5. Summary and Conclusions

The information and analysis presented in this review has provided evidence that abalone have a robust capacity to deal with suspended sediments in the water column. In particular, the results indicate that it is highly unlikely that the Yumbah land-based abalone farm would be impacted by this development. Even in the absence of an appropriate dredge management plan, suspended sediment levels are not expected to exceed values the defined threshold (25 mg/L) at which no chronic or acute effects are likely. Irrespective, a dredge management plan should be developed to further manage the risk from periods when suspended sediment levels exceed water quality criteria (Table H-12).

Analysis of the literature leads to the conclusion that abalone are more resilient to suspended sediments than other aquaculture species having adapted to environments that routinely see them exposed to elevated levels of suspended sediments. Any dredge management plan should aim to ensure that suspended sediment loads (99^{th} percentile) do not exceed 25 mg/L with median levels not exceeding 10 mg/L. A key element of the dredge management plan would be pro-active prediction of suspended sediment loads using tidal and weather data and the incorporation of real time monitoring of *in-situ* turbidity, at an appropriate location, between the dredging and construction activities and the Yumbah seawater intakes, with turbidity thresholds to trigger appropriate management interventions.

The analysis has also illustrated the vulnerability of abalone aquaculture facilities in southern Australia to climate change and particularly to increasing sea water temperatures, coupled with the ocean acidification, that is now occurring. In this context, the predicted changes in water flow on the leeward side of the causeway may result in a very slight (maximum effect less than $0.1^{O}C$) increase in water temperature in the vicinity of the seawater intakes. This increase is unlikely to be detectable particularly against the existing background of climate change induced changes to seawater temperature (and associated acidification) however, mitigation strategies (e.g. culverts through the causeway) are available should they be deemed necessary.

The analysis further highlighted the potential impact of discharges from Smith Creek on coastal water quality. A solid causeway (with a gated culvert) would provide ancillary benefits to the aquaculture farm by directing flows from Smith Creek further offshore and thereby reducing the extent to which discharges from Smith Creek mix with the intake water flowing onto the abalone farm.

Other factors including noise and vibration, light and wind-blown dust have been investigated and it has been concluded that these issues do not present problems for an abalone farming operation.

Table H-12: Summary of risks to abalone aquaculture associated with the KI Seaport development.

Ref	Activity	Hazard (Environmental Aspect)	Potential Impact	Consequence	Likelihood	Inherent risk level	Management / mitigation measures and additional information / rationalisation	Consequence	Likelihood	Residual risk level
Construction Phase										
1	Capital dredging and causeway construction	Mobilisation of marine sediments causing turbid plumes at Yumbah intakes exceeding 25 mg/L	Impacts on water quality at Yumbah intakes resulting in high levels of suspended sediment (exceeding 25 mg/L) and that compromise abalone health	Moderate	Possible	Medium	Data from hydrodynamic modelling showing ambient and plume concentrations very unlikely to exceed 25 mg/L. Comprehensive dredge management plant with *in-situ* monitoring of suspended sediment loads (via measurements of turbidity) with management intervention when threshold levels are exceeded at intermediate location. Evidence that the NOEC for abalone is 25 mg/L	Minor	Virtually impossible	Low
2	Capital dredging and causeway construction	Mobilisation of marine sediments causing turbid plumes at Yumbah intakes exceeding 10 mg/L but not exceeding 25 mg/L	Impacts on water quality at Yumbah intakes resulting in high levels of suspended sediment (exceeding 10 mg/L but not exceeding 25 mg/L)	Negligible	Likely	Low	Comprehensive dredge management plant with *in-situ* monitoring of suspended sediment loads (via measurements of turbidity) with management intervention when threshold levels are exceeded at intermediate location. Evidence that the NOEC for abalone is 25 mg/L	Negligible	Likely	Low
3	Capital dredging and causeway construction	Mobilisation of marine sediments causing turbid plumes at Yumbah intakes (<=10 mg/L)	Impacts on water quality at Yumbah intakes resulting in levels of suspended sediment (not exceeding 10 mg/L)	This is typical of ambient conditions and therefore not considered a risk						
4	Capital dredging and causeway construction	Release of anoxic sediments	Impacts on water quality at Yumbah intakes resulting in reduced levels of dissolved oxygen	Moderate	Virtually impossible	Low	No evidence for anoxic sediments at levels that would impact on ambient oxygen levels in the water at Smith Bay	No significant change from existing risk profile of farm		
5	Capital dredging and causeway construction	Release of nutrients or toxicants from sediments	Impacts on water quality at Yumbah intakes resulting in high levels of nutrients or toxicants that compromise abalone health	Major	Virtually impossible	Low	No evidence for elevated levels of any nutrients or toxicants in sediments at Smith Bay	No significant change from existing risk profile of farm		
6	Capital dredging and causeway construction	Impact of elevated turbidity on light attenuation	Impacts on water quality at Yumbah intakes resulting in reduced rates of algal photosynthesis in nursery tanks sufficient to impact on algal production and thereby juvenile abalone nutrition	Minor	Virtually impossible	Low	Anticipated levels of suspended sediments would have no material effect on algal production rates in nursery tanks (<5% without accounting for photoacclimation responses).	Negligible	Virtually impossible	Low

