Report Review

for the

Minister for Environment & Conservation

by

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Draft Report

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Executive Summary

The pumping of hypersaline water from the Coorong to the open ocean will introduce high concentrations of nutrients and microalgae into the coastal ocean. The authors of this report were contracted to provide an evaluation of the thoroughness and accuracy of Appendix E of the Aurecon report to the MDB-NRMB entitled *Preliminary Hydrodynamic Modelling for Coorong Temporary Saline Discharge*. In addition, we were asked to provide any additional analysis based on our own expertise.

We find Appendix E credible and agree that any impact will very likely be localized and transient. However, following the worst case scenario approach in the main text of the report, we note the following.

- The pumping process will convert microalgal biomass to dissolved organic matter and detritus, raising nutrient concentrations at the outflow compared to the inflow
- The most likely impact will be on the benthos, specifically that settling and nutrient absorption may cause mat-like growth that will stabilize the sandy bottom creating a significantly enhanced benthic community around the outflow
- Appendix E does not consider the bacterial portion of the community, which is capable of surviving the mechanics and large salinity changes of the pumping process
- Combining points 2. And 3. raises the possibility that a small area below any stabilized sand could become suboxic or anoxic

1. Concept clarification in Appendix E

From the statement in third paragraph of the introduction, it might be inferred that a factor 4 dilution is a common change in the ocean. More than 98% of the ocean is 34.5 and 36 ppt (Pond and Pickard 1978).

The introduction also claims a paradox because there are insufficient nutrients in the water to support the observed biomass. There is no paradox. In water bodies less than a few metres deep, benthic contributions to the microalgal biomass can dominate the overall biomass, which is the situation our own work has found for the Coorong.

Nitrogen is indeed the most likely limiting nutrient in coastal waters. Aurecon has the basic concepts of the nitrogen cycle correct and applies them in a simple fashion. However, their figure 2 of the nitrogen cycle is odd in that it is for terrestrial systems; includes a fertilizer factory; does not distinguish between oxic and anoxic processes; and is at least 15 years out of date. For contrast, we provide up to date cycles for the marine environment that include distinctions between oxic and anoxic processes (see Figure 1 on the following page).

Figure 1: Updated and Process Relevant Nitrogen Cycles

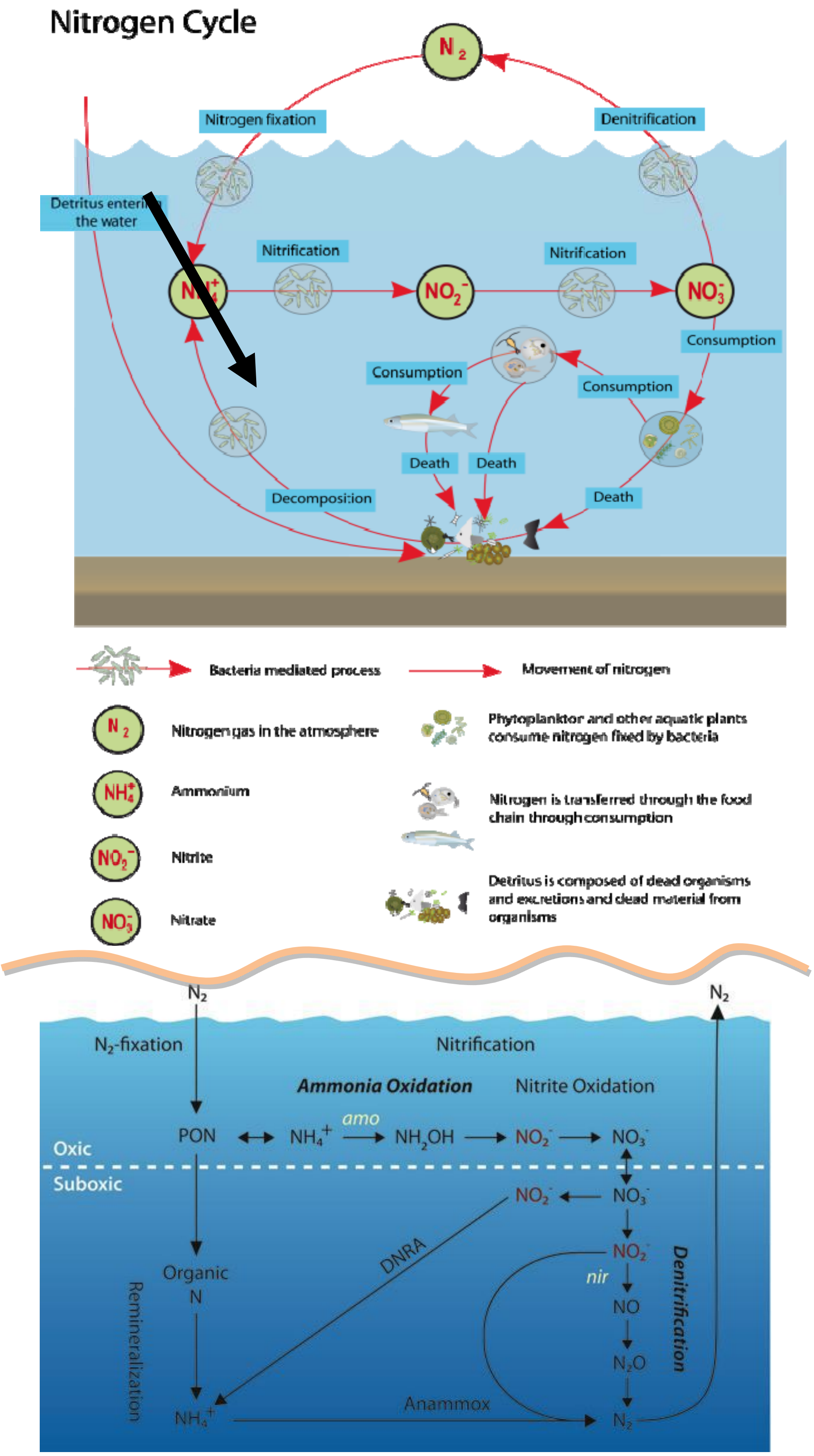

Figure 1 illustrates marine and updated nitrogen cycles. The top cycle emphasizes the transport of nitrogenous materials to the benthos as indicated by the large black arrow. The bottom version of the nitrogen cycle emphasizes the processes divided by oxic and suboxic. The thick wavy line has been added to give a rough indication of the processes that would occur in the water versus in organic matter stabilized sands. The top figure is modified from the Queensland EPA (2010). The bottom figure is modified from Francis et al. (2007).

2. Process-specific comments

2.1. Pumping

In the main analysis, it is stated that the phytoplankton going through the pump will be unlikely to survive. This is true, but Aurecon fails to point out that killing them will increase the amount of dissolved and particulate nitrogen in the water. Basically, this will take the total nitrogen and convert it to dissolved or colloidal nitrogen. In addition, the released carbon could substantially increase bacterial numbers on the discharge side. The pumping process will also take the total organic carbon and convert it to dissolved or colloidal carbon. This again will almost certainly increase bacterial numbers.

