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2 February 2024

Hon Tany Plibersek MP
House of Representatives
Parliament House
Canberra ACT 2600

Tasmanian Independent Science Council submission regarding the Federal reconsideration of the 2012 EPBC Act Decision on *Marine Farming Expansion, Macquarie Harbour (2012/6406).*

Dear Minister Plibersek,

In response to the DCCEEW request to provide comments on this matter, the Tasmanian Independent Science Council (TISC) submits the following opinion. The Tasmanian Independent Science Council is a registered non-government organisation of scientists, economists and other professionals who provide independent, non-government advice, focusing on policy reforms of significant State and National interest. We seek to inform public debate and influence legislative reform to improve outcomes for terrestrial, freshwater and marine ecosystems.

The TISC view is that the operation of intensive salmon aquaculture in Macquarie Harbour (MH) since its expansion in 2012 has had severe impacts on Matters of National Environmental Significance that are protected under the EPBC Act (Australian Government, 2013). **Based on the evidence set out below, we strongly recommend that the 2012 decision to enable the expansion of marine farming in Macquarie Harbour,** on the basis that it was Not a Controlled Action if undertaken in a Particular Manner, **be revoked and substituted with a new decision.** This activity has resulted in significant degradation of the Tasmanian Wilderness World Heritage Area (TWWHA) values and has also been a major factor in the precipitous decline in the population of the now critically endangered Maugean skate (*Zearaja maugeana*).

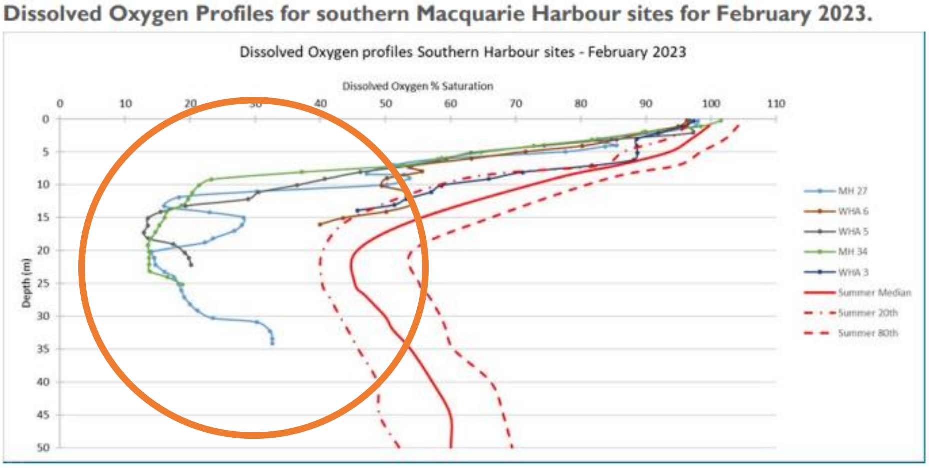
As per the EPBC Act, revocation of the decision is warranted due to substantial new information that has become available, as well as due to a substantial change in circumstances that were not foreseen at the time of the decision.

Evidence of environmental damage to Matters of National Environmental Significance since 2012 have included the following:

- A significant reduction in ***oxygen*** levels over large areas of the Harbour, and particularly to the south. Mid- and deeper water layers have been particularly affected with oxygen levels dropping to hypoxic (<4 mg/L or <30% saturation), and at times, anoxic (near zero), levels for extended periods of time (e.g. see Ross et al, 2022, CSIRO, 2020). 'Hypoxia' refers to oxygen concentrations sufficiently low to impair or kill most aquatic animals, including fish, skates, crabs and macroinvertebrates. Impairment is usually considered to set in at oxygen concentrations less than 4 mg/L, mortality at less than 2 mg/L (Gray et al., 2002; Hofmann et al., 2011).

  More recently (Feb 2023), DO levels at EPA monitoring sites in the southern Harbour (located within the WHA) measured the lowest levels yet recorded throughout much of the water column.

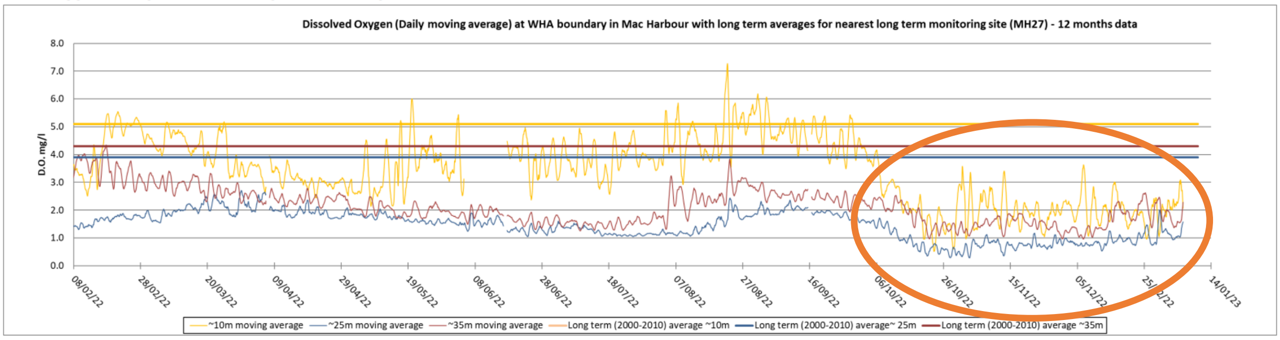
  Dissolved Oxygen Profiles for southern Macquarie Harbour sites for February 2023.



  Source EPA, 2023.

  The EPA's multi-depth sensor string located at the TWWHA boundary also recorded a sustained low-oxygen event that commenced in October 2022 and continued at least through Dec 2022 (EPA, 2023). However, the sensor string was removed at that time and apparently not replaced until Sept 2023 (EPA, 2023a) so it is not known how long this persisted.

2022 logger string data with long term average from MH27.