Ref	Activity	Hazard (Environmental Aspect)	Potential Impact	Consequence	Likelihood	Inherent risk level	Management / mitigation measures and additional information / rationalisation	Consequence	Likelihood	Residual risk level
Operational Phase										
7	Coastal zone infrastructure	Modification to coastal water levels	No known mechanism for an impact on abalone							
8	Coastal zone infrastructure	Modification to coastal circulation - currents	Waste water discharged from the abalone farm may pool in the lee of the causeway causing elevated nutrients that could be drawn back into the farm (self-pollution)	Minor	Unlikely	Low	Pass through culverts or piered section along inshore section of causeway	No significant change from existing risk profile of farm		
9	Coastal zone infrastructure	Modification to coastal circulation – water temperature	Pooling of water in the lee of the causeway causing localised warming with the result that water taken on to the farm is sufficiently warmer that increased mortality occurs	Major	Unlikely	Medium	Pass through culverts or piered section along inshore section of causeway Maximum effect size shown to be below 0.1°C	No change from existing risk profile of farm		
10	Coastal zone infrastructure	Modification to coastal circulation – Smith Creek discharge plumes	Shielding of Smith Creek plumes to the east of the causeway with potential benefits to water quality at Yumbah seawater intakes	Beneficial			Nil			
11	Ship operations	Maintenance dredging causing increases in suspended sediment loads	Impacts on water quality at Yumbah intakes resulting in high levels of suspended sediment that compromise abalone health (exceeding 10 mg/L but not exceeding 25 mg/L)	Moderate	Possible	Medium	Comprehensive dredge management plant with *in-situ* monitoring of suspended sediment loads (via measurements of turbidity) with management intervention when threshold levels are exceeded at intermediate location. Modelling data shows the likelihood of an impact is very much lower than for the capital dredging program.	Moderate	Virtually impossible	Low
12	Ship operations	Propwash and bow-wave propagation causing increases in suspended sediment loads	Impacts on water quality at Yumbah intakes resulting in high levels of suspended sediment that compromise abalone health (exceeding 10 mg/L)	Negligible	Virtually impossible	Low	Modelling data shows no evidence for a plume extending much beyond the access channel	Moderate	Virtually impossible	Low
13	Ship operations	Introduction of red-tide species	Impacts on water quality at Yumbah intakes due to elevated cell numbers of red-tide algal species	Moderate	Unlikely	Medium	Standard ballast water management systems. Natural wave energy and movement of water in bay provides risk mitigation.	Moderate	Virtually impossible	Low
14	Land operations	Airborne dust depositing on Yumbah land-based facilities	Impacts on water quality of raceways resulting in high levels of suspended sediment that compromise abalone health	Minor	Virtually impossible	Low	Strategic use of dust covers, screening vegetation and dust suppression systems	Minor	Virtually impossible	Low

Ref	Activity	Hazard (Environmental Aspect)	Potential Impact	Consequence	Likelihood	Inherent risk level	Management / mitigation measures and additional information / rationalisation	Consequence	Likelihood	Residual risk level
15	Land operations	Extraneous light from land operations	Light spill resulting in negative impacts on abalone aquaculture	Negligible	Possible	Low	No evidence for such impacts, however, strategic use of screening vegetation and light baffles could be used to further minimise light spill	Negligible	Unlikely	Low
16	Land operations	Noise and vibration from land operations	Noise and vibration resulting from land operations having a negative impact on abalone aquaculture	Negligible	Possible	Low	Noise levels are quantitatively similar to the design specifications for the Yumbah Nyamat farm (Yumbah 2018) and thus not considered to represent a risk to the animals. The strategic use of screening vegetation could further limit noise propagation	Negligible	Virtually impossible	Low

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Appendix H2 – Ecotoxicology Reports – Intertek

Appendix H2 – Part A
Total Suspended Solids Guideline Value for the Pacific Abalone - Professional Opinion

ECOTOXICOLOGY LABORATORY PROFESSIONAL OPINION:

TOTAL SUSPENDED SOLIDS GUIDELINE VALUE FOR PACIFIC ABALONE

CLIENT NAME
Environmental Projects

REPORT NO.
ECX18-1004

COMPILED BY
Dr Tristan Stringer

PROJECT NAME
Total Suspended Solids Guideline Value for Abalone

DATE
19 October 2018

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CONTENTS

INTRODUCTION

The export of commercial timber from Kangaroo Island requires a new deep-water wharf and seaport to accommodate larger bulk carriers. This seaport is currently proposed to be constructed in Smith Bay, South Australia. The environmental risk assessment for the proposed wharf has identified suspended sediments from the associated dredging operation as a potential risk to the adjacent greenlip abalone aquaculture facility. For a complete description of the project, background information and risks associated with proposed seaport and dredging operation please see environmental impact statement and Cheshire (2018).

To best assess the impacts of suspended sediments on greenlip abalone, laboratory ecotoxicity testing is planned to be conducted by Intertek. However, due to the potential issues with sourcing juvenile abalone, the laboratory testing may be delayed. Therefore, this supplementary literature-based risk assessment has been undertaken to build on the previous work to provide a literature-based intertim guideline value for total suspended solids (TSS) for pacific abalone (*Haliotis discus*) to give an interim investigation into effects of TSS on abalone until direct testing can be performed with greenlip abalone.

RISK ASSESSMENT OF SUSPENDED SOLIDS ON ABALONE

Characterisation of Risk

As described in Cheshire (2018) there are several risk categories in which suspended sediments can affect abalone:

- Physical burial, smothering, and/or the loss of attachment due to surface settling of sediments
- Impacts of suspended sediments on larval development and survival
- Impacts of suspended sediments on the survival and physiology of juvenile, sub-adult and adult abalone

While all these pose a potential risk to abalone in the general vicinity of the dredging operation, this risk assessment will solely focus on the risk posed to the abalone aquaculture operation and thus will only consider the impacts on the survival and physiology of juvenile, sub-adult and adult abalone. A broader description and discussion of the other risks is detailed in Cheshire (2018).

Literature Review

There is limited literature available on the effects that suspended sediments have on abalone, and there is no research found specifically for greenlip abalone (*Haliotis laevigata*). The following table (modified from Cheshire 2018) is a synopsis of the literature values of various abalone species sensitivity to total suspended solids. Note total suspended solids (TSS), not suspended sediment concentration, have been used in these studies. While those two methods look similar, the analytical approach for each method is different and they are not interchangeable. Without providing a comprehensive comparison of TSS and suspended sediment concentration, which can be found elsewhere, in general terms TSS for the most part does not contain as many larger / denser particles (such as fine sand) as suspended sediment concentration.

