

Enquiries: Jane O'Malley
Our Ref: 0123_2017_0921
Your Ref: DWERA-000183



26 September 2017

Dr Tom Hatton
Chairman
Environmental Protection Authority
Locked Bag 33, Cloisters Square
PERTH WA 6850

Dear Dr Hatton

Comment regarding the change to condition to extend the time limit of authorisation for the Point Grey Marina Proposal

The Peel-Harvey Catchment Council Inc. (PHCC) is opposed to the change to extend the Time Limit of Authorisation for substantial commencement for implementation of the Point Grey Marina proposal, including the proposed navigation channel across the northern end of the Harvey Estuary.

Here we present information regarding deterioration in the environmental condition of the Peel-Harvey Estuary and implications of implementation of the proposal to contribute to further deterioration in the condition of the estuary that have emerged since the proposal was previously considered by the WA Government Environmental Protection Authority in 2011. These are described in Attachments 1 to 4, but in summary we believe the key issues are:

- Research completed in 2012 by Bush et al. (ARC-Linkage Project LP0991658 *Hyper-accumulations of monosulfidic sediments: Exploring a biogeochemical extreme to resolve fundamental sulfur biomineralisation pathways*) and several publications by Morgan and others (Morgan 2012; Morgan, Burton and Rate 2012; Morgan, Rate, Burton and Smirk 2012 and Morgan Rate and Burton 2012) revealed that sediments in the Peel-Harvey Estuary contain high concentrations of acid volatile sulfides (AVS). These are indicative of monosulfidic black ooze (MBOs), which release nutrients into, and lead to localized deoxygenation of, the water column, especially upon disturbance. **This new information showed that AVS is widespread throughout the estuary, including in the Harvey Estuary, and present in concentrations several times that observed in estuaries elsewhere.**
- The ARC-Linkage project LP0991658 (Bush et al. 2012) also gave new insights into MBOs, linking their formation to fine-grained sediment, and observing their reactivity on disturbance, releasing nutrients and potentially toxic sulfides into the water column. This work identified several management implications of disturbance of these sediments through dredging operations, including ***“The mobilization of fine sediments as a result of dredging will cause MBOs materials to oxidise and release associated contaminants. Current hazards associated with the mobilization of these sediments are poorly defined. A clear understanding of these hazards will improve the environmental assessment and management of MBOs in areas of dredging and dredge disposal.”***

58 Sutton Street, Mandurah
Western Australia 6210
T: +61 8 6369 8800

www.peel-harvey.org.au

*We acknowledge the Noongar people as Traditional Custodians
of this land and pay our respects to all Elders past and present*

- Bush et al. (2012) and later Choppala et al. 2017 observed that the estuarine sediments also contain high concentrations of iron pyrite (FeS₂) which are unusually highly reactive upon disturbance, are implicated in nutrient release into the water column and also contribute to the deterioration of the environment through smothering biological surfaces, deteriorating food sources and the quality of benthic habitats through formation of iron (III). **Disturbance of these sulfidic materials through construction, operation and maintenance of the marina development therefore present a threat to the marine environment that was not previously considered in the original assessment.**
- Estuarine water quality over the period 2012-2016, in particular concentrations of dissolved nitrogen and dissolved oxygen and salinity, does not meet the Limits of Acceptable Change (LACs) as described by Hale and Butcher (2007) for the Peel-Harvey Estuary. **The new understanding of the threat of nutrient release from disturbance of sulfidic material during construction and maintenance of the proposed marina indicates that implementation of the proposal is likely to exacerbate the poor water quality.**
- The concentrations of total phosphorus and (dissolved) phosphate in the estuarine portions of the Murray and Serpentine Rivers also do not meet the LACs for the estuary.
- New data collected since the initial assessment of the proposal in 2011 shows that three of the LACs were not met for waterbirds in the Peel-Yalgorup System (PYS) Ramsar Site. Further, since 2012, the list of vulnerable, endangered and critically endangered species has expanded to include six species for which the PYS provides critical habitat. An assessment of the 11 species against which the Site met Criterion 6 for Ramsar listing shows that in the past five years only one species has reached the population threshold every year and four of the 11 species have not reached the threshold in any year. **Implementation of the proposed marina is an additional disturbance to bird habitat, foraging and reproductive behavior and thereby poses a threat to the international recognition of the PYS as a Ramsar site.**
- In 2016, the Peel-Harvey Estuarine Fishery was certified as sustainable by the Marine Stewardship Council (MSC). This certification involved development and adoption of Harvest Strategies for the target species of blue swimmer crabs and sea mullet, based on catch data from the period 2000/01 to 2011/12 inclusive. Implementation of the Point Grey proposal poses a risk to the condition of the Peel-Harvey Estuary through declining sediment and water quality. **The effect of this potential habitat degradation on catches of benthic feeders such as blue swimmer crabs and sea mullet has not been considered in setting the sustainable catch through the respective harvest strategies. Any change in the benthic environment likely to affect the abundance and distribution of these species and their prey, including the dredging operations and accumulation of MBOs through implementation of the proposed marina, may have serious implications on the MSC certification and the sustainability of the commercial and recreational fishery. Implementation of the proposal thereby has the potential to cause the closure of the recreational and/or commercial fishery due to factors other than fishing pressure, or alternatively places the MSC certification of the fishery at risk.**
- In 2013, the Commonwealth Government Minister for Environment, Heritage and Water listed the *Subtropical and Temperate Coastal Salt Marsh Ecological Community* as a threatened ecological community (TEC) in the vulnerable category. These marshes occur as fringing vegetation to the Peel-Harvey Estuary, including in the embayments of the Peel-Harvey estuary in

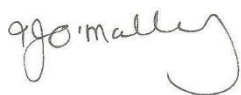
the vicinity of the proposed marina. The *Conservation Advice* notes that “population growth and development in the coastal zone ... continue to exacerbate all threats to the ecological community”. The proposed marina represents a coastal development, identified as a factor in exacerbating the threats to the TEC according to the *Conservation Advice* accompanying the listing. Dispersal of sulfidic materials (MBOs and pyrite) disturbed during construction, operation and maintenance of the proposed marina and navigation channel also present a threat to the samphire TEC. **The listing of this community as vulnerable since the initial assessment of the Point Grey Marina in 2011, and its occurrence in fringing vegetation near to the proposed site must be considered in a reassessment of the proposal. Samphire is also an important habitat for shorebirds for food and shelter.**

