carbon loads in river discharge (this is currently being undertaken). The latter should measure: (i) labile and refractory loads; (ii) rates of deposition and retention in the harbor; (iii) conversion of refractory to labile carbon; and (iv) the relative importance of pelagic and benthic BOD. Similarly, the role of fish farm carbon and nitrogen inputs on BOD should be extended to provide greater resolution of the spatial extent of deposition and the influence on benthic and pelagic BOD. Measurements should be used to support development of a more detailed quantitative carbon/nitrogen/oxygen budget for Macquarie Harbour.

- Examination of wind records, pressure, wind speed and direction to look for further DO recharge events over time should be undertaken (Again currently being undertaken, May 2015). Examining how salinity has changed in the historic records and if there are any links with a reduction or increase in dissolved oxygen would also be another useful research step in understanding the oxygen dynamics inside Macquarie Harbour. Both suggestions are in addition to those made in the first October 2014 MHDOWG report.

- Dissolved oxygen budgets indicate that there have been drops in DO in the middle of the water column since 2012. DO at these levels has improved since the August 2014 recharge but in early 2015 DO is starting to decrease again and then increased again in May 2015. Mechanisms responsible for mid water column oxygen consumption need to be investigated particularly nitrification. There may be a link between river derived nutrients into the harbour and this consumption.

The full reports provide more than 140 tables and figures which highlight changes in DO and other parameters over time and go into much greater detail in terms of the physical forces operating within Macquarie Harbour. These I'm sure have already been made available to the review panel by other parties. Again we will be more than happy to answer any questions regarding these reports.

Yours sincerely,

Dr Neil Hartstein
ADS