Table 1 - Summary of studies comparing effects of suspended sediments on various abalone (and other) species (modified from Cheshire 2018)

Species	Treatments	Period	Finding	Source
Haliotis discus hannai	TSS at: 0, 1,000, 1,500 and 2,000 mg/L	96 h	No effect on mortality. Decrease in glycogen content over 1,500 mg/L	Lee 2008
Haliotis diversicolor	TSS at: 100, 200, 300, 400 mg/L	96 h	No effect on mortality, weaker motility at higher concentrations	Wang 2007
Haliotis discus	TSS (silt and clay): 50 mg/L	48 h	No effect on mortality	Chung *et al*. 1993
Haliotis discus	TSS (silt and clay): 1000 mg/L	96 h	82.5% mortality (20°C)	Chung *et al*. 1993
Haliotis discus	TSS (silt and clay): 50, 200, 600, 1000 mg/L	96 h	*Small Size (2-2.5cm)* LC_{50} (10°C) = 813 mg/L LC_{50} (20°C) = 547 mg/L *Large Size (4-5cm)* LC_{50} (10°C) = 1077 mg/L LC_{50} (20°C) = 698 mg/L	Chung *et al*. 1993
Haliotis discus hannai	TSS at: 250, 500, 1000, 2000 & 4000 mg/L	7 d	NOEC = 250 mg/L LOEC = 500 mg/L LC_{50}= 1,888 mg/L	Yoon and Park 2011
Tigriopus japonicas (copepod)	TSS at: 31, 63, 125, 250 & 500 mg/L	7 d	LOEC = 31 mg/L LC_{50}=61 mg/L	Yoon and Park 2011
Paralichthys olivaceus (flounder fry)	TSS at: 125, 250, 500, 1000, & 2000 mg/L	7 d	LOEC = 125 mg/L LC_{50}=157 mg/L	Yoon and Park 2011
Haliotis iris	Synthetic particles 100 mg/L		No significant effect on growth or mortality	Allen *et al*. 2006

NOEC – No Observed Effect Concentration for the experimental protocol.
LOEC – Lowest Observed Effect Concentration for the experimental protocol.
LC_{50} – Concentration at which 50% mortality occurred.

Of all the literature reviewed only two studies had calculated statistical endpoints sensitivity of juvenile abalone to TSS, Chung *et al*. (1993) and Yoon and Park (2011). The other three studies, Allen *et al*. (2006), Wang (2007), and Lee (2008) saw no effects on mortality at the highest concentrations tested.

The study by Chung *et al*. (1993) examined the effects of TSS on two size categories of pacific abalone (*Haliotis discus*): small (2-2.5cm) and large (4-5 cm), at two different temperatures 10°C and 20°C. The authors found that both size and temperature affected sensitivity to TSS, with the smaller abalone being more sensitive to TSS, and that abalone exposed at 20°C were more sensitive than those at 10°C. The most sensitive treatment, the small abalone exposed at 20°C, had a resulting 96-hr LC_{50} of 547 mg/L TSS.

Unfortunately, there is no information given about controls (i.e. 0 mg/L TSS) and additionally it appears that there was only one replicate per TSS concentration used in the experimental design. This brings the validity of the calculated LC_{50}s into question.

Furthermore, it was noted that the authors do not detail what the “normal” temperature range is for *Haliotis discus* or the temperature that they were reared at (as they were from a culture facility), so it is unknown how much thermal stress the two temperature regimes (especially 20°C) had on the individuals. Also, the lack of control data did not allow the assessment of the temperature regime on mortality rate.

The study by Yoon and Park (2011) also looked at TSS effects on the pacific abalone *Haliotis discus hannai* (subspecies of *Haliotis discus*) as well as to a copepod (*Tigriopus japonicas*) and flounder (*Paralichthys olivaceus*) fry. In the study they determined a 7-day LC_{50} 1,888 mg/L TSS for 10-12-month-old juveniles at 15°C. The abalone was more tolerant to TSS than the other two species tested, copepod and flounder.

Comparing these two studies, the results show a significant difference in sensitivity for these related species. The abalone used in Yoon and Park (2011) were significantly more tolerant to TSS than those in Chung *et al*. (1993) with a 7-day LC_{50} 1,888 mg/L TSS compared to 96hr LC_{50}s from 547 – 1,077 mg/L TSS respectively. However, there is some difficulty in comparing and reviewing these studies due to the issues associated with the Chung *et al*. 1993 only having a brief description on the experimental set up and it appears that the study lacked controls and replication. This makes robust comparison and interpretation of the data challenging.

Considering these two studies and the other studies detailed in Table 1, all indicated that abalone are tolerant to suspended solids. This is discussed in great detail by Cheshire (2018) as is the rational that the ANZECC (2000) guideline value (previously referred to as a trigger value) of 10 mg/L TSS for aquaculture is overly conservative for abalone. Thus, there is justification for a new guideline value to be derived for abalone. This new guideline value aims to provide a realistic and not overly conservative guideline value as the default ANZECC (2000) trigger is likely overly conservative for abalone. Ideally this would be derived using laboratory exposures of greenlip abalone, which is planned on being conducted as soon as abalone are available for testing. However, considering that sourcing those juvenile green lip abalone can be problematic, and until laboratory studies have been performed further investigation in to the sensitivity of pacific abalone (*Haliotis discus)* is warranted.

Derivation of an Interim Total Suspended Solids (TSS) Guideline Value for Pacific Abalone

Prior to discussion on the derivation of the guideline value, it is important to highlight that this guideline value has been gathered only for total suspended solids (TSS). TSS is loosely defined as particles that remain in suspension (i.e. do not settle out, such as large sediment particles) and is determined via filtration, drying, and weighing. By nature, TSS is generally fine silts and clays, however the overall size distribution and composition (silt, clay, organic content, etc.) can vary considerably depending on the type of sediment, geology and environmental conditions.