2.2. Outflow

Settling to the seabed is likely for the remains of the dead cells and other detritus. The larger particles will settle first in the shallower water with the smaller particles settling further away in deeper water. The settling increases the likelihood of the sand in the area being stabilized by organic matter and possibly becoming suboxic or anoxic. The model makes the assumption that nutrients are passive tracers. This is an often used assumption, but ignores the dynamic between uptake and release of nutrients, and fails to recognize the episodic release from all nutrient pools.

2.3. Trophic transfer

The end of page 3 in Appendix E says that a secondary process of nutrients derived from the decay of any enhanced algal growth may further enhance algal growth. This is true. However the next phrase that qualifies this by saying “for some period following the initial discharge” could be interpreted as meaning that after the initial discharge, this mechanism will no longer contribute to enhancement. If this mechanism does operate, it is more likely to continue on and build up over time, the opposite of what is implied in the quoted statement above.

The reason for the localized nutrient build up is that the nutrients could continuously add to benthic algae which would provide a food base for a greater number of grazers. The grazers in turn will die from predation and disease. The death of grazers and other animals is a longer term process that becomes significant when the biomass and nutrients that have been stored in the higher trophic levels begin to return to the local environment.

The authors of Appendix E seem to have ignored the situation in marine environments where, unlike terrestrial environments, the vast majority of the biomass can be concentrated at the higher trophic levels. The significance of this here is that biomass concentrated in higher trophic levels would be benthic and that benthic biomass is harder to disperse with tides and currents.

The other significant point is that the biomass build up at the higher trophic levels can take months to years, meaning that an initial, short term monitoring of algal biomass is insufficient to assess impact. Implicit in a benthic build up of biomass would be a build up of the detrital food web as well, which would result in an increase in bacterial biomass. For all groups, the presence of higher overlying nutrient levels may also cause taxonomic shifts at all trophic levels. Again this might take months to years to occur. While there is a chance shifts may occur, the spatial extent of the shifts would have to be limited. Benthic community build up at outfall, would presumably decline after the 3 years of pumping ends.

3. Worst case scenarios

The noted absence of harmful algal blooms at the Murray mouth is probably in large part due to the fact that many harmful algal bloom species require calm water over large areas for many days. This condition is as unlikely to occur at the discharge point as it is at the Murray mouth.

One danger that might arise towards the end of the 3 year pumping project is a micro dead zone, primarily in the sediments. These are common where nutrient rich water flows into shallow nutrient poor water (Diaz and Rosenberg 2008).

4. Monitoring

The suggested satellite monitoring is unlikely to be effective because the area is so small on a global scale and because near shore satellite pixels are notoriously unreliable due to bottom and near shore reflections and bottom type. By the time a satellite can reliably see the effects from a 1 m outflow, the impact has already happened. If DEH is committed to a remote sensing approach then a low flyover by an appropriately equipped plane is an option. Alternately, water samples around the outflow are an option. The advantage of the water samples over the satellite or plane is that bacterial abundance and benthic oxygen values can be recorded. Sampling every two months in the first year, with a reduction to every 3 months from the second year should suffice to monitor benthic algae and bacteria assuming no build up is seen. Sampling twice in the third year, again, would be sufficient in the absence of build up.

5. Summary

Appendix E is probably correct in implying that there will be minimal impact from the pumping. Any significant impact is likely to be in the build up of biomass in the benthic community immediately around the outflow. It is probably advisable to monitor the biomass of benthic microalgae and bacteria on a regular basis for at least the first year of pumping.

6. References

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- Pond S and GL Pickard (1978) Introductory Dynamical Oceanography. Butterworth-Heinemann, Oxford, UK.

- Queensland Government, Environmental Resource Management website (accessed April 2010) http://www.epa.qld.gov.au/wetlandinfo/resources/static/images/Concept2/AllPng/Nitrogen-Cycle-LH.png

Synthesising potential impacts of the proposed South Lagoon Salinity Reduction Scheme on the Encounter Bay receiving marine environment

A report prepared for the South Australian Murray-Darling Basin Natural Resource Management Board

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March 2010

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Executive summary

Over the last five years, the ecological condition of the Coorong has declined as a result of extremely low or no inflows from the River Murray. Conditions in the South Lagoon of the Coorong, in particular, have reached a point where much of the previous biota can no longer tolerate the extreme conditions and have moved from the region or are dying.

As a result, a proposal has been put forward to pump hypersaline water from the South Lagoon of the Coorong to Encounter Bay, to lower overall salinity levels within that system.

However, the potential exists for this hypersaline water to adversely affect the ecosystem of the receiving marine environment. This report reviews the studies that have been undertaken to assess the likelihood of such adverse impacts and then syntheses the findings, in the context of the region as a whole.

These studies reviewed include the following:

- Review of existing knowledge for the region with a view to identifying any potentially vulnerable species or ecosystems (Aurecon 2009a);
- Preliminary modelling investigating the likely extent of salinity plumes in Encounter Bay (Aurecon 2009b)
- Preliminary modelling investigating the potential for nutrient enrichment in Encounter Bay (Aurecon 2009c)
- Assessing the distribution and population demographics of pipis (*Donax deltoides*) and sandy-beach infauna (Gorman *et al.* 2009);
- An assessment of the likely impacts on larval development of pipis (*Donax deltoides*)(Wiltshire *et al.* 2009);
- Habitat mapping of the coast in the region of the proposed outfall in Encounter Bay (Rowling *et al.* 2009).

Based on the information presented in these reports, it is clear that the studies undertaken were done so as preliminary investigations and that all represent snapshot assessments where surveys were undertaken only once. As a result, the methods used were not ideal and there are limitations on the conclusions that can be drawn, especially with regards to season or interannual variability and the accumulation of any sublethal effects that might arise over time. However we are able to draw some conclusions that are relevant for the approvals process that is underway for the proposal as a whole.

We have not identified a likely source of significant ecological damage to the receiving marine environments from the studies reviewed here. We acknowledge that few studies have been undertaken in the region previously but were surprised that those that we are aware of were not referred to by the authors cited here. As a result, we have taken a cautious approach to interpreting the results and have assessed whether an underestimation of any (or all) of the impacts by an order of magnitude would change the findings presented. Despite our caution, we conclude that even impacts an order of magnitude larger than those indicated would be unlikely to adversely affect the ecology of the region as a whole, nor the commercial pipi fishery, due to the relatively small footprint of the outfall in both space and time, and the inherent variability (e.g. in River Murray flows and nutrient levels) and high-energy nature of the coastline. The possibility remains for longer-term sublethal impacts but, while these have not been explicitly considered by the studies presented here, no immediate indications of these are apparent.

Limitations associated with the scope of the assessments that have been done to date, particularly with respect to sampling of spatial and temporal variability, lead us to recommend concurrent monitoring of infaunal beach communities, pipi populations more specifically, as well as the subtidal benthos. However comparisons with previous studies undertaken in the region (as far as was possible) do not suggest any immediate additional negative impacts.

Additional monitoring is also suggested for water quality variables and local threatened species populations (e.g. hooded plover and right whales) that may be affected by the proposal, but have not been quantitatively investigated by any of the studies reviewed here.