- The Tuart woodlands (*Eucalyptus gomphocephala*) are currently being considered for listing under the EPBC Act as a Threatened Ecological Community by the Threatened Species Scientific Committee. Ministerial advice is expected in late 2017 or early 2018. There are 82 tuart trees that will be destroyed through the development of the marina. **In January 2016 the Waroona/Yarloop bushfire destroyed a large portion of tuart habitat across private land, State Forest and Yalgorup National Park. The endangered Carnaby’s Cockatoos are known to nest in Tuart woodlands and so with the loss of trees due to the bushfires, it is likely that the importance of the tuart trees at Point Grey for foraging and nesting has increased significantly since the initial assessment.** Implementation of the marina proposal will in turn enable the terrestrial subdivision of the remainder of Point Grey. **This will mean the loss of a significantly larger number of tuart trees than the 82 that will be destroyed by the marina.**
- The Precautionary Principle should be applied to this assessment of the environmental condition of the estuary with respect to the Point Grey Marina proposal. The absence of new information regarding some indicators of the current condition of the estuary should not be interpreted to mean that environmental conditions have not deteriorated since the initial assessment of the proposal.

Based on this information, we reiterate our recommendation that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Should you require further information, please do not hesitate to contact Jane O’Malley on (08) 6369 8800 or email admin@peel-harvey.org.au.

Yours sincerely



Jane O’Malley
Chief Executive Officer

Enclosed:

Attach 1: Evidence of potential decline in environmental health of the Peel-Harvey estuary since 2011

Attach 2: ARC-Linkage Project Update May 2012 (LP0991658 – Bush et al. 2012)

Attach 3: Water quality and phytoplankton data collected from the Peel-Harvey Estuary 2012-2016 (DoW, 2017) compared against Limits of Acceptable Change (LACs) for the Peel-Yalgorup System (Hale and Butcher 2007) and trigger values from the ANZECC and ARMCANZ Guidelines (2000).

Attach 4: Shorebird data collected from the Peel-Yalgorup System 2008-2016 compared with Limits of Acceptable Change (Hale and Butcher 2007)

Attachment 1: Evidence of potential decline in environmental health of the Peel-Harvey estuary since 2011

In applying the *Statement of Environmental Principles, Factors and Objectives (EPA 2016)*, the EPA has identified the following key environmental factors relevant to the proposal:

- Marine Environmental Quality;
- Marine Fauna;
- Flora and vegetation;
- Terrestrial fauna.

In the following, we present evidence showing a potential decline in the environmental health of the estuary since 2012 according to these factors and the implications of this new information for implementing the Point Grey Marina proposal.

Marine Environmental Quality

Sediment Quality

Data/Findings

The sediments of the Peel-Harvey estuary contain high concentrations of monosulfidic black oozes (MBOs) which have the potential for degradation of benthic habitat and water quality. Photographs showing examples of accumulations of these MBOs in the Peel-Harvey Estuary System (PHES) are shown in Figure 1.

Since the consideration of the Point Grey Marina proposal in 2011, Morgan (2012) has published her Ph.D. thesis investigating the formation of MBOs in the PHES. In Chapter Two of this thesis (also published as Morgan, Burton and Rate 2012), concentrations of acid volatile sulfide (AVS) ranging from 34 to 335 $\mu\text{mol/g}$ were reported in sediments collected from six sites in and around the South Yunderup channel, a frequently dredged boating entrance to the South Yunderup residential canals. AVS concentration is a measure of, and a proxy for, iron monosulfides in the sediment, a major component of MBOs. Morgan (2012, p 26) noted that these concentrations were anomalously high compared with other studies of estuarine systems which are generally present at less than 100 $\mu\text{mol/g}$ AVS.

Chapter 3 of Morgan 2012 (also published as Morgan et al. 2012) presents AVS concentrations from sediment samples collected from 20 sites at various locations around the Peel-Harvey Estuary and estuarine portions of the Murray and Serpentine Rivers (i.e. the PHES). Median concentrations of replicates from each site ranged from 16 $\mu\text{mol/g}$ to 614 $\mu\text{mol/g}$, indicating that the MBOs are widespread across the PHES.

Results from a laboratory trial (Chapter 5) show that as macroalgae decompose, the nutrients ammonium (NH_4^+) and phosphate (PO_4^{3-}) are released back into monosulfide-rich PHES sediments. This cycling and subsequent release of nutrients from the sediment leads to the stimulation of further algal growth. Thus, the sulfide rich sediments of the PHES drive an internal regeneration of macroalgae. **Morgan (2012) concluded that this may be a greater environmental concern than the release of metals and deoxygenation which occurs upon disturbance of these sediments.**



Figure 1: Photographs showing monosulfidic black ooze in the Peel-Harvey Estuary System. Note the depth of the ooze in the upper photograph (Photographs courtesy R.Bush 2013).

Chapter 6 of Morgan (2012) (also published as Morgan, Rate and Burton (2012)), reports on the water chemistry and nutrient release during the resuspension of MBOs collected from the PHES in the laboratory and in-situ in the estuary during dredging operations. In summary, the resuspension of MBOs resulted in:

- rapid deoxygenation of the water column in the laboratory which was not observed during dredging
- a decrease in (water) pH in the laboratory, not observed during dredging operations presumably due to the buffering capacity of the estuary
- releases of dissolved ammonium (NH_4^+) and phosphate (PO_4^{3-}) in both the laboratory and field

The high concentrations of MBOs and nutrient cycling behavior of sediments from the PHES were also observed in the ARC-Linkage Project LP0991658 *Hyper-accumulations of monosulfidic sediments: Exploring a biogeochemical extreme to resolve fundamental sulfur biomineralisation pathways* led by Dr Richard Bush from Southern Cross University from 2009-2012. Relevant peer-reviewed publications from this study include Kraal, Burton and Bush (2013), Kraal et al. (2013), Kraal et al, (2015) and Lockhart et al (2013).

The key findings of this study and the management implications are summarized in the project update from May 2012 shown in Attachment 2. In particular, Findings 1 to 4 inclusive and Findings 6 to 9 inclusive and the associated management implications highlight:

- that favourable conditions for MBO formation and accumulation exist in the Peel-Harvey Estuary system, especially around deeper sinkholes and troughs (e.g. navigation channels)
- that MBOS are prone to scouring and resuspension
- the mobilization of fine sediments from dredging activities will cause MBO materials to oxidise and release associated contaminants
- that activities that change the benthic sediment chemistry will have a direct impact on nutrient supply and the potential to trigger cycles of algal blooms
- MBOs are impacting water quality continually as a result of minor disturbances, such as recreational boating.