The most important factor in deriving the guideline values is data quality, especially considering the limited data for abalone sensitivity to TSS. Ideally testing on the target species for the risk assessment or a species sensitivity distribution would be used to develop a guideline value for TSS, as per the methodology as detailed in ANZECC (2000), however, there is insufficient data to do so. Therefore, at this stage in the risk assessment an interim guideline value for pacific abalone is investigated.

The comparison of sensitivity of pacific abalone to greenlip abalone is not considered in this assessment. Investigation into the comparison between these species life history and sensitivity is presented elsewhere (Cheshire 2018). The results presented in this assessment should not be used as a surrogate for testing on greenlip abalone, and further investigation is required before any guideline value is derived for greenlip abalone.

Using the criteria detailed in Warne (2001) and Warne et al. (2015), which gives guidance on how data was selected for the ANZECC water quality guidelines, as well as the author's experience of conducting commercial ecotoxicology studies under a NATA (ISO 17025) framework, the data quality of Chung *et al*.

(1993) and Yoon and Park (2011) were assessed as these are the two papers which provide sensitivity thresholds for pacific abalone to TSS.

Given the issues with the lack of controls and replication in Chung *et al*. (1993) the overall quality of the data was insufficient and validity of the calculated LC_{50} data is brought into question. Therefore, the results detailed in this paper should not be used to derive a TSS guideline value for green lip abalone. Ideally there would be other data that would be sufficient to derive a guideline value, but given the lack of data, further investigation into Chung *et al*. (1993) was warranted to extract some additional data that could be used for indicative purposes. Based on the figures detailing the observed mortality rate over the test period, as well as the description of results in the text, it is clear that there was no mortality (100% survival) in all of the four size and temperature exposures up to 48-hr in the 50 mg/L TSS concentration. Therefore, we can conclude with reasonable certainty that 50 mg/L TSS is an estimated 48-hr NOEC (no observed effect concentrations) for this study.

The study design of Yoon and Park (2011) give a high level of confidence in the results and the statistical endpoints reported. Therefore, the 7-day NOEC of 250mg/L TSS is suitable to be used in guideline derivation.

The other study reviewed using pacific abalone (Lee 2008) did not see any effects on mortality rate in concentrations up 2000 mg/L TSS and no sublethal effects at 1,500 mg/L TSS. The lack of reliable and defined threshold toxicity data leaves only the Yoon and Park (2011) 7-day NOEC of 250 mg/L as a basis for estimating an interim guideline value and the rest of the data only can be used for indicative purposes.

Therefore, to ensure conservatism, especially with the lack of data, it is this author's opinion that the interim guideline value be derived by using the Yoon and Park (2011) 7-day NOEC of 250 mg/L with a 10x acute to chronic conversion factor applied. A 10x acute to chronic conversion factor was chosen as it the default correction factor used in ANZECC (2000).

Using this conversion factor, provides an interim guideline value of 25 mg/L TSS for pacific abalone. At this concentration it is expected that no sublethal effects or chronic effects would be expected for TSS to pacific abalone. It is noted that this interim guideline value is to be used only for indicative purposes. As stressed previously, the results presented in this assessment should not be used as a surrogate for greenlip abalone, and further investigation is required before any guideline value is derived for greenlip abalone.

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Warne, M.St.J. (2001) Derivation of the Australia and New Zealand Water Quality Guidelines for Toxicants. Australasian Journal of Ecotoxicology. 7:123-136

Yoon, S-J and Park, G-S. (2011) Ecotoxicological Effects of the Increased Suspended Solids on Marine Benthic Organisms. Journal of Environmental Science International: 20 (11): 1383-1394

Appendix H2 – Part B Effects of Total Suspended Solids on Juvenile Greenlip Abalone – Ecotoxicology Laboratory Test

ECOTOXICOLOGY LABORATORY TEST REPORT:

EFFECTS OF TOTAL SUSPENDED SOLIDS ON JUVENILE GREENLIP ABALONE – PILOT STUDY

CLIENT NAME
Environmental Projects

REPORT NO.
ECX18-1116-1

COMPILED BY
Dr Tristan Stringer

PROJECT NAME
Effects of TSS on Juvenile Abalone

DATE
14 December 2018

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CONTENTS

INTRODUCTION

The export of commercial timber from Kangaroo Island requires a new deep-water wharf and seaport to accommodate larger bulk carriers. The proposed seaport is to be constructed in Smith Bay, South Australia. The environmental risk assessment for the proposed wharf has identified suspended sediments from the associated dredging operation as a potential risk to the adjacent greenlip abalone (*Haliotis laevigata*) aquaculture facility. For a complete description of the project, background information and risks associated with proposed seaport and dredging operation please see the environmental impact statement and Cheshire (2018).

There are several risk categories in which suspended sediments can affect abalone Cheshire (2018) grouped them into the following categories:

- Physical burial, smothering, and/or the loss of attachment due to surface settling of sediments
- Impacts of suspended sediments on larval development and survival
- Impacts of suspended sediments on the survival and physiology of juvenile, sub-adult and adult abalone

While all these pose a potential risk to abalone in the general vicinity of the dredging operation, during the environmental risk assessment process it was determined that suspended sediments (light sediment particles that remain in suspension) is the primary risk posed to the abalone aquaculture facility, especially the juvenile abalone during the dredging. Therefore, the focus of this ecotoxicity risk assessment was on juvenile abalone.

To best assess the impacts of suspended sediments on juvenile greenlip abalone, laboratory ecotoxicity testing was undertaken with the goal to define a threshold concentration for juvenile greenlip abalone to total suspended solids (TSS). However, the sourcing juvenile greenlip abalone by commercial divers proved to be more challenging than expected and only a limited number of juvenile abalone were able to be obtained. This limited the scope of the experiments and only one concentration of TSS, 250 mg/L, was able to be assessed. Due to the lack of sensitivity data for greenlip abalone to TSS, the results while limited, provide valuable data for the risk assessment.