In summary, we conclude that the studies reviewed here present little or no evidence of likely damage to the ecosystem of Encounter Bay as a result of the proposed pumping of hypersaline water from the South Lagoon of the Coorong. The relatively small temporal and spatial footprint of the resultant plume, and the high-energy, highly-variable nature of the coastline in question suggest that local biota will be adapted to cope with changed conditions during the pumping action.

Introduction

Over the past five years, prolonged drought and extractions in the Basin have led to a decrease in flows from the River Murray over the barrages to the Coorong. As a result, salinities within the Coorong have risen steadily, with the South Lagoon most affected. In the South Lagoon, salinities have risen to the point where the vast majority of biota that previously inhabited the region is no longer able to survive the extreme conditions. In some instances, other species that are considered more typical of salt lake environments have colonised but, overall, the ecosystem is highly simplified and the risk of local extinctions of species is high. In addition, some local experts fears that a return to freshwater flows without first 're-setting' conditions in the South Lagoon may leave organisms without suitable habitat or sources of colonists in either of the two Coorong lagoons, increasing the risk of long-term ecological damage via the very event that would supposedly restore the system. These fears notwithstanding, there is little likelihood of a return to substantial freshwater flows to the Coorong in the foreseeable future due to the extremely low levels of the Lower Lakes, so the extreme conditions in the South Lagoon of the Coorong are likely to continue in the interim.

In order to redress the ecological damage that is currently occurring, it has been proposed that a short-term pumping system be installed to pump up to 250 ML/day of hypersaline water from the Coorong South Lagoon to Encounter Bay, at a location near Policemans Point and Woods Well. Pumping is proposed to be undertaken continuously for a period of three years, with discharge occurring either on the adjacent ocean beach, or in the nearby surf zone offshore. Salinities in the South Lagoon of the Coorong fluctuate seasonally and annually, but are currently in the order of 150 parts per thousand (ppt).

While the likely benefits of this action for the Coorong have been demonstrated through modelling (Lester *et al.* 2009), the effects of the discharge of hypersaline water to Encounter Bay has the potential to cause ecological damage to the receiving environments. Given that the proposed outfall location falls between two marine parks (i.e. West Kangaroo Island Marine Park to the north & Upper South East Marine Park to the south), and the local commercial pipi (*Donax deltoides*) fishery, in particular, governmental approvals (under EPBC and South Australian EPA legislation) are needed to allow this action to proceed. In order to contribute to the approval process, and to understand any possible negative effects of this action, likely impacts on the hydrodynamics and ecology of Encounter Bay have been investigated through a range of targeted studies.

The aim of this report is to summarise and synthesise the findings of the various studies that have been undertaken into the likely impact of pumping hypersaline water from the South Lagoon of the Coorong to Encounter Bay on the receiving environments. In undertaking this synthesis, emphasis has been placed on identifying knowledge gaps that may be relevant to understanding the likely impact, as well as our current understanding of the physical and ecological properties of Encounter Bay.

Described benefits to the Coorong

A study was undertaken to investigate the likely hydrodynamic and ecological impacts of the proposed pumping of hypersaline water from the South Lagoon of the Coorong to Encounter Bay (Lester *et al*. 2009).

The assessment was based on a hydrodynamic model and an ecosystem states model for the Coorong that were used in sequence over a 20-year model run. Additional details relating to the development and use of the models are presented in Lester *et al*. (2009).

Initially 87 scenarios were assessed for the Coorong to identify which of a suite of proposed actions (including pumping, increasing connectivity at Parnka Point, additional dredging at the Murray Mouth and construction of a regulator at Parnka Point) was likely to have the most positive effects on the hydrodynamics and ecosystem states of the Coorong. Each potential intervention was compared with a baseline scenario that involved no intervention and no freshwater flows over the barrages. Results from these initial scenarios were assessed based on deviations from the baseline scenario based on water levels and salinities in the South Lagoon. Options including a combination of dredging works at Parnka Point to increase connectivity and pumping appeared to yield the most improvement and were identified for further modelling in a second-round of analyses.

A further 20 scenarios were further investigated. These included assessments of two rates of pumping, various times for the start of the intervention and various levels of channel works at Parnka Point. Those scenarios investigating the higher rate of pumping were not considered further due to practical constraints associated with pumping at that rate. All remaining scenarios showed positive impacts, compared with the baseline scenario, of substantially lower salinities in the South Lagoon. Scenarios combining works at Parnka channel with the pumping of the South Lagoon had the greatest impact on water levels and salinities in the South Lagoon, and also longer-lasting and more profound effects on the predicted mix of ecosystem states.

Undertaking channel works to increase connectivity at Parnka Point is a culturally sensitive matter and is being considered separately from the pumping works at this point in time. Investigations of pumping in isolation showed a lower level of recovery than when this action was taken in combination with channel works, with the benefits eroding over time; however, significant benefits compared with the baseline scenario were still evident.

None of the intervention scenarios investigated was an adequate replacement for a return to barrage flows. However, in the short term, and in the absence of a return to historical levels of barrage flows, pumping of hypersaline water from the South Lagoon of the Coorong (with or without the additional intervention of channel works at Parnka Point) provides significant benefits to the South Lagoon, by lowering salinities without negatively affecting water levels (provided pumping is undertaken appropriately) and improving the mix of ecosystem states predicted for the Coorong. No negative effects were detected for the North Lagoon based on this modelling as a result of the intervention.

Finally, a rapid response in terms of acting on this intervention was also recommended. This was to minimise the likelihood of local extinctions in the region due to ongoing extremely-adverse conditions. A monitoring program to assess the progress of the intervention was also highly recommended, to allow managers to adapt the proposed action in response to any unexpected (good or bad) consequences, and to ensure that the expected results were forthcoming.

Additional modelling was undertaken by BMT-WBM (2009) to better resolve the effects of pumping and of increasing the connectivity between the two lagoons at Parnka Point. This report agreed with the previous modelling work (Lester *et al.* 2009) that pumping hypersaline water to Encounter Bay would significantly lower salinities in the South Lagoon of the Coorong, despite some systematic issues associated with calibration in the South Lagoon. The authors found that, in contrast to earlier work, there was little effect of dredging (or some other channel works) at Parnka Point. However, the level of connectivity modelled was only effectively half that investigated in the previous work (a 50 m wide channel compared with a 100 m wide channel), so it is not surprising that the resulting impact was smaller. This discrepancy is, for the purposes of this document and the current proposal, unimportant, as the channel works at Parnka Point do not form part of the proposed management action.

Finally, additional hydrodynamic modelling was undertaken to investigate several additional options that were suggested following the completion of the initial modelling (Webster 2010). The effects of locating the pump in several locations, installing a pipe through which flows would be passive and also of additional flows from the Upper South East Drainage scheme (entering via Salt Creek at the southern end of the South Lagoon) were all investigated. The results of this additional modelling indicated that the proposal outlined above (for pumping in isolation) remained the most feasible (but with similar caveats regarding the additional benefits associated with channel works at Parnka Point).

Review of studies undertaken to assess likely impacts on the marine environment

A number of studies were commissioned by the South Australian Natural Resource Management Board to specifically investigate the likely impact of the proposed pumping (and the associated outfall) on the receiving environment of Encounter Bay. In addition, we are also aware of several additional studies that have been done in the region, and, have summarised information from those where we believe it is relevant to understanding the overall impact that the proposed management action is likely to have on the region.