Finding 5 states that the coarser sediments with lower monosulfide content have high concentrations of pyrite (FeS_2), another major potential source of acidity and water column deoxygenation. These materials should be a key aspect of environmental impact assessments for developments involving benthic disturbance.

In a more recent study, Choppala et al. (2017) reported that in addition to the very rapid oxidation of monosulfides, unusually high rates of pyrite oxidation were also observed upon disturbance of sediments from the Peel-Harvey Estuary System, most likely due to the presence of very fine nanocrystals of FeS_2 . The investigators also concluded that *“No significant release of trace metals was observed during resuspension of sulfidic sediments. However, disturbance to these estuarine sediments increases Fe(III) formation and further deteriorates the environment through smothering biological surfaces, deteriorating food sources and the quality of benthic habitats.”*

These findings were not considered during the initial assessment of this proposal.

Implications

The very high concentrations of MBOs (and pyrite), the greater extent of their occurrence in the PHES and the improved understanding of their tendency to rapidly form and accumulate, especially in channelized areas of the PHES are now acknowledged in the peer reviewed literature. Recent studies showing the unusually reactivity of pyrite and the potential for degradation of the benthic environment on disturbance also add to the understanding of the consequences of disturbing sediments in the PHES. With this greater understanding, it is apparent that the construction and maintenance of the proposed marina poses greater risks to the quality of the marine environment than when the proposal was considered in 2011.

It is clear that the disposal of dredge spoil from the initial construction of the proposed marina and navigation channel and the on-going maintenance dredging of the channel poses a greater management problem for the managers of the estuary than considered in the initial assessment.

It is also likely that the tidal current associated with the Dawesville Channel (up to 12 knots) will cause the mobilisation of accumulated MBOs from within the proposed new navigation channel leading to oxidisation and the release of associated contaminants. Current hazards associated with the mobilisation of these sediment are not understood.

Both on shore and in-estuary disposal of dredge spoil involve a significant footprint for treatment and disposal of the MBOs. In-estuary disposal involves covering of the estuary floor elsewhere and even with careful site selection and monitoring the risk of smothering of the benthic flora and fauna remains. Relocating the spoil and associated MBOs elsewhere in the estuary does not reduce the risk of future resuspension and mobilization. On-shore treatment and disposal needs to be carefully managed to reduce the risk of acid sulfate drainage on aquatic and terrestrial environments.

Based on this new information, implementation of the proposal will exacerbate the poor sediment quality and lead to a deterioration in water quality in the PHES. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not be extended.

Water Quality

Consistent with the obligations under the Ramsar Convention, the Ecological Character of the Peel-Yalgorup System was described by Hale and Butcher (2007) as part of the process of developing the Management Plan (PHCC 2009) for the Ramsar-listed Peel-Yalgorup System (PYS), a wetland of international importance. Based on the Ecological Character Description (Hale and Butcher 2007), and given the limited resources generally made available for monitoring, a monitoring and evaluation program was developed (Hale 2008) for the Ramsar Site Management Plan, to set a baseline for the critical components and processes of the system against which changes in the character of the system may be assessed. Limits of Acceptable Change (LACs) were identified and threshold values set (in some cases upper and lower). A LAC is defined as “a variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed’ (Hale and Butcher 2007, p.10). To date a lack of resources have meant only certain elements of the 12-program monitoring guide have been implemented. A precautionary approach

needs to be taken as direct and cumulative impacts on the Ecological Character are not been monitored.

In March 2017 the Peel-Yalgorup System Ramsar Technical Advisory Group (TAG) met to consider information and monitoring data gathered regarding the current status of the system according to the monitoring guide and the LACs. These considerations form an initial framework for the assessment of the condition of the PYS Ramsar site (see Attachments 3 and 4).

Estuarine water quality and phytoplankton are two components for which sufficient data existed to enable LACs to be set in 2007. The results of the 2017 comparison with the LACs are summarised in Attachment 3, with a precis and discussion of the relevance to the Point Grey Marina proposal presented below.

Water Quality A & Phytoplankton: Peel-Harvey Estuary

Data / Findings

The (then) Department of Water monitors estuarine water quality and phytoplankton through water sampling and analysis. Phytoplankton and in-situ measurements of physical variables (e.g. pH, dissolved oxygen, electrical conductivity) are measured fortnightly. Nutrient concentrations were not monitored in the Peel-Harvey Estuary between September 2013 and June 2016, due to a lack of resources, but are now monitored monthly. Some monitoring sites are located outside of the PYS Ramsar site boundaries but within the estuarine portions of the Murray River and Serpentine River that drain into the estuary. Water quality parameters provided by the Department of Water for the period 2012-2016 were compared against both the LACs and trigger values from the ANZECC and ARMCANZ (2000) Guidelines (i.e. the ANZECC Guidelines) where available.

For the period 2012 to 2016 inclusive, the LACs were NOT MET for:

- ammonium and oxidized nitrogen concentrations in the estuary and estuarine portions of the Serpentine River and Murray River
- total phosphorus and phosphate concentrations in surface and bottom waters of the estuarine portion of the Serpentine and Murray Rivers, although the LACs were met for the Peel Inlet and Harvey Estuary.
- salinity at the mouth of the Harvey Estuary during winter
- salinity in the Peel Inlet and Harvey estuary in 2012, 2013 and 2015
- chlorophyll a in the Serpentine River during autumn
- dissolved oxygen in bottom waters of the Murray River

Implications

These exceedances of LACs indicate that the system is currently under significant stress. As described in the section on sediment quality above, nutrient release (in particular ammonium and oxidised nitrogen) and depletion of dissolved oxygen are associated with disturbance of MBOs during dredging operations, in-estuary disposal of dredge spoil and disturbance by boating activities associated with the construction and use of the proposed marina and channel. These activities are likely to exacerbate the current poor condition of the estuary.

The proposed navigation channel is also likely to affect the hydrodynamics of the estuary. It is not known what impact this would have on salinity which fails to meet the LAC for the Ramsar site. A current ARC-Linkage Project (LP150100451 *Balancing estuarine and societal health in a changing environment*) led by Murdoch University is developing a hydrodynamic model of the PHES which could be used to investigate the impact. This model might also be used to predict sediment dispersal and the effect of climate change on estuarine water quality and hydrodynamics in the context of the proposed marina and navigation channel.