METHODOLOGY

Abalone collection

Juvenile abalone (approx. 15 - 20 mm) were collected by SARDI (South Australian Research and Development Institute) divers over a four-day period (12/11/18 -1 5/11/18). The abalone were sent and received by Intertek on (16/11/18). Upon receipt of the juvenile abalone they were placed into a ~100 L holding tank with ~60 L of filtered seawater (sourced from Fremantle, Western Australia). “Live rocks” (rocks that are covered in a biofilm of bacteria and algae) were added to the tank for the juvenile abalone to graze on and to provide them with a suitable habitat to live on. The holding tank was maintained under constant aeration at 18°C with a 12:12 light:dark cycle for three days prior to commencing exposures. Routine water changes were conducted every 2-3 days to maintain water quality.

Total suspended solids test solution

Prior to test initiation a 250 mg/L total suspended solids solution was prepared. To prepare the suspended sediments solution sediment sourced from Smith Bay, Kangaroo Island, South Australia was gently sieved through a 63 µm sieve and the <63 µm sediment fraction was collected. An initial trial showed that this <63 µm sediment fraction stayed in suspension under gentle agitation (to prevent settling over time). The dry <63 µm sediment was then weighed using an analytical balance and then added to 0.45 µm filtered seawater (sourced from Fremantle, Western Australia) at a loading ratio of 250 mg/L.

Experimental setup

To ensure that the suspended sediments remained in suspension over the duration of the exposure period a special testing apparatus was created. The testing apparatus was based on Yoon and Park (2011) and consisted of a 600 ml HDPE funnel fitted with an air lift at the bottom of the funnel to maintain dissolved oxygen and suspended sediment concentration. Figure 1 details the test apparatus.

Due to the limited number of individuals available for testing, only one suspended sediment treatment (250 mg/L TSS) was tested alongside seawater controls. Both the treatment and the controls consisted of four replicates with four juvenile abalone per replicate. Once placed into the test apparatus the juvenile abalone were exposed to the suspended sediments for 24 hours at 18°C with a 12:12 light:dark cycle. Water quality parameters were maintained at salinity of 34‰, pH 8.2, and dissolved oxygen (DO) >90% saturation. After the 24-hour exposure period, the test apparatus and juvenile abalone were transferred into a 5 L beaker containing 4 L of fresh filtered seawater (Figure 3) for a further 48 hours for post exposure observations. To minimise handling stress of removing the juvenile abalone from the test apparatus instead the whole test apparatus was moved to the clean seawater after being gently rinsed with filtered seawater.

Abalone were not fed during the test period. Mortality and behavioural observations were made twice daily over the testing and observation period.