These studies include:

- Review of existing knowledge for the region with a view to identifying any potentially vulnerable species or ecosystems (Aurecon 2009a);
- Preliminary modelling investigating the likely extent of salinity plumes in Encounter Bay (Aurecon 2009b)
- Preliminary modelling investigating the potential for nutrient enrichment in Encounter Bay (Aurecon 2009c)
- Assessing the distribution and population demographics of pipis (*Donax deltoides*) and sandy-beach infauna (Gorman *et al.* 2009);
- An assessment of the likely impacts on larval development of pipis (*Donax deltoides*)(Wiltshire *et al.* 2009);
- Habitat mapping of the coast in the region of the proposed outfall in Encounter Bay (Rowling *et al.* 2009).

A review of each study is presented below, outlining the purpose of each, the methodology used and a summary of the main findings. We have also highlighted areas where we believe that the methods used may have affected the authors' ability to come to the stated conclusions and areas where the results and conclusions of one study affect those of others. We have cross-referenced between studies as appropriate.

Review of existing knowledge for the region with a view to identifying any potentially vulnerable species or ecosystems

A preliminary review of the available data and assessment of the likely impacts of the proposed management action on the Coorong and Encounter Bay (Aurecon 2009a).

The report describes the current environments of the Coorong and Encounter Bay coastline, and identifies all matters of national environmental significance, as defined by the *EPBC Act* 1999. For each of the identified EPBC-listed species, the likelihood of that species first using the region and then being affected by the proposal is given.

The authors identify saline plumes in the marine environment, possible nutrient inputs to the marine environments, pipi (*Donax deltoides*, also known as locally Goolwa cockle) fisheries, and populations of hooded plovers (*Thinornis rubricollis*) and syngnathid pipefish (Family Syngnathidae) as potentially being affected by the proposed plan. The pipefish would only be affected if suitable subtidal habitat existed in the vicinity of the proposed outfall.

Each stage of the construction and operation process has been investigated, with likely impacts and recommended mitigating actions being identified. Preliminary assessments and further studies have been recommended. Based on these recommendations, as well as consultation with local experts, the remaining studies that have been reviewed herein were designed and undertaken to investigate the less well-known effects on the receiving marine environment.

While an extensive list of EPBC-listed threatened taxa were identified as potentially using the local environment, many of them are unlikely to be affected by the pumping operation (e.g. due to their habitat preferences). Of those listed, we believe that right whales (*Eubalaena australis*) may be most likely to be affected by the operation. Right whales are known to use shallow, inshore embayments to migrate through the region and bear their young near Victor Harbour and to be affected by noise. None of the subsequent studies focused on the use of the region by right whales, so a monitoring program designed to determine whether Encounter Bay is used regularly, or collaboration with existing whale monitoring programs, would be advisable. It is likely that an assessment of the impact of the proposal on right whales (or other marine mammals) could be done in conjunction with organisations already monitoring their movement within and use of the region.

The authors suggest that there may be an effect of the proposed management action on the Coorong commercial fishery. We believe that this is highly unlikely given the current lack of commercially-fished species using the South Lagoon of the Coorong. In fact, it is possible that the fishery may benefit, if the region becomes habitable by commercial species once again as a result of lowered salinities.

Beach access might be more of an issue than is suggested in this report, although this isn't necessarily as a result of the pipeline and outfall. In each of the past three years, the beach has washed out due to storms and been closed (P. Fairweather, pers. obs.). This means that maintenance around the pipe is likely to be needed before the beach could be accessed by traffic again, should this occur in the future. There may also be implications for the structural integrity of the outfall, and burial at depth is likely to be needed if the outfall is located in the swash zone, in particular.

This report has highlighted those taxa that are most likely to be affected by the proposed management intervention and mitigation strategies that could be implemented for each. The majority of recommended further studies have been undertaken (and are reviewed below) so that the overall degree of impact could be assessed where knowledge gaps existed. However, the recommended mitigation strategies should still be implemented, particularly regarding the hooded plover, which were not the subject of any further investigation.

Preliminary modelling investigating the likely extent of salinity plumes entering Encounter Bay

A hydrodynamic model for the region was developed by Aurecon (2009b) to investigate the effect that high-salinity discharge from the Coorong may have on the hydrodynamics of Encounter Bay.

The 3-dimensional hydrodynamic model was developed using existing data for the region. The modelling focused on finding the footprint of a plume of more than 1 part per thousand (ppt) of excess salinity (with a background salinity of 35-36 ppt, this was set at 37 ppt), which was defined as likely to be ecologically significant. Distance to a 50-fold dilution (38.34 ppt) was also investigated. Due to time constraints and the complexity of the task, Aurecon (2009b) focussed on identifying and modelling so-called 'worst case' scenarios for the region. These included extended periods (three days) of combined low winds, neap tides and low waves. Two scenarios were evaluated; one with constant shore-parallel winds; and another with constant winds from the direction of Hindmarsh Island (NW; thus, roughly off-shore winds). Two possible discharge locations were also considered; one on the beach; and the other into the surf zone.

There was some variability in the extent and direction of the plume of saline water depending on the scenario investigated. Unsurprisingly, wind direction affected the extent and direction of the plume, with winds from the NW resulting in a larger plume than shore-parallel winds. Discharge to the beach also created a larger plume than discharge into the surf zone, although the difference appeared to be relatively small (i.e. less than twice the size). Despite these differences, the extent of the plume of more than 1 ppt excess salinity (to 37 ppt) tended to range between 1.5 and 2 km under most scenarios, with the most-severe extending up to 3 km. Fifty-fold dilution (to 38 ppt) tended to be achieved within a 2-km radius of the outfall location.

Hydrodynamic modelling was undertaken prior to completion of ecotoxicological studies on pipi development (see below), so plume sizes reported do not precisely match those concentrations found later to be biologically significant for pipis (e.g. > 45 practical salinity units, which is ~ 45 ppt, and has been shown to be the lower limit for salinities that affect pipi larval development). Thus areal extent has been estimated for plumes of this magnitude from the figures provided. Based on these illustrations, under worst-case conditions, we estimate that salinities high enough to inhibit larval development of commercially-important species, are likely to extend for a maximum of 750 m along the beach.

Modelling limitations prevented the exploration of longer modelling runs. However, a preliminary analysis of prevailing conditions in the region indicate that worst-case conditions investigated here are likely to occur less than 1% of the time, and it is very unlikely that they would persist continuously over a three-day period. Thus, salinity plumes are likely to dissipate over substantially shorter distances than indicated here for the vast majority of time. However, the potential impacts of longer-term but smaller increases in salinity has not yet been addressed in detail, either from a hydrodynamic perspective, nor for the ecology of Encounter Bay.

Preliminary modelling investigating the likelihood of nutrient enrichment in Encounter Bay

Following their hydrodynamic modelling, Aurecon (2009c) also undertook a preliminary modelling exercise investigating the likely spread of nutrients from the outfall on the Coorong beach and compared the likely levels to the relevant ANZECC and South Australian EPA trigger levels.