To our knowledge, the comparison of measured water quality and phytoplankton against the LACS shown in Attachment 3 has not been made previously and so was not considered at the time of the initial approval. Based on this new information, implementation of the proposal will exacerbate the poor water quality in the PHES. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Marine Fauna

Waterbirds

Comparison with LACs

In addition to considering water quality, in March 2017 the PYS Ramsar TAG also considered observed data for shorebirds. The annual Shorebird 2020 count is held in early February each year. A summary of observations by PHCC of various shorebirds drawn from this dataset 2008-2016 inclusive compared with the LACs for the system is shown in Attachment 3.

Three of the indicators were outside the range of the LACs indicating the system is under stress:

- Sharp-tailed Sandpipers only exceeded 1% threshold of the Flyway populations based on the 5th Edition of the World Population Estimates (Wetlands International, 2012) in 2009, 2010 and 2014 i.e. three out of nine years rather than the minimum of three years out of five years.
- The nests of Little Black and Little Pied Cormorants declined during the period 2008-2016
- The number of Little Pied Cormorant eggs had declined from a low base level.

Performance against Ramsar Criterion 6

Table 1 shows the abundances of the 11 species of shorebird for which the Peel-Harvey Estuary portion of the Ramsar site meets Criterion 6 for Ramsar listing i.e. that "A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird". When compared with the 1% of the World Population Estimate, only one of these species met Criterion 6 in each year 2012-2017. Of the other 10 species, four did not meet Criterion 6 in any year and another three in only one year 2012-2017.

Table 1: Abundances of 11 shorebird species observed from the annual Shorebird 2020 Count in the Peel-Yalgorup Ramsar System from 2012 to 2017 inclusive compared with the 1% of the World Population Estimate (1% of WPE, 2012) for each. Note the 1% WPE data was sourced from [Wetlands International \(2017\)](#) and abundance data sourced from PHCC's analysis of the Peel-Yalgorup System's annual Shorebird 2020 Counts undertaken in partnership with Birdlife Australia each February.

Note that the 11 species are those that met Criterion 6 for Ramsar listing of the Peel-Harvey Estuarine portion of the wetland system. Cells highlighted in red indicate instances where the observed number fails to exceed the 1% threshold.

Species	Abundance for Peel-Yalgorup System (Shorebird 2020 Count)						1% WPE (2012)
	2012	2013	2014	2015	2016	2017	
Australasian Shoveler	0	50	484	1	0	2	250
Banded Stilts	1	39202	856	7468	462	200	3700
Curlew Sandpiper	0	12	31	20	6	11	1400
Eurasian Coot	28	109	127	35	27	3	10000
Fairy Tern	105	51	243	307	181	45	120
Grey Teal	1335	9403	6103	4179	112	627	20000
Musk Duck	13	318	186	134	31	9	250
Red-Capped Plover	659	1452	1238	1224	1067	812	950
Red-necked Avocets	36	316	590	428	2	197	1100
Red-necked Stint	4511	4330	4344	5077	4468	5974	3200
Sharp-tailed Sandpiper	257	1583	3550	1365	1390	721	1600

New EPBC Act listings

In May 2015 both the Eastern Curlew (*Numenius madagascariensis*) and the Curlew Sandpiper, (*Calidris ferruginea*) were listed under the Australian Government EPBC Act as Critically Endangered. The Peel Inlet and Harvey Estuary provide habitat to both these species of migratory birds. The Curlew Sandpiper is one of the 14 species of birds through which the PYS meets Ramsar listing Criterion 6 for Waterbirds. The 1% population threshold for Curlew Sandpipers has been set at 1800 for the Peel-Harvey Estuary.

Since the initial assessment in 2011 the following four species of migratory shorebirds have been listed (on 5th May 2016) as threatened species that should be observed in the PYS Ramsar site (S. Vine (Birdlife Australia) 2017, personal communication, 31 August).

- *Calidris tenuirostris* (Great Knot) Critically Endangered
- *Calidris canutus* (Red Knot) Endangered
- *Charadrius leschenaultii* (Greater Sand Plover), Vulnerable
- *Limosa lapponica menzbieri* (Bar-tailed Godwit (northern Siberian)), Critically Endangered

Further to the Fairy Tern being placed on the IUCN Red List in March 2011, these 2015 and 2016 listings of vulnerable, endangered and critically endangered bird species mean that the Ramsar site now qualifies against Ramsar Criterion 2, "that a wetland should be considered internationally important if it supports vulnerable, endangered or critically endangered species (or threatened ecological communities)".

Implications

The PYS is recognised by the Ramsar Convention as a wetland of international importance. Three of the seven criteria on which this listing is based relate directly to the Peel-Harvey Estuary and are dependent on the wetland sustaining populations (Criterion 5: >20,000 in total annually; and Criterion 6: at least 1% of the world's population of 11 species) of various species of migratory birds and shorebirds at critical times in their life cycles (Criterion 4).

New data collected since the initial assessment of the proposal in 2011 shows that three of the LACs were not met for waterbirds in the PYS. Further, since 2012, the list of vulnerable, endangered and critically endangered species has expanded to include six species for which PYS provides critical habitat. An assessment of the 11 species against which the Site meet Criterion 6 shows that in the past five years only one species has reached the population threshold every year and four of the 11 species have not reached the threshold in any year.

Implementation of the proposed marina is an additional disturbance to bird habitat, foraging and reproductive behavior and thereby poses a threat to the international recognition of the PYS as a Ramsar site. During construction, maintenance (dredging) and on-going use of the proposed marina facilities (and the terrestrial development that the marina will enable), there is a high risk of boats and humans disturbing bird behavior and preventing them from feeding, disturbance and loss of habitat (e.g. samphire and mudflats) as well as loss of habitat for benthic fauna upon which some birds prey. This is particularly important for migratory birds, including the six species recently placed on the EPBC threatened migratory species list, to re-fuel for their return journey to the northern hemisphere.

We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Benthic invertebrates

Data

In a study of benthic macroinvertebrate fauna, Wildsmith et al. (2009), investigated four sites in the PHES, including one at Point Grey. This study showed pronounced declines in benthic invertebrate fauna from the mid-1980s to mid-2000s in the PHES, with major reductions in diversity and density. Crustacea, the most sensitive of the taxa to environmental stress has become proportionally less abundant and represented by fewer species leading Wildsmith to conclude that the benthos of the Peel-Harvey Estuary is apparently more stressed than previously, probably due to the effects of a greater increase in system use. Although this paper predates the initial assessment, we believe that the original assessment did not adequately consider the risk to benthic fauna and the benthic flora.