Figure 1: Test apparatus (side view) with juvenile abalone

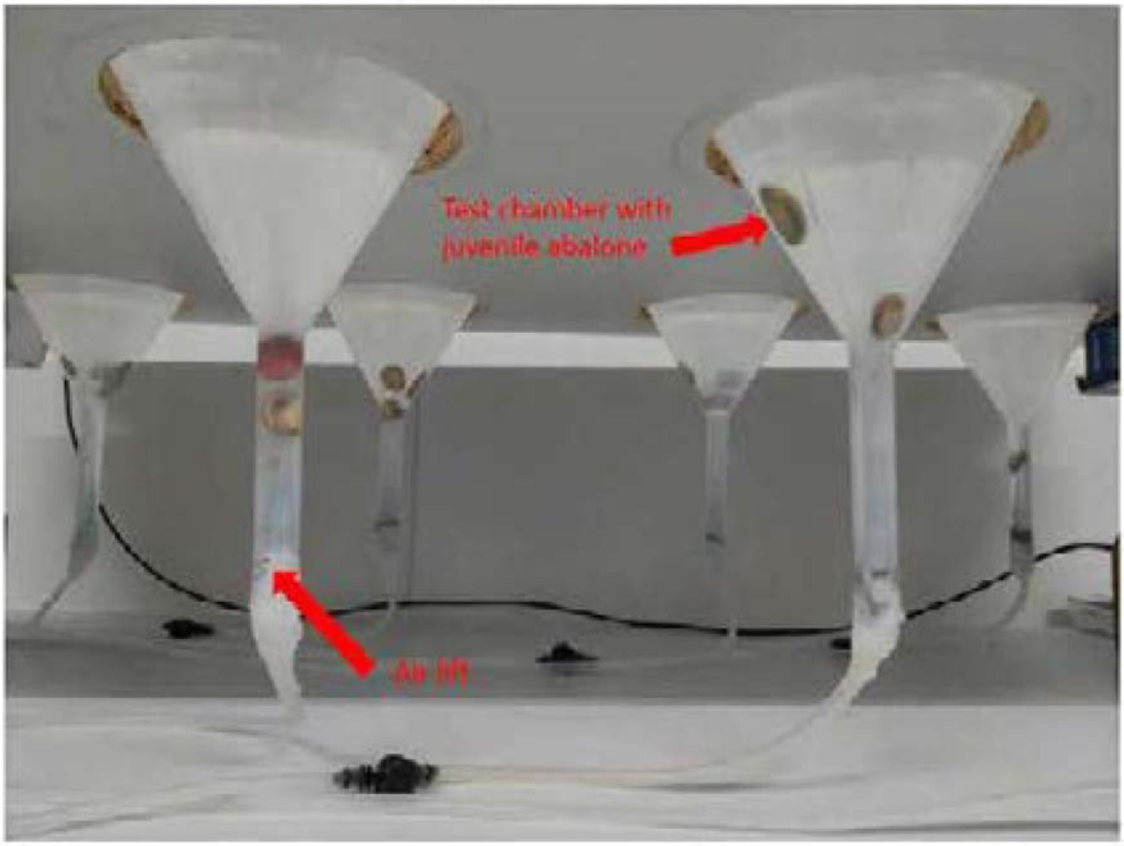

Figure 2: Test apparatus (top view) with juvenile abalone

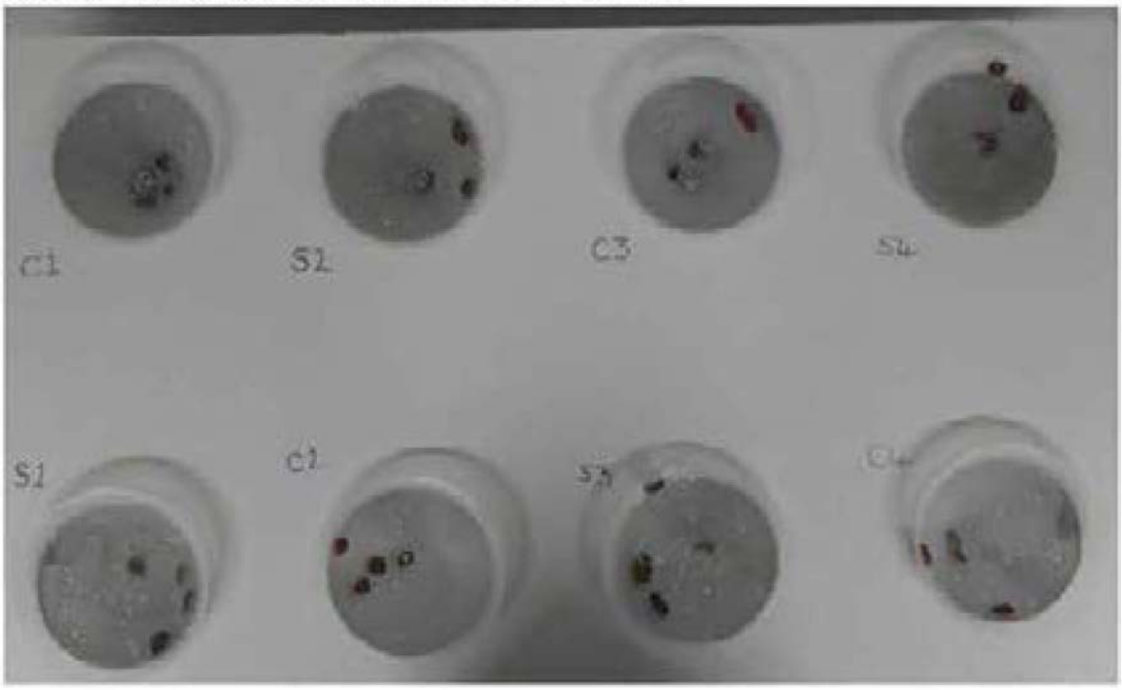

Figure 3: Post exposure observation period where juvenile abalone and test apparatus were transferred to 5L beakers

RESULTS

No mortality was observed in either the controls or in the 250 mg/L TSS treatment group (Table 1). There were no noticeable behavioural changes between the controls and treatment groups during the exposure and post exposure test periods.

Table 1 - Concentration-response data for juvenile abalone exposed to suspended sediments

JUVENILE ABALONE	CONTROL	250 MG/L TSS
Survival	100 ± 0 %	100 ± 0 %

CONCLUSIONS

Despite the limited nature of this pilot study only being able to test one concentration of total suspended solids (TSS) it provided valuable information on the sensitivity of greenlip abalone to suspended sediments. No effects on mortality or behaviour were observed during the test (both exposure and observation periods) and despite the relatively weak statistical power of the experimental set up as no mortality was observed (i.e. 100% survival in all replicates) it suggests with a high confidence that exposure to 250 mg/L TSS will not adversely affect juvenile greenlip abalone when exposed for up to 24 hours.

The results from this study are consistent with previous studies with other abalone species detailed in Table 2 and discussed elsewhere (i.e. Cheshire (2018) and Stringer (2018) ECX18-1004).

Table 2 - Summary of studies comparing effects of suspended sediments on various abalone (and other) species (modified from Cheshire (2018) and updated with results from current study)

Species	Treatments	Period	Finding	Source
Haliotis laevigata	TSS: 0, 250 mg/L	24 h	No effect on mortality.	Current study
Haliotis discus hannai	TSS at: 0, 1,000, 1,500 and 2,000 mg/L	96 h	No effect on mortality. Decrease in glycogen content over 1,500 mg/L	Lee 2008
Haliotis diversicolor	TSS at: 100, 200, 300, 400 mg/L	96 h	No effect on mortality, weaker motility at higher concentrations	Wang 2007
Haliotis discus	TSS (silt and clay): 50 mg/L	48 h	No effect on mortality	Chung *et al.* 1993
Haliotis discus	TSS (silt and clay): 1000 mg/L	96 h	82.5% mortality (20°C)	Chung *et al.* 1993
Haliotis discus	TSS (silt and clay): 50, 200, 600, 1000 mg/L	96 h	*Small Size (2-2.5cm)* LC_{50} (10°C) = 813 mg/L LC_{50} (20°C) = 547 mg/L *Large Size (4-5cm)* LC_{50} (10°C) = 1077 mg/L LC_{50} (20°C) = 698 mg/L	Chung *et al.* 1993
Haliotis discus hannai	TSS at: 250, 500, 1000, 2000 & 4000 mg/L	7 d	NOEC = 250 mg/L LOEC = 500 mg/L LC_{50}= 1,888 mg/L	Yoon and Park 2011
Tigriopus japonicas (copepod)	TSS at: 31, 63, 125, 250 & 500 mg/L	7 d	LOEC = 31 mg/L LC_{50}=61 mg/L	Yoon and Park 2011
Paralichthys olivaceus (flounder fry)	TSS at: 125, 250, 500, 1000, & 2000 mg/L	7 d	LOEC = 125 mg/L LC_{50}=157 mg/L	Yoon and Park 2011
Haliotis iris	Synthetic particles 100 mg/L	-	No significant effect on growth or mortality	Allen *et al.* 2006

NOEC – No Observed Effect Concentration for the experimental protocol.
LOEC – Lowest Observed Effect Concentration for the experimental protocol.
LC_{50} – Concentration at which 50% mortality occurred.