Marine systems in general tend to be nitrogen limited. Thus, there is the potential for discharge from the outfall to enhance algal growth within the region. Based on available water quality data for the region, background chlorophyll *a* concentrations tend to be relatively high compared with ANZECC guidelines. This suggests that these guidelines may not be entirely appropriate for this coastline (possibly due to local upwelling creating a higher nutrient environment than many other coastal regions in Australia) or possibly that there are other nearby sources of pollution.

Waters in the South Lagoon of the Coorong have higher nutrient loads than those of Encounter Bay. However, the nutrient tonnage per annum that is likely to be exported to Encounter Bay via the outfall is within the range of values for historical nutrient export through the Murray Mouth in times of high flow, according to nutrient budgets developed for the region (Brookes *et al.* 2009). These budgets demonstrate the extreme variability in nutrient loads delivered to the region through the Murray Mouth (varying with freshwater flows). The nutrient inputs from the outfall, however, will be delivered as a (or two) point source inputs, rather than the more-diffuse input via the Murray Mouth.

According to modelling undertaken, based on likely worst-case conditions, nutrient concentrations are likely to fall under ANZECC guidelines within 200 m of the outfall for total nitrogen, oxidised nitrogen, ammonia, total phosphorus and pH. Guidelines relating to turbidity, chlorophyll *a* and soluble phosphorus were not likely to be met over this distance (although phosphate and chlorophyll *a* already regularly exceed the guidelines, suggesting that the ANZECC triggers are not locally relevant). In addition, the report is written as though all sources of nutrients were equal (and harmful), whereas nutrient inputs associated with freshwater sources are, in fact, necessary food sources for filter-feeders such as pipis (see below), upon which the commercial fishery is based. Thus, the effects of elevated phosphate and chlorophyll *a* are likely to be more complex than is implied by simply exceeding a recommended level.

Other inputs to the marine environment may include phytoplankton, which has the potential to change the primary productivity of the region. However, the current phytoplankton community in the South Lagoon of the Coorong is likely to be highly salt-tolerant, and is thus considered unlikely to survive the transition to the lower-salt environment of Encounter Bay by the authors. Similarly, the pumping process itself was considered likely to kill phytoplankton prior to release into Encounter Bay. No evidence supporting either of these assertions was offered, but both suppositions appear reasonable.

The final discussion relating to blue-green algae (or cyanobacteria) is not considered to be particularly useful, as it lacks context as to the local algal community. Many species of cyanobacteria (or even some strains of the toxic species) are not toxic, and many toxic oceanic blooms are, in fact, associated with dinoflagellates, rather than cyanobacteria. Thus, we doubt the relevance of the speculative discussion here to the proposal at hand.

*Assessing the distribution and population demographics of pipis (***Donax deltoides***)*

A study undertaken by Gorman *et al.* (2009) investigated the current demographics and distribution of pipis (*Donax deltoides*, also known locally as Goolwa cockles) on the Coorong Beach, near the proposed location of the outfall.

Sampling was undertaken along a 10-km stretch of beach (5 km either side of the proposed outfall), with a total of 21 sites sampled at increasing intervals as distance to the proposed outfall site increased. Sampling was conducted over a month and three transects per site were sampled by commercial fishers using commercial cockle rakes (44 mm mesh). In addition, one sample per site was collected to assess length–frequency for smaller cockles using a net with a 1-mm mesh.

Relative catches of cockles were highly variable, but appeared to increase in a northerly direction. Catches within the sampling zone were an order of magnitude lower than are regularly recorded within the commercial fishing zone (based on survey data from the commercial fishing zone reported by Gorman *et al.* 2009). Shell length was reported as being less than that recorded within the fishery also, but the lack of replication at the within-site scale (i.e. only one sample was taken per location) meant that this finding may be confounded by unmeasured small-scale variability. However, this study is consistent with the usual standard of fisheries assessments undertaken, and thus the reader can be reasonably confident in the conclusions that are drawn.

Based on these findings, the authors concluded that the region of the beach that could potentially be affected by the outfall was not a major source of breeding adults and that the outfall was unlikely to affect pipi populations in the region or the commercial fishery.

The use of commercial cockle rakes for most of the sampling means that majority of effort was focused on adult cockles that were already of legal collection size. Most available methods are selective regarding sizes but this method only yields large cockles. Thus, little information has been gathered with respect to juvenile or small adult populations that were postulated to be most vulnerable to the effects of the outfall (and were also investigated by Wiltshire *et al*. 2009). Additional studies (see below) relating to the effects of increased salinity on larval and juvenile development suggest that this may not be a major concern as salinity was not found to retard development until levels more than 40 (with all salinities reported in practical salinity units, which are therefore dimensionless), but the lack of data relating to the distribution and population demographics of juvenile and young adults is a significant knowledge gap (see James and Fairweather 1995 for several methods of efficiently sampling this cohort of the pipi population). However, the focus on adult pipis does tend to support the authors' finding that the region does not support a large adult population likely to be a recruitment source for the region.

Some details of the sampling are not clearly specified within the report, especially regarding the height on the shore or distance across the shore where pipis were sampled or found. Systematic sampling, or haphazard sampling based on expert opinion, are common methods used in fisheries assessments, but random sample placement provides the greatest inferential power or potential for data analysis (Downes *et al*. 2002). How this aspect of the sampling relates to the distribution and mobility of pipis on this shore is unclear but appropriate rapid methods do exist (see James & Fairweather 1995) for determining the vertical or cross-shore distribution of the main concentration of pipi populations, and undertaking similar sampling in the future would substantially improve the inference that could be drawn from the studies.

Effectively this report is presented in two parts and the latter concerns animals other than pipis living in the beach sediments. This part did not seem to have been done to same degree as the cockle study, and so we are less convinced by this part of the project. Thus, in addition to the pipi sampling, five core samples were also collected in each of the high shore, mid shore and low shore (after James & Fairweather 1996) to assess infaunal communities on the beach. Each site was sampled once. The manner in which the sediment samples were handled was not what could be considered standard for surveys of this type that would allow easy comparison of the resulting data with the sandy beach literature more generally. Infauna (sampled using cores) appeared quite depauperate, but very little analysis was done (i.e. no multivariate analysis) and the findings were not compared to data that had been collected in the region previously (e.g. see McLachlan *et al.* 1996; Morcom *et al.* 2009; P. Fairweather, unpublished data). We would expect to have seen a wider range of infaunal biota, based on those previous studies, and so the beach ecosystem is probably still suffering, even in late 2009, from two very large storms that had occurred since 2007 (P. Fairweather, pers. obs.), each of which led to the closure of the beach to all traffic by 4WD vehicles.

*Assessing the likely impacts on larval development of pipis (*Donax deltoides*)*

A study undertaken by Wiltshire *et al.* (2009) investigated the potential effects of elevated salinity (and other constituents in waters from the South Lagoon) on the larval development of pipis. The study involved laboratory trials, exposing pipis to different concentrations of water from the South Lagoon (and thus different salinities) at a range of life stages to determine the effect at several stages of development that were likely to be sensitive to salinity.