Similar rigorous studies of the benthic fauna of the Peel-Harvey Estuary System have not been undertaken since the work of Wildsmith (2009), however the above-mentioned ARC-Linkage Project (LP150100451 *Balancing estuarine and societal health in a changing environment*) aims to replicate this work at more sites (>100) spread more widely across the Peel-Harvey Estuary System as well as develop an index of ecosystem health based on benthic invertebrates and investigate the effects of perturbation (e.g. dredging operations) on benthic invertebrates, commencing late 2017.

Fish

Data

As part of a \$14.5 Million initiative by the State Government to gain third-party assessment of sustainability in its managed fisheries, the Marine Stewardship Council (MSC) in June 2016 certified the Peel-Harvey Estuarine Fishery as sustainable for certain fishing methods for the target species of blue swimmer crabs and sea mullet. The certification is underpinned by Harvest Strategies for the Blue Swimmer Crab resource (Department of Fisheries, 2015a) and Finfish resources (Department of Fisheries, 2015b) of the Peel-Harvey Estuary. Each Harvest Strategy prescribes targets, limits and thresholds based on catch and catch rate data for the target species from both the recreational and commercial sectors, set from baseline data collected in 2001/02 – 2011/12 inclusive. Catches of by-catch and retained species (e.g. tailor, yellow-eye mullet, and whiting) are also considered in the Harvest Strategy for Finfish in assessing the sustainability of the estuarine fishery.

Control rules are set based on observed catch and catch rate against the targets, limits and thresholds. These control rules are linked to management actions to protect the sustainability of the fish stocks. For example, an exceedance of the limit may lead to closure of the recreational and/or commercial fisheries.

Implications

As described above, implementation of the Point Grey proposal poses a risk to the condition of the Peel-Harvey Estuary through declining sediment and water quality. The effect of this potential habitat degradation on catches of benthic feeders such as blue swimmer crabs and sea mullet has not been considered in setting the sustainable catch through the respective harvest strategies. **Implementation of the proposal thereby has the potential to cause the closure of the recreational and/or commercial fishery due to factors other than fishing pressure, or alternatively places the MSC certification of the fishery at risk. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.**

Flora and Vegetation

Salt Marsh (Samphire) Threatened Ecological Community

New information

In 2013, the Commonwealth Government Minister for Environment, Heritage and Water listed the *Subtropical and Temperate Coastal Salt Marsh Ecological Community* as a threatened ecological community (TEC) in the vulnerable category. These marshes occur as fringing vegetation to the Peel-Harvey estuary, including in the embayments of the Peel-Harvey estuary in the vicinity of the proposed marina. The *Conservation Advice* notes that “population growth and development in the coastal zone ... continue to exacerbate all threats to the ecological community”. These threats include *inter alia* clearing and fragmentation, recreation, eutrophication and acid sulfate soils, all of which are potential impacts of the proposed development.

Implications

Preliminary results from a survey of vegetation fringing the Ramsar wetlands undertaken by PHCC in Sep 2017/18 show the occurrence of samphire in the vicinity of the proposed marina development (R. Paice 2017, personal communication, 20 Sep.).

The proposed marina represents a coastal development, identified as a factor in exacerbating the threats to the TEC according to the Conservation Advice accompanying the listing. Dispersal of sulfidic materials (MBOs and pyrite) disturbed during construction, operation and maintenance of the proposed marina and navigation channel also present a threat to the samphire TEC.

The listing of this community as vulnerable since the initial assessment of the Point Grey Marina in 2011, and its occurrence in fringing vegetation near to the proposed site must be considered in a reassessment of the proposal. Samphire is also an important habitat for shorebirds and their prey. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Tuarts

New information

The Tuart woodlands (*Eucalyptus gomphocephala*) are currently being considered for listing under the EPBC Act as a Threatened Ecological Community by the Threatened Species Scientific Committee. Ministerial advice is expected in late 2017 or early 2018. There are 82 tuarts that will be destroyed through the development of the marina (RPS 2011 p.56). **In January 2016 the Waroona/Yarloop bushfire destroyed a large portion of tuart habitat across private land, State Forest and Yalgorup National Park.**

Implications

The *endangered* Carnaby's Cockatoos are known to nest in Tuart woodlands (e.g. at Lake Clifton, Biota 2006) and so with the loss of trees due to the bushfires, it is likely that the importance of the tuart trees at Point Grey for foraging and nesting has increased significantly since the initial assessment.

Implementation of the marina proposal will in turn enable the terrestrial subdivision of the remainder of Point Grey. While this submission is directly relevant to the proposal for the navigation channel and the marina only, their development is commercially interdependent with the development of the terrestrial subdivision and construction of Point Grey, and therefore this should be considered in respect to this assessment. Implementation of the terrestrial subdivision will mean a significantly larger number than the 82 tuarts associated with the marina development will be destroyed through clearing of 3.6 ha (canopy cover) of foraging habitat and 30.45 ha (canopy cover) of foraging and nesting trees in the *E. gomphocephala* vegetation unit. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Seagrass

New information

A survey of submerged aquatic vegetation coverage and diversity is proposed via the above-mentioned ARC-Linkage Project LP150100451 to be completed 2019/2020. A report by Pedretti *et al.* (2009) predates, but does not appear to have been considered in the 2011 assessment. The

report (p. 64) notes, “The distribution of seagrass had also altered; in 2009 the greatest densities of biomass occurred on the north eastern shoreline of the Harvey and in the areas around the Dawesville and Mandurah Channels.” In her PhD thesis Veale (2013) made the observation that habitat and/or food in the form of macroalgae or seagrass seems to have the most influence on the fish fauna of the Peel-Harvey Estuary.

Implications

The areas referred to by Pedretti et al (2009) will be directly impacted by the channel dredging. Noting that the navigation channel will be dredged to 4m, an assessment must be undertaken to determine the ability of the seagrasses to recolonise to this depth, after having been removed by their roots, and/or whether they can undertake such re-colonisation in benthic habitat that has rapidly accumulating sulfidic material (MBOs and pyrite) associated low oxygen levels.

We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

Terrestrial Fauna

See the discussion above regarding loss of Tuarts as habitat for Black Cockatoo.

Other considerations

Application of the Precautionary Principle

As discussed above, the PYS Ramsar TAG met in March 2017 to consider the condition of the Ramsar site with respect to the LACS. The dominating factor in these considerations was the lack of data. This was the case in 2007 when the Ecological Character Description of the Ramsar site was developed, and remains so in 2017. In 2007 there was insufficient data to even set baseline LACs for a number of the components and processes and this continues to be the case in 2017. Table 3 below summarises the knowledge gaps identified in 2007 by Hale and Butcher (2007) with respect to the monitoring and evaluation of the PHES that still exist and are relevant in 2017.