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Appendix H2 – Part C
Effects of Sawdust on Juvenile Greenlip Abalone – Ecotoxicology Laboratory Test

ECOTOXICOLOGY LABORATORY
TEST REPORT:

EFFECTS OF SAWDUST ON JUVENILE GREENLIP ABALONE – PILOT STUDY

CLIENT NAME
Environmental Projects

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ECX18-1116-2

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Effects of Sawdust on
Juvenile Abalone

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INTRODUCTION

The export of commercial timber from Kangaroo Island requires a new deep-water wharf and seaport to accommodate larger bulk carriers. The proposed seaport is to be constructed in Smith Bay, South Australia. The environmental risk assessment for the proposed wharf has identified that sawdust poses a potential risk to the adjacent greenlip abalone (*Haliotis laevigata*) aquaculture facility. For a complete description of the project, background information and risks associated please see the environmental impact statement and Cheshire (2018).

There is currently no information on the potential effects of sawdust on abalone. To best assess the impacts of sawdust on juvenile greenlip abalone, laboratory ecotoxicity testing was undertaken with the goal to define a threshold concentration for juvenile greenlip abalone. However, the sourcing juvenile greenlip abalone by commercial divers proved to be more challenging than expected and only a limited number of juvenile abalone were able to be obtained. This limited the scope of the experiments and only one concentration of sawdust, 35 mg/L was able to be assessed. Due to the lack of sensitivity data for any abalone species to sawdust, the results while limited, provide valuable data for the risk assessment.

METHODOLOGY

Abalone collection

Juvenile abalone (approx. 15 - 20 mm) were collected by SARDI (South Australian Research and Development Institute) divers over a four-day period (12/11/18 -1 5/11/18). The abalone were sent and received by Intertek on (16/11/18). Upon receipt of the juvenile abalone they were placed into a ~100 L holding tank with ~60 L of filtered seawater (sourced from Fremantle, Western Australia). "Live rocks" (rocks that are covered in a biofilm of bacteria and algae) were added to the tank for the juvenile abalone to graze on and to provide them with a suitable habitat to live on. The holding tank was maintained under constant aeration at 18°C with a 12:12 light:dark cycle for three days prior to commencing exposures. Routine water changes were conducted every 2-3 days to maintain water quality.

Due to the limited number of abalone obtained the abalone that were used in these sawdust exposures were the same individuals that were exposed to the suspended solids (see Intertek report ECX18-1004-1). The abalone were given a 6-day depuration period between exposures and allowed to feed on live rocks.

Sawdust test solutions

Prior to test initiation a sawdust solution was prepared at a loading ratio of 35 mg/L. Bluegum (*Eucalyptus globulos*) sawdust was provided to Intertek for use in the experiments. To isolate the finest fraction of the sawdust, which is most likely to be transported to the abalone aquaculture facility, the sawdust provided was gently sieved through a 63 µm sieve and the <63 µm sawdust fraction was collected. The <63 µm sawdust was then weighed using an analytical balance and then added to 0.45 µm filtered seawater (sourced from Fremantle, Western Australia) at a loading ratio of 35 mg/L. This loading ratio of sawdust was chosen as it is 10x the 99th percentile of sawdust deposited on abalone cages.

Experimental setup

To ensure that the sawdust remained in suspension over the duration of exposures a special testing apparatus was created. The testing apparatus was based on Yoon and Park (2011) and consisted of a 600 ml HDPE funnel fitted with an air lift at the bottom of the funnel to maintain dissolved oxygen and distribution of sawdust. Figure 1 details the test apparatus.

Due to the limited number of individuals available for testing, only one sawdust treatment (35 mg/L) was tested alongside seawater controls. Both the treatment and the controls consisted of four replicates with four juvenile abalone per replicate. Once placed into the test apparatus the juvenile abalone were exposed to the sawdust for 24 hours at 18°C with a 12:12 light:dark cycle. Water quality parameters were maintained at salinity of 34‰, pH 8.2, and dissolved oxygen (DO) >90% saturation. After the 24-hour exposure period, the test apparatus and juvenile abalone were transferred into a 5 L beaker containing 4 L of fresh filtered seawater (Figure 3) for a further 48 hours for post exposure observations. To minimise handling stress of removing the juvenile abalone from the test apparatus, the whole test apparatus was moved to the clean seawater after being gently rinsed with filtered seawater.

Abalone were not fed during the test period. Mortality and behavioural observations were made twice daily over the testing and observation period.