- In addition to direct impacts on fauna, fluctuating oxygen levels in MH are likely to remobilise sediment-bound ***heavy metals*** and can increase the toxicity of mercury through methylation processes These potential impacts have not been monitored in MH and could be an important factor in the ecosystem decline, including the Maugean skate.
- A serious and rapid **decline in the highly endangered *Maugean skate*** population has been clearly documented, including the near absence of juveniles and viable egg masses (Moreno & Semmons, 2023, Moreno et al, 2020)
- Widespread ***degradation of the benthos*** has been previously documented, at times extending from salmon leases well into the WHA (e.g. EPA, 2020). This has included extensive colonies of *Dorvellid* worms and benthic bacterial mats of *Beggiatoa* (Ross et al, 2016). While these impacts appear to have reduced as of January 2020 (Ross et al, 2022), regular system-wide benthic monitoring is not routinely carried out and no updated information has been published since January 2020.
- Other evidence of widespread ***ecosystem degradation*** has been documented in recent publications and conversations with knowledgeable individuals. This includes a possible major ecosystem shift to a bacteria- and *Archea*-dominated system (Ross et al, 2022), as these organisms are able to thrive in low-oxygen environments. A shift of this nature would have serious implications for the entire food chain in the Harbour. Other evidence includes severe outbreaks of sea lice that prey on fish and other organisms, increasing numbers of invasive species such as the European green crab, and the recent migration of seals into the harbour (attracted to aquaculture pens). Seals are also known to prey on skates. Large salmonid mortalities have also been periodically reported as a result of disease, elevated temperatures and low oxygen conditions, including over 1.3 million fish that died during an outbreak of POMV disease over the summer of 2017/18 (ABC, 2018).

Context, history, and scale of salmonid aquaculture in MH

MH is one of the largest and deepest coastal embayments in Australia - second in area only to Port Phillip Bay, and six times the size of Sydney Harbour. This is a highly stratified, poorly flushed, low-oxygen system, with a highly restricted outlet. MH is a complex system in terms of bathymetry, tides, winds and freshwater inputs, and is difficult to model and predict accurately. The Harbour has a long history of pollution by mining wastes resulting in widespread sediment contamination by copper and other metals (Teasdale et al, 2003), and has also experienced highly modified flows associated with hydropower development for more than 50 years. Given the poorly flushed, low-oxygen nature of the harbour, and the pre-existing stressors – MH was a poor choice for high-intensity open pen aquaculture and the decision to rapidly expand production was controversial at the time.

Low intensity salmonid farming has been undertaken in MH since the 1980s, with an annual production of <1000 tpa (tonnes per annum) farmed in relatively small cages located in the northern harbour. Following the approval of expansion in 2012, however, production extended into the southern parts of the harbour and grew rapidly to > 20,000 t in 2015/16 (Ross et al, 2022), with severe consequences for benthic health and DO levels. This has been progressively scaled back and now sits at about 9000 tpa. While this is a relatively small proportion of salmonid production for the state as a whole (and a relatively small proportion of associated jobs), this resulting pollution is still a heavy load on a highly stressed system, that has not recovered from the previous overproduction.

Analysis of recent Google Earth Pro imagery indicates that there are currently about 130 very large (168m circumference) pens, distributed across ten leases. Each 168m pen can hold up to 90,000 large salmon at the current stocking rate of 15 kg/m3, or more than ten million fish in all. Based on a biomass of 9000 tonnes of fish, the estimated annual bioavailable nitrogen load (517t) and solid waste load (1823t) would be equivalent to the sewage generated by a city of over one million people, or double Canberra's population. Discharge of a similar quantity of pollution into a sensitive coastal waterway from sewage or industrial emissions would not be acceptable under the principles of Acceptable Modern Technology, and we believe that similar standards should apply to large-scale fish farming.

Adequacy of regulation, monitoring and public reporting

The compliance limits set in the original Environmental Licenses (ELs) for the MH leases were inadequate to ensure the health of system. In particular, the criterion for dissolved oxygen (DO) concentrations was set at a depth of 2 m, and no compliance criteria were established for mid- or deep-water depths, where oxygen depletion is most likely to occur. It is very disappointing that the new ELs (issued on 30 Nov 2023) have maintained this single 2 m depth DO criteria, despite this major flaw having been raised by a number of external reviewers, including IMAS (Ross et al, 2022) and the EPA-commissioned independent review by the Scottish Association for Marine Science (SAMS, 2022). Thousands of fish could die (and indeed have done so), whilst still meeting this criterion.

The EL conditions are also inadequate in that the monitoring of impacts on the Maugean skate is still not required, and heavy metal monitoring is limited to zinc concentrations in sediments and water on the lease – rather than copper and other metals that are known to occur in MH as a legacy of mining operations. Copper is extremely toxic to marine life, which is why it has historically been used as an antifoulant on boat hulls and other marine infrastructure.

Finally, while lease-specific quarterly reporting to the EPA is required, there is no condition in the MH ELs that requires annual reporting on the water quality or benthic habitat condition for the harbour as a whole. This is in contrast to other marine farming areas around the state that require annual, public BEMP reports to be completed, as well as Annual Environmental Reports for newer ELs. While considerable system-wide monitoring and reporting has previously been completed by IMAS and CSIRO, this has been grant-dependent and ceased as of 2020. Very little of the monitoring undertaken by the EPA has been compiled or reported - resulting in significant gaps in the record and precluding a whole-of-ecosystem understanding of conditions and trends.

Action needed

Given the continued poor condition of MH – including areas within the TWWHA – and the serious decline in the Maugean skate population, the TISC recommends that ***fish farming operations in MH should be halted, and the harbour be allowed to fallow, until dissolved oxygen has returned to pre-expansion levels and the skate is no longer threatened with extinction***. Re-commencement of fish farming should only be considered **after** a full recovery and only if it can be convincingly shown that other measures can maintain a healthy environment, that strict, independent monitoring is implemented, and that operations will cease immediately if any criteria are exceeded.