Table 2: Peel-Harvey Estuary Key Knowledge Gaps at 2007 still relevant in 2017 (adapted from Hale and Butcher 2007, p. 18):

Component / process	Knowledge Gap
Water Quality – Acid sulfate soils, MBOs and other sulfidic materials	The effect on water quality (pH and contaminant concentrations) is not known or understood
Aquatic Plants	Community composition, distribution and temporal patterns of seagrass and macroalgal communities within the estuary
Littoral vegetation	Current extent and condition of salt marsh vegetation
	Current extent and condition of paperbark communities
Fish	Current community composition and abundance of fish communities

Hale and Butcher (2007, p17) state, “Short-term limits of acceptable change (with a corresponding intensive monitoring program) have been set for measures for which change can be detected in the short term” (e.g. water quality). Conversely for other measures, for which change may take longer periods to detect, long-term limits were set. Finally the key biological components are considered. For most of these, quantitative LACs are difficult to determine, either due to a lack of baseline data, inherent high levels of natural variability, or in the case of many waterbird species, factors outside the site affecting their distribution and abundance observed at the site. For this reason, although strict “limits of acceptable change” cannot be set for these components, they form an important element of the monitoring program. Outcomes of the monitoring program are to be reviewed for broad trends and the information used to review and refine the limits of acceptable change for the site.” They also make the assertion that “Maintaining the conditions of the abiotic environment and the primary producers should protect these faunal components and processes” (p. 128).

In regard to the Peel-Harvey Estuary and the “Primary responses” components of Seagrass, Macroalgae, Samphire and Paperbark communities, at 2007 the current extent and biomass was unknown which meant that a baseline for these components needed to be determined before a LAC could be set (Hale & Butcher, 2007, Table 40: Limits of Acceptable Change, p.129). **This remains the case in 2017.**

With regard to the Peel-Harvey Estuary’s “Key species and communities” there was insufficient publicly available data in 2007 to set a baseline and determine a LAC. This was addressed in part by the MSC accreditation process and will be addressed in the future by the ARC-Linkage Project LP150100451.

Other knowledge gaps identified in preceding sections which are relevant to assessing the impact of the proposed marina development on the Peel-Harvey Estuary System include:

- Seagrass: extent, diversity and ability to recolonise at 4 m depth and once roots are removed
- Benthic invertebrates: species diversity, richness, spatial distribution
- Hydrodynamic modelling of the PHES to predict sediment dispersal, salinity and nutrient concentrations and the effect of climate change

Implications

The Precautionary Principle should be applied to this assessment of the environmental condition of the PHES with respect to the Point Grey Marina proposal. The absence of new information regarding some indicators of the current condition of the PHES should not be interpreted to mean that environmental conditions have not deteriorated since the initial assessment of the proposal. We therefore recommend that the Time Limit of Authorisation for substantial commencement of the proposal is not extended.

References

- ANZECC and ARMCANZ 2000, Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.
- Biota 2006, Perth Bunbury Highway (Kwinana Freeway Extension and Peel Deviation) Targeted threatened fauna survey. R.E & C. Johnstone and T.Kirkby, Biota Environmental Services Pty. Ltd. A report prepared for Main Roads Western Australia May 2006.
- Choppala, G., Bush, R., Moon, E., Ward, N., Wang, Z., Bolan, N., Sullivan, L. 2017, Oxidative transformation of iron monosulfides and pyrite in estuarine sediments: Implications for trace metals mobilisation, *Journal of Environmental Management*, 186 (2), 158-166.
- Department of Fisheries 2015a, Blue Swimmer Crab Resource of the Peel-Harvey Estuary Harvest Strategy 2015 – 2020 Version 1.0 West Coast Estuarine Managed Fishery (Area 2) and the Peel-Harvey Estuary Blue Swimmer Crab Recreational Fishery. Fishery Management Paper No. 273. Department of Fisheries, Perth.
- Department of Fisheries 2015b, Finfish Resources of the Peel-Harvey Estuary Harvest Strategy 2015 – 2020 Version 1.0 West Coast Estuarine Managed Fishery (Area 2. Fishery Management Paper No. 274. Department of Fisheries, Perth.
- Hale, J. and Butcher, R., 2007, Ecological Character Description of the Peel-Yalgorup Ramsar Site, Report to the Department of Environment and Conservation and the Peel-Harvey Catchment Council, Perth, Western Australia.
- Hale, J 2008, Monitoring and Evaluation Guide for the Peel-Yalgorup Ramsar Site. A report to the Peel-Harvey Catchment Council and the Department of Environment and Conservation.
- P Kraal, P, Burton, E.D. and Bush, R.T. 2013, Iron monosulfide accumulation and pyrite formation in eutrophic estuarine sediments, *Geochimica et Cosmochimica Acta* ,122, 75-88
- Kraal, P., Burton, E.D., Rose, A.L., Cheetham, M.D., Bush, R.T., Sullivan L.A. 2013, Decoupling between water column oxygenation and benthic phosphate dynamics in a shallow eutrophic estuary. *Environmental Science and Technology*. 47 (7), 3114–3121.
- Kraal, P, Burton, E.D.,AL Rose, A.L., Kocar, B.D., Lockhart, R.S., Grice, K., Bush, R.T., Tan, E. and Webb, S.M. 2015, Sedimentary iron–phosphorus cycling under contrasting redox conditions in a eutrophic estuary, *Chemical Geology*, 392, 19-31
- Lockhart, R., Berwick, L., Greenwood, P., Grice, K., Kraal, P. and Bush, R.T. 2013, Analytical Pyrolysis for Determining the Molecular Composition of Contemporary Monosulfidic Black Ooze, *J. Analytical and Applied Pyrolysis*, 104, 640-652
- Morgan, B. 2012, Sulfur geochemistry as a driver of trace element, rare earth element and nutrient cycles in eutrophic estuarine sediment. Ph.D. thesis, University of Western Australia.

Morgan, B., Burton, E.D. and Rate, A.W. 2012, Iron monosulfide enrichment and the presence of organosulfur in eutrophic estuarine sediments, *Chem. Geol.*, 296-297, 119-130.

Morgan, B., Rate, A.W., Burton, E.D. and Smirk, M.N. 2012, Enrichment and fractionation of rare earth elements in FeS and organic-rich estuarine sediments receiving acid sulfate soil drainage, *Chem. Geol.*, 308-309, 60-73.

Morgan, B., Rate, A.W. & Burton, E.D. 2012, Water chemistry and nutrient release during the resuspension of FeS-rich sediment in a eutrophic system, *Sci. Total Env.*, 432, 47-56.