Four trials were conducted across various life stages from fertilisation to the development of juvenile pipis. Five salinity treatments were applied to each of the four life stages (with five replicates of each). Salinities ranged over 36, 38, 40, 45 & 50 (with all salinities reported in practical salinity units, which are therefore dimensionless). Salinities measured in parts per thousand (as has been done in studies summarised above) are approximately equivalent in the practical salinity scale for the range of values included in these studies. Exact conversions between the scales are complex and have not been attempted. Salinities were manipulated by mixing seawater collected from the Adelaide metropolitan coastline (at West Beach) with water collected from the South Lagoon of the Coorong. De-ionised water was used where necessary to lower salinities from ambient concentrations. All water was filtered prior to use to remove planktonic and other particles.

Results were quite consistent across each of the four developmental stages investigated (i.e. fertilisation, development of the trochophore larvae, development of well-developed D larvae and development of juvenile pipis). Development from fertilisation to the trochophore larval stage showed a significant decline above salinities of 40 (in the range of 40 to 45) and an additional decline when salinities exceeded 50. A similar pattern emerged for development beyond the trochophore larvae stage, with progressively fewer well-formed D-larvae at salinities of 45 (thus declining between 40 and 45) and virtually none when salinities reached 50. Increasing mortality of D-larvae was observed for salinities above 45, although the difference was not statistically significant until salinities of 50. Larval pipis were significantly smaller (~16%) when salinities exceeded 50, but no other differences were observed.

For juvenile pipis, methodological problems meant that differences in mortality could only be calculated for day 14 of the trial (rather than sequentially between day 0 and day 14). Again, differences were only observed at salinities of 50, but results were quite variable at salinities of 45 as well (although the overall mortality did not differ from that of lower salinities).

Overall the results were very consistent across ages, with salinities held at 50 adversely affecting every stage. This may also be true for salinities of 45, but 40 and below were fine for all stages. Life stages most sensitive to elevated salinities appeared to be the development of the egg, following fertilisation and then the development of well-formed D-larvae, both of which were affected in the range of salinities between 40 and 45. Other life stages were also affected, but not until salinities reached more than 50. The authors were of the opinion that additional time would not have altered these findings for some stages, but that continued slow development was possible in others. No details were provided as to the expected length of time pipis could spend in each developmental phase (e.g. what is the usual length of time that a pipi spends as a trochophore larva compared with time as a juvenile?) nor how the experimental time (of 14 days) compared with this expectation (i.e. the closer the two, the more potential there would be for slowed development to be missed by this experiment). The expectation of the authors was that this region may be a recruitment source for the region (based on previous work undertaken by King (1985) and Ferguson & Mayfield (2006)), in which case, the proposed outfall may have the potential to impact pipi populations throughout the region, including the commercial fishery. However, this seems relatively unlikely, now that results are available relating to the maximum saline plume that is likely, and the distribution of pipis in the region capable of acting as recruitment source.

In discussing the effects of salinity on the development of pipis, the authors did not consider any potential impacts of other constituents in the water collected from the Coorong, how these may have interacted with salinity nor what these constituents may have been. The use of water collected from the Coorong provided some control for those constituents that were not filtered out, but the use of water from the metropolitan coast, rather than Encounter Bay may have masked (or indeed created) interactions that have not been identified. Impacts associated with temperature differences (especially related to development times) in the waters of the Coorong and those of Encounter Bay were also not assessed.

Placing the study in the context of the proposal as a whole, it is difficult to assess how relevant the observed differences in larval development are for two reasons. Firstly, the trials were (necessarily) conducted over very short time frames (14 days). Thus, it is difficult to extrapolate to effects that may not be manifest over short time frames (particularly for potentially longer developmental pathways such as the growth of juvenile pipis), or may be sub-lethal and thus cumulative (e.g. the impacts of smaller larvae on their subsequent development and survival) as time constraints prevented following a single cohort through all the developmental phases. Secondly, the majority of salinities that were tested were well above the salinities that are likely to be experienced over the vast majority of the coastline (less than 3km; Aurecon 2009b), meaning that many of the findings are likely to be irrelevant to much of the region, while the smaller but cumulative effects are less-well understood. As this was the first study into the possible effects of elevated salinities, this is somewhat inevitable, but additional work would clarify these two points.

However, the consistency in the observed results (with no significant effects observed for salinities less than 40, a level likely to be exceeded for only 0.75 km of coastline under likely worst-case conditions; Aurecon 2009b) support the conclusion that the effects on pipi development are likely to be small. This, combined with the low numbers of juvenile and large adult pipis (likely to be a reproductive source) found in the region, suggest that the risk of an overall effect on pipi populations in the region is also likely to be quite small.

Mapping habitats along the coast of Encounter Bay

A habitat mapping exercise was undertaken offshore in Encounter Bay in the vicinity of the proposed outfall (Rowling *et al.* 2009). This was done primarily to ground-truth previous work (Haig *et al*. 2006) that had been done at a broader scale in the region that suggested that the predominant habitat was bare sand, which was likely to be of little ecological significance compared to other habitats located further along the coast.

Prior to the study, it was felt that the high energy coastline and the constant movement of sand in the region, along the longest & highest energy beach in Australia (Short & Woodroffe 2009) were likely to prevent the establishment of many sessile species that may form the basis of complex benthic assemblages (e.g. seagrasses). However, some complex reef habitats had been noted further along the coastline, which were likely to support more diverse communities that may include EPBC-listed taxa. List searches suggested that EPBC-listed taxa possibly in the region included a number of pipefish (Family: Syngnathidae) as well as some marine mammals, most of which (the syngnathids in particular) were only likely to occur in complex and vegetated habitats such as reefs and seagrass beds. In addition to the EPBC-listed taxa, species of commercial interest were also noted that may be present within the region (e.g. abalone *Haliotis* spp., southern rock lobster *Jasus edwardsii*, pipis and mulloway *Argyrosomus hololepidotus;* now renamed *A. japonicus*).

Habitat mapping was undertaken using a transect approach. The number of transects undertaken was not specified, but appeared from the various figures presented to be approximately 18. The exact number undertaken is not crucial, provided overlap of the swathes was achieved (but again, this was not specified). Transects were 2 km in length. Swathe bathymetry was taken on each transect, with remote video ground-truthing undertaken on two transects and benthic grabs and beam trawls undertaken for infauna and epibiota on three transects. The transects were arranged so that the proposed outfall was in the middle of the set surveyed.

Video ground-truthing was done using five drops of 40 to 100 m along each two kilometre transect. Sampling for infauna and epibiota were done using three grab samples per transect as close to the shore as possible, with contents sieved through 1-mm mesh, and three tows per transect using the trawl which were also taken as close to the shore as possible. The locations of the samples in this manner means that they were not sampled randomly and may be spatially auto-correlated, which as implications for the inference that can be drawn from the results (i.e. they cannot automatically be generalised to the wider region).

Habitat mapping showed that the areas surrounding the proposed outfall location were entirely comprised of soft sediments. Some relief was evident and finer sediments were found to the north of the transect grid. The depths at each transect were only vaguely specified (i.e. one given per transect) and ranged from 9 to 20 m, according to Appendix 1. However, weather conditions prevented surveying particularly close to the short (which was not unexpected given the high energy nature of the coastline). Video ground-truthing exposed no reef or seagrass habitat within the area.