The primary cause of oxygen depletion in the harbour is salmonid production (respiration plus breakdown of faeces and uneaten feed), and fallowing is by far the fastest and most direct solution. Eliminating or significantly reducing fish biomass was the highest priority action set out by your Department's Conservation Advice (DCCEEW, 2023). Previous modelling undertaken by the Fisheries Research and Development Corporation (FRDC) found that, in the absence of fish farm loading, a 50 per cent reduction in hypoxic volume, and a 43 per cent increase in healthy water would result (Wild-Allen et al, 2020).

Inadequacy of alternative solutions

There are a number of other actions that have been recommended to hasten the oxygen recovery process and/or to reduce risks to the Maugean skate, as identified by your Department in addition to the removal of biomass, specifically: alteration of hydro flows on the Gordon River, the Macquarie Harbour Oxygen Project, a ban on gill netting, and the Maugean skate captive breeding program. While some of these may have the potential to accelerate the rate of recovery, ***these should be implemented <u>in addition to</u> removal of salmon biomass, not as an alternative***.

With the exception of the additional restrictions on ***recreational gill-netting***, none of the other identified solutions – i.e. manipulation of river flows, direct oxygen injection or captive breeding - can be reliably implemented in the short-term, and all carry significant risks and costs that have not yet been fully articulated or addressed. The predictive modelling alone (needed to assess and design mitigation options) is likely to take at least 6 to 12 months. In the meantime, the Maugean skate is very likely headed for extinction.

We are particularly concerned about the ***Macquarie Harbour Oxygen Project*** (MHOP) as this is a high-risk gamble for an estuary of this scale and complexity, that comes with the added complications of possible remobilization of heavy-metal contaminated sediments. There is virtually no public information available about the risks or costs of the MHOP. Design details have also not been made available, and the modelling needed to accurately design and predict outcomes has yet to be developed. See attached TISC summary on the practicalities and risks of the MHOP for details (Appendix A). Furthermore, a large-scale oxygenation system based on barges is likely to generate substantial noise and light, and consume large amounts of diesel or other fossil fuels.

It appears that the goal of the MHOP is to improve oxygen levels in the mid-depths of the harbour to offset future salmonid farming inputs (and likely to improve salmonid fish health), rather than to address the past accumulation of organic pollution that continues to draw down oxygen across the harbour. It is unclear how this approach would benefit the Maugean skate, whose reproductive success depends on conditions on the harbour floor and in areas not necessarily adjacent to fish farms.

We are concerned that this approach will delay the rapid response needed to prevent extinction of the skate, whilst enabling unsustainable fish-farming operations to continue for at least another two-years. Furthermore, no information has been provided about the likely high costs involved in an expanded reoxygenation scheme, and how these would be covered, beyond the $7 million already funded by industry and government for an initial trial (ABC, 2023).

The MHOP comparison with the Swan-Canning oxygenation project is not convincing, given the vast differences in scale between the two systems. The Swan Canning oxygen remediation project was designed for a very narrow, shallow riverine system that has less than 1/1000th the volume of MH. This relatively small, land-based project took over three years to design, test and implement and costs about $1 million/yr to operate during periods of low oxygen conditions. (WA Dept of Water and Environmental Regulation, 2023)

The largest estuarine reoxygenation system that we are aware of was designed for the deepening of the Savannah Harbor (Georgia, USA). This project is designed to increase oxygen levels in a volume approximately one-third the size of that in MH, and only operates during summer months. The cost to construct the Savannah Harbor oxygenation scheme was over $A150 million, and operating costs are more than $A4.5 million/yr to operate). The design, testing and construction process took more than a decade to complete. (USACE, 2021)

Another estuarine reoxygenation system is the Thames bubbler. This two-barge system is designed for occasional use (10-15 d/yr) as an emergency response to low oxygen events associated with combined sewage overflows (New Scientist, 2023). The annual cost to operate the Thames oxygenation barges for these short periods of time is nearly $A500,000 (Servomex, 2021). The barges are not intended as a long-term solution and are due to be phased out once the sewage overflow problems are resolved within the next few years.

Ultimately, the key factor controlling large-scale DO dynamics in MH is periodic recharge events during which large volumes of oxygenated marine water are pushed into the harbour (DCCEEW, 2023). Large-scale recharge events occur once every few years. The conditions under which these occur are difficult to predict, but appear to include some combination of NW winds and low atmospheric pressure. While recharge events have long-term benefits for the harbour as a whole, the short-term impacts of a rapid recharge event can be devastating for fish that live in the water column if anoxic bottom water is pushed up into intermediate depths. In this context, an off-set scheme that seeks to re-oxygenate intermediate depth water would be completely overwhelmed by a recharge event, and would likely obscure interpretation of the pilot trial results.

Modification of flows from the Gordon is another untested proposal. It is unclear if this could be delivered operationally, or if the Hydro (and the state, as the beneficiary of this Government Business Enterprise) would be willing to bear the financial cost. We have seen no further details of this proposal, but it is likely that several years will be required to accurately model and monitor alternative flows scenarios and their consequences for dissolved oxygen as well as for electricity generation. We note also that flows from the Gordon River have been modified for over 50 years now, without any evidence that this has been a factor in the recent decline of the Maugean skate or has caused the reduced DO levels in the Harbour since 2012.

Finally, ***captive breeding*** is a last resort with no guarantee of success, as recently demonstrated by death of two of the four recently captured adults. Even if successful, the juveniles must be returned to their habitat asap, and the harbour needs to have recovered sufficiently to ensure their survival. Given their large size, likely long time to sexual maturity, and relatively low fecundity, captive breeding of this species seems a particularly risky proposition, and we would anticipate multiple years of trial and error to even begin to assess the suitability of this mitigation strategy.