Figure 1: Test apparatus (side view) with juvenile abalone

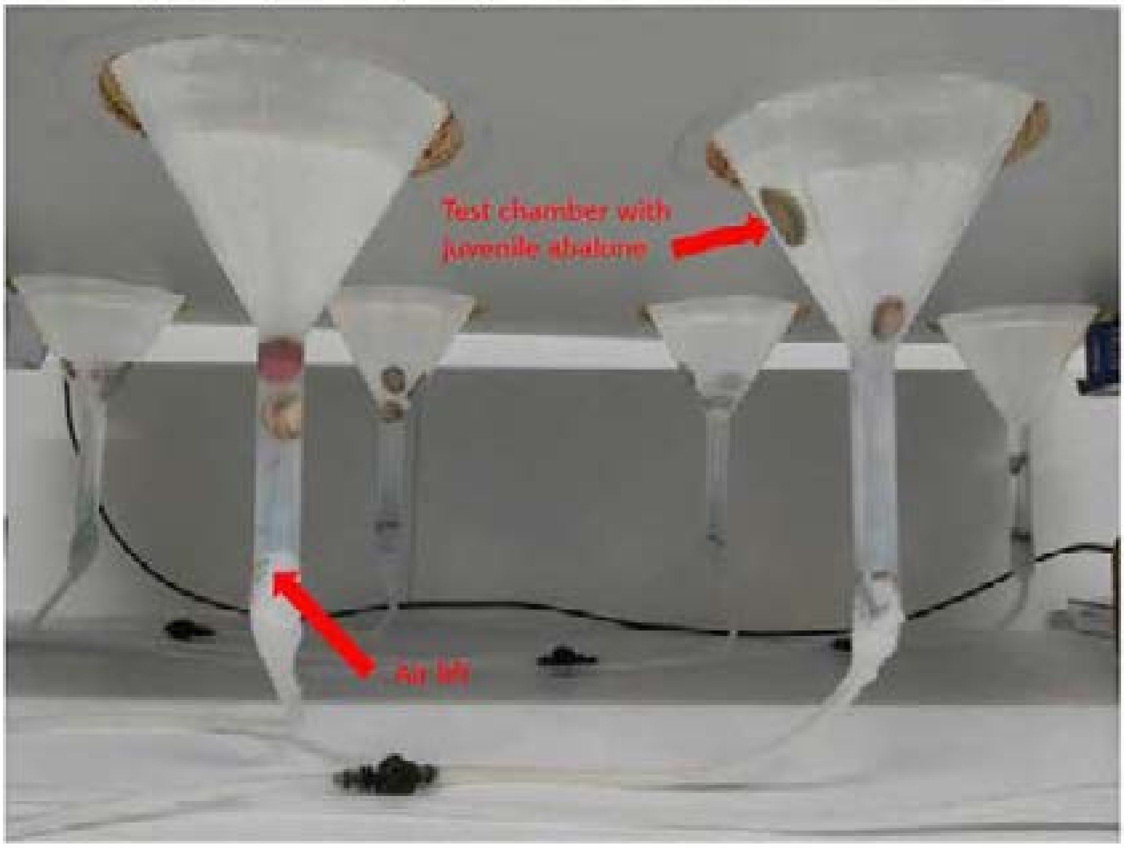

Figure 2: Test apparatus (top view) with juvenile abalone

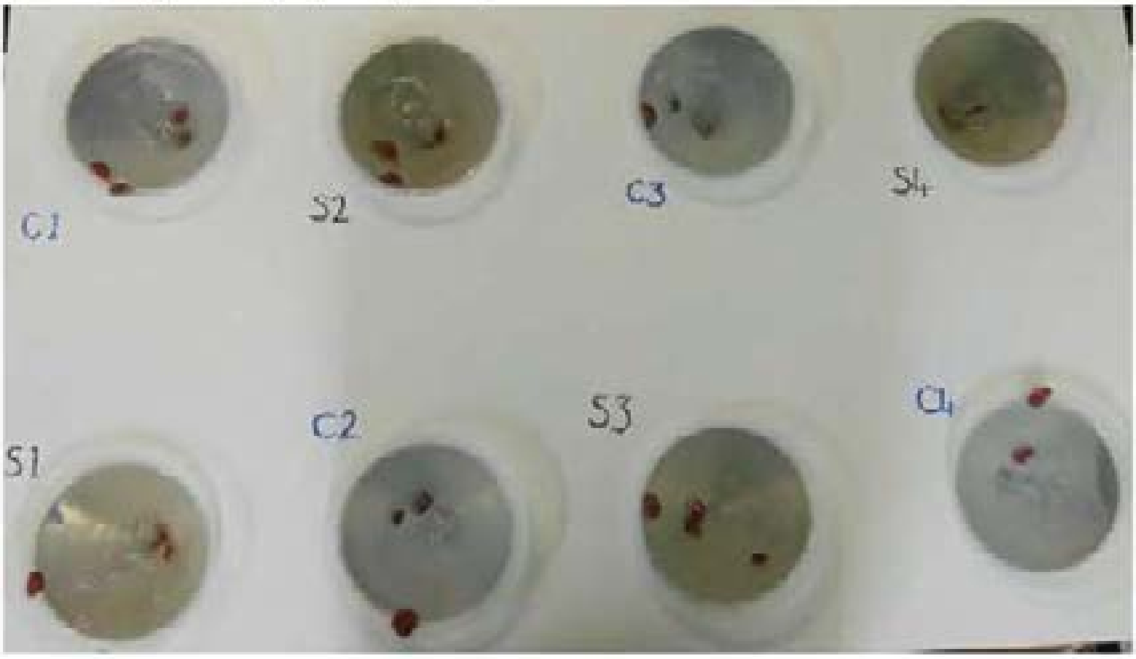

Figure 3: Post exposure observation period where juvenile abalone and test apparatus were transferred to 5L beakers

RESULTS

No mortality was observed in either the controls or in the 35 mg/L sawdust treatment group (Table 1). There were no noticeable behavioural changes between the controls and treatment groups during the exposure and post exposure test periods. It is noted that over time the colour of the water changed in the sawdust test solution (see Figure 2), due to leaching of the organic materials (i.e. tannins, wood oils, etc.) from the sawdust.

Table 1 - Concentration-response data for juvenile abalone exposed to sawdust

JUVENILE ABALONE	CONTROL	35 MG/L SAW DUST
Survival	100 ± 0 %	100 ± 0 %

CONCLUSIONS

Despite the limited nature of this pilot study only being able to test one concentration of total sawdust it provided valuable information on the sensitivity of greenlip abalone to sawdust. No effects on mortality or behaviour were observed during the test (both exposure and observation periods) and despite the relatively weak statistical power of the experimental set up as no mortality was observed (i.e. 100% survival in all replicates) it suggests with a high confidence that exposure to sawdust at loading ratios of up to 35 mg/L will not adversely affect juvenile greenlip abalone when exposed for up to 24 hours.

REFERENCES

Cheshire, A. (2018) Assessment of risks and mitigation strategies to the Yumbah Aquaculture Facility from the Construction and Operation of the proposed KI Seaport. Prepared for Kangaroo Island Plantation Timber Pty Ltd. 24 September 2018.