Surveys of infauna revealed that pipis (*Donax deltoides*) were the most abundant taxon. The distribution of worms in the samples was quite patchy, but the dominance of pipis is as we would expect. Total abundance appeared to increase with distance south along the transect grid (across three transects), with the northernmost transect having a statistically-distinct infaunal assemblage compared with the transect located near the proposed outfall and the southernmost transect. Variability between the three transects was high. The major difference between the transects appeared to be that the two southern transects were characterised by pipis, in addition to the crustaceans that also characterised the northern transect. However, no statistical testing was undertaken on these differences, and the choice of division between the northern and the two southern transects appeared arbitrary (i.e. a case could also be made to split all three transects based on the presented results).

A similar trend was observed for epibiota, as measured using the trawl samples, but again there was no statistical testing of these differences undertaken. Prickly toadfish (*Contusus brevicaudus*) was easily the most abundant taxon. The most widespread taxon was the sand crab (*Ovalipes australiensis*), which was caught in all nine trawls conducted. No EPBC-listed species were recovered from the trawl samples. Prickly toadfish, ornate cowfish (*Aracana ornata*) and sand crab characterised the epibiota, with the addition of pipis in the southern transects. Significant differences were also recorded between trawls that were towed towards the shore compared with those that were towed away from shore.

Weather restrictions meant that tows all sampling was conducted approximately 2 km offshore, at a minimum. Thus, the inshore region and shallower depths remained unsampled. However, the high-energy swash zone that persists for the majority of the year inshore of that point means that any more complex biogenic habitat in that zone is unlikely. Surveys of the beach and intertidal zones (Gorman *et al.* 2009; P Fairweather, unpublished data) also failed to find evidence of more-complex habitats or more-diverse communities in the swash or near-shore zone (although again, much of the swash remained unsampled).

The significant difference in epibiota collected on shore-ward trawls when compared to those collected ocean-ward was not discussed in the report. Given that three trawls were completed on each transect, and explicit information was provided as to the direction that was sampled twice in each instance and whether this was consistent between transects (although the positional information presented in Appendix 1 suggests that trawls were consistently aligned between transects), this difference has the potential to confound results at larger spatial scales (i.e. between transects). This difference suggests that the sampled assemblages must have been affected by some artefact (e.g. mismatched depths between trawls, the dredge scaring off nekton or some other idiosyncrasy of the sampling process), rather than a true difference in biotic assemblages. The general absence of threatened taxa that are likely to be significantly adversely affected means that this methodological artefact is unlikely to affect the conclusions of the study as a whole, but should additional sampling be undertaken (e.g. as part of a monitoring program), or smaller-scale differences be of interest, then determining the reason for this difference may be of value.

Overall, no habitats or biota were discovered that were unique to the region surrounding the outfall. The prevailing habitat (un-vegetated soft sediments) is very common along that coastline, tends to have quite low biotic diversity and tends not to support species of particular conservation value. Thus, there is no indication that the proposed outfall is likely to adversely affect the ecological diversity of the wider region based on these findings.

Discussion of these findings, especially of additional monitoring that is needed

Overall, the impression that is gained from reviewing the studies that have been undertaken to date into the likely effect of the outfall on the receiving environments of Encounter Bay is that the studies have been undertaken in a very short space of time. They seem very much to be quite preliminary assessments that were needed to provide relatively immediate information into any potential major issues associated with the outfall. As a result, the methods that have been used (the level of replication and the time frames over which studies have occurred, in particular) are not always ideal. For example, each study is a snapshot with a single sampling trip (or experiment) so it is not possible to infer seasonal or temporal differences from this work. Thus, our ability to draw detailed conclusions on the basis of these surveys is limited. However, many of these limitations were unavoidable in the circumstances under which the studies were undertaken and, in the context of this synthesis report, some relevant conclusions can still be drawn. The aim of this report was to identify whether any evidence existed that the proposed outfall would have a significant deleterious effect on the ecology of Encounter Bay, and the preliminary reports available do provide information on this score.

Based on the surveys reviewed here, we have not identified a likely source of significant ecological damage to the receiving environments of Encounter Bay. This should be interpreted with the caveat that very little data exist on the ecological communities of Encounter Bay in general, and its intertidal and beach communities, in particular. This is obvious from the lack of previous studies that have been included in the documents reviewed, and suggests a gap in the monitoring programs undertaken in the region. However, it is significant that the two previous studies conducted in the region, of which we are aware, have not been referred to by the authors of relevant studies reviewed here (e.g. McLachlan *et al.* 1996; Morcom *et al*. 2009; P. Fairweather, unpublished data).

Given this low level of basic understanding of ecological communities in the region, and the preliminary nature of the studies undertaken, we have taken a cautious approach to interpreting the data presented. Thus, we have considered whether the conclusions relating to likely ecological damage would change if findings were an order of magnitude different from the true value in local populations.

Hydrodynamic modelling indicated that salinities of greater than 1 ppt in excess of background salinities (35-36 ppt; thus +1 ppt is 37 ppt) were unlikely to extend beyond a 3-km radius from the outfall location, and that the worst case conditions leading to plumes of this extent were likely to persist less than 1% of the time. This concentration of salinity did not produce any disruptions to larval development in pipis (the only taxon for which toxicity testing was done). In addition, this level of variability is likely to be experienced over many years by near-shore communities (although usually towards lower salinities) as a result of large variability in the magnitude of flows from the River Murray through the Murray Mouth, suggesting that near-shore communities in this region are likely to be adapted to dealing with variable salinities. Even if the findings of the pipi toxicity testing has underestimated, the impact of high salinities on development (such that 37 ppt was likely to inhibit development), and the hydrodynamic modelling were also out by an order of magnitude and the plume was actually to occur 10% of the time (or over 30 km for 1% of the time), the continuous spawning of pipis throughout the year (King 1985; Murray-Jones & Steffe 2000; Ferguson & Mayfield 2006), suggests that such short-term disruption would not be sufficient to affect the population as a whole.

Furthermore, plumes with concentrations known to be high enough to inhibit development (i.e. > 45 ~ 45 ppt) were of such a limited extent (~ 750 m as a maximum) that should these occur an order of magnitude more frequently (thus 10% of the time) or over a greater area (thus 88 km^2, based on a semicircle with a radius of 7.5 km), this is also likely to still be insufficient to affect the population as a whole over the three-year life-span of the pumping proposal due to the extent of similar habitat in the region and the still-short duration of the severe impact.

Considering pipis, the adult population in the vicinity of the outfall was recorded as approximately 5% of that found in the commercial fishery. Thus, even an increase of an order of magnitude would place densities at around 50% of those observed in the commercial fishery. While this would be more significant, it is still unlikely to represent a major threat to the local population. This relatively-small population is unlikely to be acting as a recruitment source for the rest of the region, particularly when the relatively small size and durations of those plumes likely to inhibit pipi reproduction are considered. If such a source population did exist along the southern Coorong beach, it is unlikely to be confined to the small extent (in space and time) that would be affected by the outfall. If the area affected has been underestimated then the low density of pipis still implies that not much damage would be done by the outfall to the total population in this region. However, additional monitoring of larval and juvenile pipis, with additional replication at small scales, may be necessary to ensure that this is not the case.