Costs and benefits

Oxygen injection projects are expensive, and it is unclear how a program at the scale of MH could be funded, and whether it would in fact benefit the Maugean skate, or restore previous oxygen levels more broadly. For example, the cost to inject 459t of oxygen into the Swan-Canning estuary in 2019/20 (Western Australian Government, 2020) was nearly one million dollars – and this was using a land-based system. At an equivalent cost of about $2000/t, the cost to inject 20 tpd (7300 t/yr) into MH could be nearly $15 million per year.

The Savannah Harbour re-oxygenation project is closest in scale to the proposed MHOP (two shore-based oxygenation plants with a combined capacity of 18 tpd) but will only operate during summer months. The cost allocated for its construction was about $AU 150M, with annual running costs (summer only) estimated at about $AU 4.5M (USACE, 2017).

The two mobile reoxygenation barges on the Thames operate on an as-needed basis in response to low-oxygen events. Each barge can inject up to 30 tpd and were used for a total of 215 hours in 2022 (New Scientists, 2023). The annual cost to operate these two barges is about $AU 1M (Servomex, 2021), or $4651/hour (or $100,000 per day).

Summary, and the question of jobs

The responsibility of the Minister under the EPBC Act is to consider environmental Matters of National Importance - specifically the values of the TWWHA and the imminent extinction of the Maugean skate - and to act accordingly to protect these. To us the decision is obvious – remove the fish and fallow the harbour until the system recovers and the skate is no longer threatened with extinction. Some of the other actions proposed could possibly accelerate this recovery, but should not be used as a reason to stall on the top priority action, as identified by your Department: the elimination or significant reduction in fish biomass.

In the meantime, we would strongly recommend that alternative job opportunities or support arrangements be developed to support the estimated 54 FTE direct aquaculture jobs in Tasmania's West Coast community (Australia Institute, 2023). Given the rapidly warming waters in MH, this is an important proactive action that should be progressed, regardless of the current situation, as the Harbour is rapidly reaching temperatures at which salmonid aquaculture will soon become unviable.

For example, the $7M that is currently being invested in the MHOP gamble (ABC News, 2023) would support 50 workers at $70,000/yr over a two-year period. Other employment alternatives could include land-based aquaculture trials for high value products such as abalone, crayfish, eels, seaweed or other marine products. Or – as is increasingly the case around the world (e.g. Ernst & Young, 2020; Rabobank, 2019) – salmon raised in fully-recirculating land-based systems. Tasmania's West Coast could be well-placed for these opportunities, with cold, offshore water temperatures, abundant freshwater resources, large supplies of renewable energy (hydro and wind) together with a government-funded aquaculture hub and a skilled workforce.

We strongly recommend that a series of workshops be initiated by the Federal and State Governments to genuinely explore opportunities and creative strategies to transition Tasmania's aquaculture industry out of open-pen operations in sheltered waterways such as MH. In 2023, the TISC prepared the attached *Plan B: An Alternative Vision for Salmon Aquaculture in Tasmania* (Appendix B). *Plan B* offers these and several other recommendations for transitioning to a more sustainable future.

Thank you for the opportunity to provide input, and please contact us if you would like any further information.

We also request that a member of the TISC be added to the National Recovery Team to provide a Tasmanian-based, independent scientific NGO perspective.

Sincerely,

Christine Coughanowr Dr Jen Sanger

Co-chairs, on behalf of the Tasmanian Independent Science Council

ABOUT THE TASMANIAN INDEPENDENT SCIENCE COUNCIL

The Tasmanian Independent Science Council is dedicated to science-based policy reform to ensure the long-term health of Tasmania's environment. The Council includes scientists and professionals who provide independent, non-government advice, focusing on policy reforms of significant State interest. We seek to inform public debate and influence legislative reform to improve outcomes for terrestrial, freshwater and marine ecosystems.

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APPENDIX A:

Further considerations for the Macquarie Harbour Oxygenation Project (MHOP)

Two primary aspects of the MHOP are addressed in this paper: 1) the practicality of the exercise and how it compares with similar projects worldwide, and 2) the implications of the oxygenation for the harbour, its ecosystem and importantly the Maugean skate (if the engineering challenges can be overcome and it is not halted prematurely because of some unforeseen ecological effect)

Practicality

Many examples of oxygenation (with pure oxygen) or aeration (with air) of water bodies are extant around the World. However, the great majority are relatively small freshwater systems—lakes, ponds or reservoirs; their driver for action is often eutrophication resulting from excessive nutrients in runoff. Far fewer examples exist of oxygenation/aeration in estuarine or marine situations. The oft-quoted examples are fjords[1]. However, when the considerable volumes of hypoxic bottom waters in Scandinavian fjords are tackled, or have been proposed for attention, it has not been by direct injection of oxygen or air (or re-injection of oxygen- or air-infused subsurface waters). Examples of an alternative approach have been used in Masfjorden (Norway)[2] and By Fjord (Sweden)[3], where oxygen-rich freshwaters have been piped to bottom waters to disrupt stratification and aerate bottom waters through induced circulation. This approach was considered as one of a number of options in an engineering proposal put before the MHOP project team. It was rejected for being too risky. Other examples of oxygenation systems in fjords are directed to improving the vitality and health of farmed salmonids in open cages[4], and not for the benefit of the entire water body.

The example put forward by Salmon Tasmania (and the MHOP project) is an operating scheme in the Swan-Canning estuary of Western Australia[5]. This shallow, tunnel-type, salt-wedge estuary is quite unlike Macquarie Harbour in scale or hydrodynamics. The volume of water oxygenated by one of their pumping stations (estimated on the basis of – mean depth: 3 m; mean width:75 m; oxygenation extent: 12,000 m, i.e. volume of 3 x 75 x 12,000 = 2,700,000 m^3 or 0.0027 km^3 — refer to published paper[5]) is almost three orders of magnitude less than what would need to be oxygenated in Macquarie Harbour. The Harbour (according to Wikipedia) is 315 km^2 with an average depth of 15 m, i.e. 4.725 km^3. The

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[1] Although in casual discussions with scientists from IMAS it has been intimated that oxygenation/aeration projects have been run in Chilean fjords, I could not find any published reports of these.