Pedretti Y.M., Kobryn H. T., Sommerville E.F., and Wienczugow K., 2011, Snapshot Survey of the Distribution and Abundance of Seagrass and Macroalgae in the Peel-Harvey Estuary from November/December 2009; Report to Department of Water, Institute for Environmental Science, (Report No. MAFRA 11/1), Murdoch University.

PHCC 2009, Peel-Yalgorup Ramsar Site System Management Plan, Peel Harvey Catchment Council, Mandurah

RPS 2011, Public Environmental Review Point Grey Marina EPA Assessment No. 1751

Veale, L.J. 2013, Inter-period comparisons of the ichthyofaunas of two nearby, modified estuaries and the biology of *Pelates octolineatus* (Terapontidae), PhD thesis, Murdoch University, Western Australia.

Wetlands International (2017). *Waterbird Population Estimates*. Retrieved from <http://wpe.wetlands.org> on Tuesday 26 Sep 2017

Wildsmtih, M.D., Rose, T.H., Potter, I.C., Warwick, R.M. Clarke, K.R. and Valesini, F.J. 2009. Changes in the benthic macroinvertebrate fauna of a large microtidal estuary following extreme modifications aimed at reducing eutrophication, *Marine Pollution Bulletin*, 58(9), 1250-1262.

Peel Harvey ARC Project Update: May 2012

PARTNER ORGANISATIONS

WA Department of Environment, WA Transport, WA Water, Murray Shire, Mandurah City Council, Southern Cross University, Curtin University, University of WA

PROJECT SUMMARY

The chemistry of anoxic aquatic environments such as the Peel Harvey estuary is dominated by reactions with reduced sulfur, yet many of the fundamentally important reactions are highly transient and elusive. This project is exploring the extreme sedimentary conditions of a eutrophic estuary where hyper-accumulations of iron monosulfide prevail. Reduced inorganic sulfur and organo-sulfur compounds occur in abnormally high concentrations in these sediments, providing an ideal natural material to unravel sulfur biomineralisation pathways.

KEY FINDINGS UPDATE (2011-2012)

Finding 1: Channels in the Peel-Harvey and deep holes in the lower reaches of the tributary rivers provide highly favourable conditions for monosulfidic black ooze (MBO) (this is well known).

Management Implication: Changes to bedform that result in sinkholes and troughs will enhance localised MBO accumulation. This has relevance to developments that involve new dredging and maintenance dredging of navigational channels.

Finding 2: The formation of MBO is strongly linked to the presence/deposition of fine-grained sediment (silt), '*find the silt and you find the monosulfidic sediments*'. The fine sediments appear to restrict oxygen diffusion into the sediment, enhancing the formation and preservation of otherwise labile iron monosulfide minerals.

Management Implication: Understanding catchment sediment yield and the mobilization and redistribution of fine sediments within the Peel-Harvey is necessary to predict the accumulation of MBO.

Finding 3: Fine sediments associated with MBO are likely to include both contemporary catchment inputs and sediment redistribution within the estuary.

Management Implication: The construction and on-going management of man-

made channels in the Peel Harvey estuary will need to account for the hazard of MBO accumulation in their design and on-going maintenance.

Finding 4: MBO are prone to scour and suspension.

Management Implication: The mobilization of fine sediments as a result of dredging will cause MBO materials to oxidize and release associated contaminants. Current hazards associated with the mobilisation of these sediments are poorly defined. A clear understanding of these hazards will improve the environmental assessment and management of MBO in areas of dredging and dredge disposal.

Finding 5: Coarser sediments (silty sands) hold only small amounts of iron monosulfide (FeS), but have high contents of pyrite (FeS₂), another major potential source of acidity and cause of deoxygenation.

Management Implication: The sandy textured sediments of the Peel Harvey estuary have exceptionally high pyrite contents. The oxidation and acidification hazard for these materials is substantial and should be a key aspect of environmental impact assessment for developments involving benthic sediment disturbance.

Finding 6: Thin, buried layers of monosulfidic sediments (e.g. resulting from incomplete removal during dredging) completely dominate the sediment porewater chemistry, providing nutrients and high levels of dissolved sulfide to the sediment porewaters and overlying water column.

Management Implication: Chronic impacts from even very small amounts of MBO material in dredge disposal areas may cause these areas to become hotspots for prolonged nutrient release and sulfide toxicity. The disposal of dredge materials containing MBO needs further consideration.

Finding 7: The availability of Fe limits monosulfidic sediment formation in the Peel Harvey. Fe-rich runoff or groundwater that enters the estuary will potentially increase the rate and magnitude of sulfidic sediment accumulation. The sensitivity of the Peel Harvey estuary to the addition of Fe is yet to be fully quantified.

Management Implication: Activities in the catchment (particularly near shore), that may enhance the supply of Fe to the estuary in either run-off or groundwater, are likely to directly enhance iron sulfide formation.

Finding 8: Although phosphorus burial is limited in the MBO sediments, stable Fe oxides seem to play an important role in long-term phosphorus retention from the overlying water column.

Management Implication: Phosphorus cycling within the Peel-Harvey sediments may be sufficient to fuel major productivity and blooms, irrespective to the contemporary supply of nutrients in run-off. Activities that change the benthic sediment chemistry will have a direct impact on nutrient supply and potential to

trigger cycles of algae blooms.

Finding 9: Preliminary ^{210}Pb analyses indicate that the top ~ 20 cm of the sediment can be disturbed and readily remobilised by turbulent flows.

Management Implication: *The data indicates that MBO materials are impacting water quality continually as a result of even minor, but regular disturbances, such as general recreational boating.*

Finding 10: A detailed geochemical appraisal of the Murray River shows a dominance of terrestrial carbon input compared to the estuary.

Management Implication: *The processes driving MBO accumulation within the lower river systems differ somewhat to the open estuary. Different issues are at play in these adjacent waterways, resulting in the MBO's exhibiting different properties and hazards.*

Attachment 3: Water quality and phytoplankton data collected from the Peel-Harvey Estuary 2012-2016 (DoW, 2017) compared against Limits of Acceptable Change (LACs) for the Peel-Yalgorup System (Hale and Butcher 2007) and trigger values from the ANZECC and ARMCANZ Guidelines (2000).

Note that it is assumed here that the LACs for concentrations of nitrate and ammonium are expressed as the equivalent concentration of nitrogen (N) and phosphate as phosphorus (P) equivalent.