Surveys for other taxa in the region suggest that the area around the outfall does not contain a particularly diverse faunal or floral assemblage. No EPBC-listed taxa were recorded in the region either. These findings were consistent across habitat mapping, subtidal and beach infaunal surveys and cockle-specific surveys. Searches for EPBC-listed taxa that were potentially in the region, however, highlighted a long list of taxa, some of which are only likely to be present seasonally, or in associations with suitable habitat (e.g. syngnathids are associated with reef and seagrass habitats, not un-vegetated bare sand). Therefore, one-off surveys, of the kind undertaken in the studies reviewed here, are unlikely to detect the full suite of taxa, potentially including some EPBC-listed taxa, in the region. But, given the small area of likely impact, the lack of understanding of whether threatened taxa do use the region is not considered sufficient to warrant the delay of the proposed management action, particularly in light of the benefits identified for the Coorong and the urgency of the required action.

The intertidal survey reviewed here investigating beach infaunal communities (Gorman *et al.* 2009) is likely to have significantly undersampled the region (with only 315 cores totalling 0.37 m^3 sampled across all 21 sites and then only an unspecified volume of sediment as a subsample was actually sorted in the lab). Previous studies have recommended that volumes of 0.075 m^3 per beach zone are required to adequate represent infaunal sandy beach communities (Schlacher *et al.* 2008). For the number of sites surveyed here, with three beach zones, that would constitute a volume of 4.73 m^3, although it is likely that fewer sites, with a greater volume sampled per site would provide additional information for a similar level of effort.

Based on the little data that was presented within that report, it is possible to determine that an average of 0.16 organisms were collected per core taken. This is only 12% of the collection rate achieved over two years by Fairweather (unpublished data), where 1.32 organisms were collected on average per core (despite very similar core sizes) and 108 cores comprising 0.68 m^3 sampled despite only six sites being used. No comparisons were possible with the other previous study (McLachlan *et al.* 1996) based on the data presented, although would be possible using the original data sets. McLachlan *et al.* (1996) found 11 macrofaunal taxa on each of the Coorong and Goolwa Beaches (having sampled 1.13 m^3); based on this we would have expected to find more crustaceans (especially several amphipods), polychaetes in the genus *Nephtys*, and bivalves in the genus *Paphies*. It is possible that the intertidal biota during October 2009 was at a historical low due to being on the rebound from several incidents of storm disturbance (P. Fairweather, unpub. data). If that is the case then the abundance and richness of these infaunal assemblages is likely to be higher in coming years as recovery from disturbance ensues. Such comparisons are difficult because the abundances are not presented in the reports (we would recommend the data display used in McLachlan *et al.* 1996) and the lab-based sorting methods seem to have included meiofaunal nematodes that are normally omitted from most macrofaunal studies. Further comparisons could be drawn if the full data set were available to us.

Nevertheless infaunal communities are known to be highly variable in space, even at small spatial scales (i.e. within centimetres and metres), so undersampling is highly likely without considering the inherent variability in the community. Thus, we cannot draw any definitive conclusions from this work. However, the studies undertaken previously (McLachlan *et al.* 1996; P. Fairweather, unpublished data) do not identify any additional taxa that are likely to be more affected by the outfall than those that were identified by Gorman *et al.* (2009).

The preliminary work that was done to investigate the likely nutrient impacts in Encounter Bay suggested that high concentrations of phosphorus, chlorophyll *a* and turbidity, compared with the appropriate ANZECC guidelines, were likely as a result of the proposed pumping action. However, it is also stated that background nutrient levels are already high compared with (or exceeding) those guidelines. Thus it is likely that the local situation (e.g. the nearby upwelling zones) mean that the guidelines may be less applicable to this stretch of coastline than other regions within South Australia. In fact, it is likely that Encounter Bay has been receiving lower levels of flow-related nutrients, as a result of low and zero freshwater flows over the barrages and out of the Murray Mouth in recent years, which may be responsible for declining catches in the local pipi fishery over the past few years. Thus, the impact of these nutrients is likely to be complex, but not necessarily wholly-negative. Furthermore, both phosphorus and chlorophyll *a* concentrations tend to be highly buffered in marine environments, so there may be little overall impact anyway.

Of potentially greater concern are any other species or components found in the South Lagoon of the Coorong that may also be exported with the hypersaline water (e.g. any resident viruses). All constituents of the water are not likely to be killed during the pumping process, or necessarily as a result of the difference in salinity in the receiving waters. Thus we recommend advice be sought regarding any potential threats of this nature from researchers who have been studying microbial communities in the Coorong for several years (i.e. J. Mitchell and L. Seuront of Flinders University).

The snapshot nature of the studies undertaken mean that it is not possible to extrapolate the findings to describe seasonal or annual variability, nor to predict long-term sub-lethal effects that might accumulate as a result of the proposed pumping. Thus, we recommend concurrent monitoring in the marine environment to ensure that the proposal does not have unintended negative consequences. In particular, we recommend monitoring of larval and juvenile pipis (using methods specifically targeting these size classes, rather than adults), with associated water-quality monitoring so that any changes in density can be related to any changes in salinity or nutrients, for example, that may have occurred. We also recommend ongoing surveys, at seasonal intervals, to confirm the lack of EPBC-listed species in the region. We also recommend additional surveys of beach infaunal communities (i.e. not focused on pipi populations) to assess any broader impacts over time. For those species that are more likely to be affected (e.g. hooded plover, southern right whale), this could well be achieved by collaborations with independent researchers or governmental managers already monitoring their populations within the region, rather than by designing entirely new studies. In this way, the impact of the management action will be documented and any unexpected impacts detected quickly. This would allow management actions to be modified as required to minimise any such impacts on the marine environment.

Conclusions

The studies that have been reviewed here present very little or no evidence of likely ecological damage to the receiving waters of Encounter Bay as a result of the proposed pumping of hypersaline water from the South Lagoon of the Coorong. While the studies have been done as one-off surveys (for the most part) and the methods are not always ideal, this should be considered in the context of the receiving environment. Encounter Bay is one of the highest-energy coastlines in Australia (Short and Woodroffe 2009). Conditions experienced during habitat mapping attempts where surveys were restricted to 2 km offshore (and hence waters deeper than 8 m) due to rough seas, are the norm for this region rather than the exception. Highly variable flows, and their associated nutrient inputs, from the River Murray are again the norm for the region, with the ecological communities of Encounter Bay likely to be adapted to deal with this variability and level of disturbance. While it is true that prolonged drought and a lack of freshwater flows and nutrient inputs may have stressed Encounter Bay ecosystems over the past few years (e.g. declining catches in the pipi fishery over the last 2 years), there is nothing in these studies that suggests that pumping hypersaline water from the South Lagoon of the Coorong to Encounter Bay is at risk of causing significant further ecological damage to the receiving environment. Thus, given the current parlous state of the South Lagoon ecosystems, and predicted benefits arising for those ecosystems, there appear to be substantially greater benefits arising from the proposal than negative impacts.

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