[2] Aksnes, D.L., Darelius, E. and Berntsen, J., 2023. Mitigation of oxygen decline in fjords by freshwater injection. *Estuarine, Coastal and Shelf Science*, *284*, 108286.

[3] Stigebrandt, A., Liljebladh, B., De Brabandere, L., Forth, M., Granmo, Å., Hall, P., Hammar, J., Hansson, D., Kononets, M., Magnusson, M. and Norén, F., 2015. An experiment with forced oxygenation of the deepwater of the anoxic By Fjord, western Sweden. *Ambio*, *44*, pp.42-54.

[4] https://www.bronkhorst.com/int/markets/miscellaneous-applications-en/aeration-in-fish-farming-a105/. Accessed 17 January 2023.

[5] Larsen, S.J., Kilminster, K.L., Mantovanelli, A., Goss, Z.J., Evans, G.C., Bryant, L.D. and McGinnis, D.F., 2019. Artificially oxygenating the Swan River estuary increases dissolved oxygen concentrations in the water and at the sediment interface. *Ecological engineering*, *128*, pp.112-121.

preferred Maugean skate domain[6] is at depths of 5–15 m equating to 70 km^2(Bell et al. 2016, FRDC report); 70 km^2 x 10 m is 0.70 km^3. Macquarie Harbour is a microtidal, drowned-river-valley estuary[7] with modified fjordic-type circulation[8] and maximum depths of about 50 m.

The only somewhat comparable study to MHOP has been developed by the US Army Corps of Engineers in the Savannah Harbour (Georgia, USA). As part of deepening the harbour in the estuary of the Savannah River, there was a commitment to improving the hypoxia in the estuary bottom waters, which was predicted to worsen with the increased depth. As is the trademark of the Corps of Engineers, this was a massive project ("The largest water oxygenation effort to date, costing about [US]$100 million [for two stations], is well underway as part of the Savannah Harbor Expansion Project (SHEP).")[9]. The effort involved in this project consumed a decade from original planning[10] to final verification report of the prototype project[11]. Although it will only operate during the summer months (15 June – 30 September), it will be estimated to cost "[US]$3 million per year to pump extra oxygen into the waterway"[12]. The SHEP reoxygenation project is looking to deal with ~230,000,000 m^3 based on the computational model grid (see Table 2.1 and Fig. 2.3[10]). However, this is the absolute maximum volume that was being considered in the model. From what I can see in the results of the trials[11], oxygenation at the far ends of the grid would not/did not occur. Even being generous with the volume oxygenated, SHEP is only a third of what is required in Macquarie Harbour. Furthermore, one might note from the results that even under favourable oxygenated conditions, the greatest increase in DO was just 0.68 mg/L (Table 7-1)[11].

Several common features arise from evaluating the two estuarine oxygenation programs—the WA Department of Water on the Swan-Canning estuary and the USACE SHEP on the

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[6] Bell, J.D., Lyle, J.M., Semmens, J.M., Awruch, C., Moreno, D., Currie, S., Morash, A., Ross, J. and Barrett, N., 2016. *Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour*. FRDC Project No 2013/008 report. Institute for Marine & Antarctic Studies (IMAS), University of Tasmania, February 2016. https://www.frdc.com.au/sites/default/files/products/2013-008-DLD.pdf. Accessed on 17 January 2024

[7] Edgar, G.J., Barrett, N.S., Graddon, D.J. and Last, P.R., 2000. The conservation significance of estuaries: a classification of Tasmanian estuaries using ecological, physical and demographic attributes as a case study. *Biological Conservation*, *92*(3), pp.383-397.

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[9] *Oxygenating System in Savannah Harbor Expansion is Largest to Date*, 24 July 2019. https://www.waterwaysjournal.net/2019/07/24/oxygenating-system-in-savannah-harbor/. Accessed 17 January 2024.

[10] Tetra Tech, (2010). *Oxygen Injection Design Report Savannah Harbor Expansion Project Savannah, Georgia – Final*. 15 October 2010. https://www.sas.usace.army.mil/Portals/61/docs/SHEP/Reports/GRR/4%20Oxygen%20Injection%20Design%20Report%20October%202010.pdf. Accessed 17 January 2024.

[11] USACE and others, (2021). *Startup Run Data Collection and Modeling Report for the Oxygen Injection System Environmental Testing for the Savannah Harbor Expansion Project – Final*. March 2021. U.S. Army Corps of Engineers, Savannah District. https://www.sas.usace.army.mil/Portals/61/docs/SHEP/DO_STR/File%20updates/SHEP_Startup%20Run%20Report_FINAL_20210331_w%20Appendices3.pdf?ver=pxRBB2h4YTPhxjpBrHhlug%3d%3d. Accessed 17 January 2024.

[12] *Groups won't fight Savannah harbor oxygen injector test,* 15 September 2019. https://www.savannahnow.com/story/news/2019/09/16/groups-wont-fight-savannah-harbor-oxygen-injector-test/2763099007/. Accessed 17 January 2024.

Savannah estuary—even though they are on quite different scales. The first is their expense, and I am only going to consider running costs, because I do not have the information for the Swan Canning system CAPEX. It is US$3M (≅$4.3M in 2019) per year for the summer months in the Savannah estuary, which equates to $14.6M for year-round operation. With their two large stations, the Corps of Engineers could deliver 19.24 t O_2 per day. The four much smaller stations in Perth (two on the Swan and two on the Canning) cost $950,000 per year (in 2019-20) and they were capable of delivering ~1.4 t O_2 per year. Both Savannah and Perth are land-based on the shores of the estuary, with access to electrical power and oxygenation plants in an urban area, and their use was only during certain times of year (summer months and 'oxygenation season', respectively). There is also a proportionality with their costs. This contrasts with the premium that will arise from a continuous barge-mounted oxygen system in the remote west of Tasmania that is proposed in MHOP (for delivery of a projected maximum of 5 t O_2 per day).