Water Quality A & Phytoplankton: Peel-Harvey Estuary (Hale and Butcher 2009)		
Component	Measure	Current status (Met ■ ; Borderline ■ ; Outside Acceptable Range ■)
Estuarine Water Quality: Nutrients	Total phosphorus concentrations < 30 µg P / L	Median Total Phosphorus (2012 to 2016) <ul style="list-style-type: none"> The Peel-Harvey Estuary met the LAC for both surface and bottom waters. ■ Serpentine River surface and bottom waters exceeded the LAC (same as the ANZECC guideline). ■ Murray River surface and bottom waters exceeded the LAC only in autumn. Bottom waters exceeded the LAC in summer and winter. ■
	Median phosphate (PO ₄ ³⁻) concentration < 10 µg P / L	Median filterable reactive phosphorus (2012-16) <ul style="list-style-type: none"> Serpentine River exceeded the LAC and the ANZECC guideline for both surface and bottom samples in spring ■ and exceeded ANZECC for Surface in spring and ANZECC and the LAC for Bottom waters in spring.
	Total nitrogen < 750 µg N / L ANZECC & ARMCANZ (2000)	Median total nitrogen (2012-16) <ul style="list-style-type: none"> There is no LAC for total nitrogen, however, Serpentine River exceeded the ANZECC guideline for surface and bottom samples in all periods.
	Median ammonium (NH ₄ ⁺) concentration < 10 µg N / L	Median ammonia / ammonium (2012-16) <ul style="list-style-type: none"> The LAC is set at a lower concentration than ANZECC trigger value (40 µg N / L). Nearly all results for the two rivers and Peel-Harvey Estuary, over the period exceed the LAC ■. The Serpentine River waters exceed ANZECC Guidelines in all seasons except autumn.
	Median oxidised nitrogen (NO _x ⁻) concentration < 10 µg N / L	Median total oxidised nitrogen (2012-16) <ul style="list-style-type: none"> The LAC is exceeded in top and bottom waters of both rivers and the estuary for all seasons. ■ The LAC is set lower than the ANZECC Guideline (40 µg N / L) so only the surface waters from the Murray River (in winter) and Serpentine River (in winter and spring) and the bottom waters from the Serpentine (in winter and spring) exceeded the ANZECC Guideline value.

Attachment 3: Water quality and phytoplankton data collected from the Peel-Harvey Estuary 2012-2016 (DoW, 2017) compared against Limits of Acceptable Change (LACs) for the Peel-Yalgorup System (Hale and Butcher 2007) and trigger values from the ANZECC and ARMCANZ Guidelines (2000).

Note that it is assumed here that the LACs for concentrations of nitrate and ammonium are expressed as the equivalent concentration of nitrogen (N) and phosphate as phosphorus (P) equivalent.

Water Quality A & Phytoplankton: Peel-Harvey Estuary (Hale and Butcher 2009)		
Component	Measure	Current status (Met ■ ; Borderline ■ ; Outside Acceptable Range ■)
	Chlorophyll a – median concentrations < 10 µg/L	Median chlorophyll a (2012-16) <ul style="list-style-type: none"> The waters of the Peel-Harvey estuary within the boundaries of the PYS Ramsar site do not exceed the LAC or ANZECC Guideline values ■. The concentration of chlorophyll a exceeds the LAC only in the Serpentine River waters (in integrated samples only) during autumn ■. Note that integrated samples are collected from the whole depth profile while surface samples are collected from the upper 0.5 m of the water column.
	Dissolved Oxygen 70–80 % saturation	Dissolved oxygen (2012-2016) <ul style="list-style-type: none"> The median concentrations met the LAC for the surface waters of the estuary and rivers ■. The waters near the bottom of these waterways also met the LACs with the exception of the Murray River ■.
	pH > 7 at all times	pH (2012-2016) <ul style="list-style-type: none"> The median pH for the surface and bottom waters of the estuary and rivers met the LAC. ■
	Salinity <ul style="list-style-type: none"> Winter salinity in the centre of the Peel Inlet and Harvey Estuary < 30 ppt for a minimum of 3 months. Water in the Harvey River mouth over winter < 3 ppt 	<ul style="list-style-type: none"> The LAC for the Peel-Inlet and Harvey Estuary was met in 2014 and 2016 but not in 2012, 2013 or 2015 ■. The salinity at the mouth of the Harvey River exceeded the LAC each year 2012-2016 inclusive ■.

Attachment 4: Shorebird data collected from the Peel-Yalgorup System 2008-2016 compared with Limits of Acceptable Change (Hale and Butcher 2007)

Component	Measure	Current status (Met ■ ; Borderline ■ ; Outside Acceptable Range ■)
Waterbirds A: Red-Necked Stints & Sharpies	The PYS will support more than 1% of the Flyway populations at a min of 3 years out of 5.	For the period 2008 to 2016: <ul style="list-style-type: none"> Red-necked Stint exceeded 1% threshold all years except 2008. ■ Sharp-tailed Sandpipers only exceeded 1% threshold in 2009, 2010 and 2014 i.e. three out of nine years. ■
Waterbirds B: Cormorants-Ornithological Technical Services' report July 2016	Measure the breeding status of the Little Black and Little Pied Cormorants at Len Howard Reserve to assess maintenance of PYS ecological character to inform limits of acceptable change for breeding waterbirds.	The July report compares findings with the 2010 monitoring report – colours indicates trends as LACs not set: <ul style="list-style-type: none"> Number of nests had significantly declined. ■ Number of active nests showed a slight increase. ■ Number of Little Black eggs had increased. ■ Number of Little Pied eggs had declined from a low base level. ■
Waterbirds C: Hooded Plovers 2012 to 2016	The PYS supports more than 60 Hooded Plovers three years out of five. PYS supports successful breeding of Hooded Plovers three years out of five.	<ul style="list-style-type: none"> Nesting data for the Hooded Plovers indicates the LAC is met. ■ The 1% threshold for Hooded Plover was exceeded in all years for the period 2001 to 2016 except for 2014 and 2015. ■ Caution is noted due to the two recent years in which it wasn't met. ■
Shorebird 2020 Count Trends Over Time	Criteria 5 for Ramsar Listing: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.	<ul style="list-style-type: none"> The 20,000 threshold was exceeded every year between 2008 and 2016 with over 90,000 counted in 2013 and the lowest being ~28,000 to ~30,000 in 2008, 2009, 2011 and 2016. ■ In 2015 40 different shorebird species were recorded. In all other years for the period 2008 to 2016, 50 or more species were recorded with the highest being 62 in 2013. ■