Dispersal (mixing and advection) of injected water in both the Savannah and Swan-Canning estuaries is assisted by the tidal streams. The Savannah estuary is mesotidal with a maximum tidal range of 3 m and although Swan-Canning estuary is microtidal (<1 m), the tidal excursion in this shallow and relatively narrow estuary is quite sufficient to disperse the injected oxygenated water[13]. Macquarie Harbour is also microtidal (<0.5 m) and while the currents through Hells Gate at the mouth and over the sill (~5 m) can be strong, they are rapidly attenuated in the vast body of the harbour. High flows in the tributary rivers would have once hastened estuarine circulation, but the construction of dams has damped riverine discharge.

Although a few reported freshwater systems with injection of air or oxygen approach the volume of Macquarie Harbour, e.g. Swiss lakes and large hydroelectric reservoirs in North America[14], the volumes of their hypolimnions being treated is not stated but would be a lesser fraction of the total. Owing to their land-based infrastructure and quiescent bottom waters, a network of simpler diffuser frames on the bottom can be used coupled to a liquid oxygen supply or air compressors to oxygenate or aerate the hypolimnetic waters. These freshwater bodies are also not experiencing the amount of labile organic matter that is raining down on the sediments of Macquarie Harbour.

It is clear that MHOP will be a challenge well exceeding reported oxygenation programs elsewhere globally. This ensues from its remote location, the use of a barge-mounted system, the high energy demands, the requirement for continuous oxygenation, the susceptibility to rough weather (wind and waves) and the inflated cost. Another aspect is that operational programs, such as Swan-Canning estuary and Savannah Harbour, have taken several years to many years to go from design to full operation. This is not the time scale that Macquarie Harbour or the Maugean skate have.

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[13] Larsen, S.J., Kilminster, K.L., Mantovanelli, A., Goss, Z.J., Evans, G.C., Bryant, L.D. and McGinnis, D.F., 2019. Artificially oxygenating the Swan River estuary increases dissolved oxygen concentrations in the water and at the sediment interface. *Ecological Engineering*, *128*, pp.112-121.

[14] Beutel, M.W. and Horne, A.J., 1999. A review of the effects of hypolimnetic oxygenation on lake and reservoir water quality. *Lake and Reservoir Management*, *15*(4), pp.285-297.

Prospects and implications of the oxygenation exercise

For this section, we will assume the oxygenation of the subsurface Macquarie Harbour and its successful re-injection of the now oxygen supersaturated water can be achieved and maintained (long-term sustained operation was one of the key questions raised by opponents of SHEP[12]). It will also be assumed that the DO acts as an inert tracer (or dye, as tested in SHEP), and the supersaturated water remains neutrally buoyant or marginally buoyant and begins to mix and disperse laterally through the harbour at mid-depths—as planned in MHOP. Of course, all of these physical processes need to be demonstrated. But what of the biological implications? Highly oxygen supersaturated water will never have been encountered by life forms (especially microorganisms) in Macquarie Harbour. It will represent an abrupt change in the oxidation-reduction (redox) conditions in the subsurface waters. Such redox changes and their implications for microbial communities and biogeochemical reactions have been modelled to induce regime shifts and hysteresis (tipping points).[15] Another aspect of oxygenation that is still to be fully understood is the observation that the process leads to greater oxygen demand in bottom waters than initially estimated or even modelled. This situation eventuates from heightening of sediment oxygen demand and has been studied more in freshwater than marine systems. It appears to operate by oxygenation steepening the diffusive gradient across the diffusive boundary layer (at the sediment-water interface)[16], which can apply equally to freshwater and marine systems. The main location of oxygen consumption in Macquarie Harbour can be assumed to be the sediments, but other studies of similar coastal systems have revealed water-column uptake can also be considerable[17]. This possibility needs to be resolved in Macquarie Harbour

The effectiveness of lengthy periods of oxygenation, and even artificial mixing, of subsurface waters has been questioned as to its effectiveness in ensuring change right down to the sediments. For example, in two Swiss lakes even with prolonged (10 y) oxygenation of subsurface waters[18], no change in the release of phosphorus was observed because the sediment-water interface remained anoxic, owing to unchanged high sedimentation rates of organic matter and despite the overlying waters having become oxic. An analogous situation could manifest in Macquarie Harbour with aquaculture being the persistent supply of organic matter to the sediments. Since the Maugean skate is a benthic species, and perhaps more importantly, if its eggs are deposited on the enduringly anoxic sediments, MHOP may achieve no improvement for the skate even though demonstrating that the hypoxic condition of subsurface waters had been ameliorated.

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[15] Bush, T., Diao, M., Allen, R.J., Sinnige, R., Muyzer, G. and Huisman, J., 2017. Oxic-anoxic regime shifts mediated by feedbacks between biogeochemical processes and microbial community dynamics. *Nature Communications*, *8*(1), 789.

[16] Bierlein, K.A., Rezvani, M., Socolofsky, S.A., Bryant, L.D., Wüest, A. and Little, J.C., 2017. Increased sediment oxygen flux in lakes and reservoirs: The impact of hypolimnetic oxygenation. *Water Resources Research*, *53*(6), pp.4876-4890.

[17] Fennel, K. and Testa, J.M., 2019. Biogeochemical controls on coastal hypoxia. *Annual review of marine science*, *11*, pp.105-130.

[18] Gächter, R. and Wehrli, B., 1998. Ten years of artificial mixing and oxygenation: no effect on the internal phosphorus loading of two eutrophic lakes. *Environmental science & technology*, *32*(23), pp.3659-3665.

A major risk with MHOP is that patchy oxygenation could be achieved at least in the short term, and demonstrated through observations and modelling, but the only benefit that it might bring is to pelagic fish, i.e. the farmed salmonids. For the reasons outlined above, it is quite probable that Maugean skates will not benefit from MHOP, because their preferred habitats are scattered throughout the harbour and not covered effectively by the oxygenation efforts. The failure of MHOP—for the skate—could arise either because the scale of oxygenation required dwarfs any technology that can be deployed, or that the habitat of the skate (benthic zone/sediment-water interface) proves impenetrable because of the obstacle of sediment oxygen demand being sustained by the fallout of labile organic matter and/or the legacy of the organic matter burden already carried by the harbour sediments.

APPENDIX B:

PLAN B: AN ALTERNATIVE VISION FOR SALMON AQUACULTURE IN TASMANIA

GROWING PAINS

Salmon farming in Tasmania has grown up. Once a small, niche business owned by Tasmanians, production has more than doubled in the past decade and is now valued at well over one billion dollars/year. The three original companies have recently been acquired by multinational corporations that have seen record profits in the past 12 months.

The increased scale of production has entailed new technologies. Tasmania now boasts some of the largest salmon cages in the world, giant well boats to bathe and transfer fish, centralised automated feeding systems and robotic net cleaners. These efficiencies have not resulted in a proportional increase in jobs, particularly in regional areas.

This rapid growth has also been accompanied by increasing environmental and social impacts, including water pollution, algal blooms, marine debris, noise and light. Tasmanians are increasingly concerned about the scale and pace of expansion and many are demanding a reduction in nearshore farming operations. Further expansion without robust scientific and regulatory frameworks is clearly a risky proposition.

Finally, the longer-term viability of farming salmon in a region with rapidly warming coastal waters needs careful consideration. Tasmania has already experienced significant salmon mortalities associated with disease, low oxygen and jellyfish, all of which will be worsened by climate change. This is not unique to Tasmania, and huge investments are being made globally in land-based and offshore technologies to transition to a more sustainable model. Tasmania needs a clear plan and incentives to make a similar transition or we are likely to be left behind.

WHY PLAN B?

In April 2022, the Tasmanian Government commenced a process to develop a 10-year salmon plan. Key stakeholders, including the Tasmanian Independent Science Council (TISC), were invited to participate in a 'consultative and collaborative' process to provide input to this plan. The TISC has participated in all aspects of this consultation process, but our input—along with that of many other organisation and individuals—has been largely ignored.

Rather than criticising a flawed process and deeply unpopular outcome, we prefer to take a more positive approach, and we hope that this alternative Plan B can provide the basis for a more constructive and better-informed result.

WHY A TEMPORARY PAUSE IN FURTHER GROWTH IS NEEDED

The TISC strongly recommends a pause on further growth until existing operations have been fully reviewed and adjusted to ensure sustainable production that does not damage the environment and is supported by the community. This pause is also needed to ensure that the scientific understanding, regulatory controls, and incentives are in place to manage future growth, limit biosecurity risks and support long-term employment and revenues to the state.

VISION

A profitable salmon industry that coexists with healthy marine and freshwater environments, provides good economic value to the Tasmanian people, and does not detract from the use and enjoyment of our shared waterways.

We envisage a more vibrant, more innovative, more sustainable salmon industry that will deliver the following five wins for Tasmania. The transition out of shallow coastal waterways onto land and/or further offshore is already happening globally, and Tasmania is in a position to deliver a genuinely sustainable, high value product through clever policy, incentives and targeted investment.

WIN #1 SECURE JOBS IN REGIONAL AREAS AND A FAIR ECONOMIC RETURN

Further increases in the volume and scale of production are not guaranteed to preserve jobs in regional communities and may in fact result in a decline due to further automation, giant well boats, more centralised operations and seasonal worker schemes. A network of distributed, land-based RAS facilities may offer better opportunities for secure, regionally-based jobs. Genuinely offshore production could also support regional jobs, particularly if processing occurs in Tasmania – not, as is increasingly the case, interstate.

Regional communities - and Tasmania as a whole – would be far better off with a system similar to the Norwegian model, whereby substantial taxes and fees are levied, and funds are distributed between the state and the regions. Alternatively, additional lease and/or production-based charges could be introduced to support a wide variety of social, economic and environmental initiatives in regional areas.

WIN #2 A CLEAN AND HEALTHY ENVIRONMENT

Tasmania's global brand depends on a clean and healthy environment, and our population expects the same. This is not negotiable. The continued pollution of shallow, nearshore waterways by open pen salmon farming cannot continue, nor should further expansion into nearshore waters be permitted. Clear policy, strong regulations, comprehensive monitoring and transparent reporting are needed to reverse and prevent environmental harm. Additional funding will be required for this and should be distributed through an independent mechanism to prevent real or perceived bias.

WIN #3 LONG-TERM SUSTAINABLE GROWTH FOR AQUACULTURE

A global shift is currently underway towards land-based and offshore salmon aquaculture, driven by climate change, evolving technologies and consumer demand for high quality, ethical products. Tasmania cannot hope to compete with industrial-scale nearshore production without serious damage to our brand and environment. By combining our natural advantages (cool climate, freshwater, green energy), skilled workforce and end-to-end production systems Tasmania has the potential to become a world leader in higher value, more sustainable aquaculture. An open-minded and creative strategy is needed to achieve this goal.

WIN #4 WORLD CLASS SCIENCE AND INNOVATION
Tasmania is already a global hub for marine science, including aquaculture research and development, and is well placed to develop and export related innovative technologies. The CSIRO, IMAS and Blue Economy CRC play important roles in this space and should be encouraged to contribute to the transition described above. For example, scalable Integrated Multi-trophic Aquaculture systems associated with land-based salmon production could produce a range of seafood and seaweed products as part of the wastewater treatment process. Additional resources are needed to support these initiatives, along with a funding model that will ensure independence.

WIN #5 A SOCIAL LICENSE TO OPERATE
A commitment to the above four wins will go a long way towards achieving social license, which can only be built on trust. Trust is in currently in short supply and will require genuine transparency, respect and a meaningful response to address community concerns as they are raised.

KEY STRATEGIES & ACTIONS FOR INCLUSION IN PLAN B

1. **Implement a pause on further growth of tonnage/biomass** (not leased area) until existing operations have been fully reviewed and adjusted to ensure sustainable production that does not damage the Tasmanian marine and/or freshwater environments, limits biosecurity risks and supports long-term employment and revenues to the state. We suggest that a period of 2 to 3 years may be needed for this review.

2. **Reduce biomass levels in nearshore operations and retire unsuitable leases**, particularly those in areas with limited flushing, high ecological values and/or significant public amenity (e.g. Long Bay, Macquarie Harbour, areas of the Channel/Huon and Okehampton Bay).
    - Review/audit all current leases – both operational and unused – for current or potential impacts to environment and amenity.
    - Evaluate local, intermediate and broad-scale impacts; risk assessment and identify/prioritise high-risk leases.
    - Establish carrying capacity and set-lease specific limits on pollution
    - Revise Environmental Licenses and/or retire marine farming leases/licenses in unsuitable areas

3. **Investigate and plan for future land-based / off-shore production and develop incentives to transition away from nearshore operations**
    - Undertake a detailed and fully independent review of both land-based and off-shore production options
    - Identify suitable locations for land-based and off-shore operations, in consultation with the community

- Investigate and offer incentives to transition to cleaner production methods, e.g. low lease rates on land for RAS facilities, subsidised renewable energy
- Set clear, publicised timelines for implementation

4. **Support genuinely independent, world-leading science** as a basis for planning and management. This will require an **independent funding mechanism** to avoid real or perceived bias and should be fully funded by the aquaculture industry. Unredacted scientific reports should be made readily available to the public in a timely manner. Additional research is needed to address key gaps including:
    - Multi-sector marine spatial planning, comprehensive baseline and follow-up surveys as a pre-requisite for new leases and for all lease renewals, to be repeated every 5 years; carrying capacity modelling; improved Broadscale Environmental Monitoring Program (BEMP) designs; impacts on protected species; and risks to freshwater systems, including potential health risks associated with toxic algal blooms
    - Impacts of climate change, and new/emerging health and safety impacts on humans or native species

5. **Ensure independent and rigorous regulation, management and enforcement**
    - Modify legislation and practices such that the EPA is clearly independent from political and industry influence
    - Complete and implement legislative/regulatory reviews, including a review of the Marine Farming Act 1995
    - Restructure the Marine Farm Review Development Panel (MFRDP) to its previous role as a decision-making body, not an advisory role to the Minister. Broaden the membership to include conservation and Indigenous representation as well as members from affected communities
    - Complete regulatory tools, including environmental, operational and biosecurity standards. Standards should include lease-specific limits on production and more comprehensive monitoring and compliance criteria
    - Fully regulate and monitor associated operations, including well boats and their discharges, desalination plants, net cleaning facilities, and fish waste composting and reuse facilities

6. **Implement full transparency and regular reporting**
    - Prepare and publish annual reports on salmon production and impacts at state, regional and lease-specific levels
    - Expand salmon portal to include up-to-date information on biomass, pollution loads, water quality, salmon escapes, disease & mortalities, use of antibiotics and other therapeutants, seal and bird mortalities, etc. ‘Compliant’ is not a meaningful indicator, nor is ‘Y/N’ for seal deaths and other criteria

7. **Undertake genuine community engagement, including regular workshops to discuss and resolve concerns**

- The annual environmental reports above should be presented to the public at workshops, along with monitoring results, operational context and future plans. Questions and concerns raised require clear answers and meaningful solutions. In some regions, biannual or quarterly meetings may be warranted.
- Representatives from the community and NGOs should be included on planning, review and decision-making committees, such as the MFRDP and EPA Board

8. Ensure a fair economic return to Tasmania

Growth in the industry must be accompanied by growth in real jobs (FTE), and growth in revenues to Tasmania

- Initiate an independent expert review of costs and benefits of the Tasmanian salmon industry and how this can be optimised for the benefit of the state and affected local communities. This should include improved financial transparency, an analysis of direct and indirect jobs, implications of continued automation, adequate fees to ensure full cost recovery of management, science and training, possible auction of production quota/leases, payment of royalties or Gross Product Value fees, payment of Council rates, rehabilitation bonds, etc.
- Investigate what is considered a fair return overseas, and how this is implemented
- Consult with affected communities on their views, and be responsive to these views
- Increase fees and rents to cover full costs of salmon-related regulation and management, including monitoring and scientific studies, reporting, training and the use of public infrastructure.

9. Increase job security for Tasmanians

- Undertake an independent accounting of direct and indirect jobs and where these are located
- Assess job loss implications of continued automation, interstate processing and seasonal worker schemes, and develop ways to increase and protect Tasmanian jobs, particularly in rural and remote areas, such that job losses will be offset with new jobs for resident populations at good pay

10. Improve monitoring and management of freshwater operations

- Document current and future freshwater requirements for the production of smolt and bathing of caged fish, and determine if/how these can be provided without adverse impacts on community supplies or the environment
- All freshwater hatcheries and smolt production facilities should be Recirculating Aquaculture Systems (RAS), and clear design criteria must be established to define this. Large-scale flow-through hatcheries should no longer be permitted in Tasmania. A policy and sunset clause are needed to convert existing flow-through operations to RAS within no more than 3 years. Flow-through hatcheries that discharge contaminated water should no longer benefit from trivial non-consumptive water allocations fees (approximately $400/year, regardless of the volume used).
- Review/audit current hatchery operations, including impacts to environment and amenity. Prioritise worst performing operations and set specific limits on pollution

- Develop clear RAS standards for existing and future inland fish farms
- Link water license fees to discharge quality, with higher fees applied to poorer quality discharges
- Convert large flow-through systems to RAS within 3-years or retire them from service
- Improve monitoring of hatchery effluent, including potential health risks associated with cyanobacterial toxins on drinking water supplies and recreational activities.