WEST PILBARA IRON ORE PROJECT – ANKETELL POINT PORT

REVIEW OF PREDICTION OF IMPACTS ON CORAL SPAWNING

Report: MSA168R1

Report to:

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Document Information

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JOB	MSA168
CLIENT	API Management Pty Ltd
USAGE	This review provides advice to API Management from a coral biologist with experience in evaluating the effects of dredging on coral spawning and settlement independent to development of API's impact prediction.
PRECIS	This review found that the PER assessment of whether coral spawn was at risk of impact was overly constrained by inappropriate thresholds applied to water quality criteria. The review suggests that spawning impacts would be best managed through the results of a revised model interrogation conducted closer to the time of spawning.
KEYWORDS	Coral spawning, Anketell Point, impact prediction

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V1 5 May 2011	JAS	Internal Review
V2 6 May 2011	JAS	Client Review
V3 18 May 2011	JAS	Final

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1.0 SUMMARY

API Management Pty Ltd (API) is undertaking an assessment of the environmental impacts of the West Pilbara Iron Ore Project's Anketell Point Port Development proposal (the Proposal). A Public Environmental Review/Draft Public Environmental Report (PER) has been prepared to evaluate potential impacts of the Proposal and made available for public submissions, which closed on 28 February 2011.

The PER concludes that the potential for suspended sediment concentrations elevated as a result of dredging to impact on the fertilisation of spawned coral gametes and the survival of resultant larvae is low. In a submission on the PER, the WA Department of Environment and Conservation (DEC) recommended that API obtain an independent expert review of their assessment.

This review has examined the Coral Spawn component of Section 9.3.2 of the PER and its Supporting Study 7.1. The findings in those documents have been examined based on the published evidence supporting the case that elevated suspended sediments can cause impacts on coral reproductive processes of broadcast spawning corals between gamete expulsion and the settlement of larvae.

The review finds that:

- the approach to evaluating the impact potential of dredging on coral spawning used by API is valid;
- the conclusion of the PER, that a stoppage period for the planned dredging may not provide material benefits to the success of coral spawning products, may be correct, however it is not adequately supported by evidence presented in the PER;
- there are flaws in the logic chain presented in this section of the PER.

The PER's conclusion rests principally on the predictions of a model showing the likely dispersal of coral larvae relevant to two water quality thresholds. Duration criteria in the thresholds cause the areas of potential impact to be predicted as small and distant from dredging. These duration criteria are not supported by existing theories on how suspended sediment might impact coral gametes or larvae.

The review findings do not show that the overall conclusion of the PER is incorrect, merely that, based on the current case, it is not supportable to the degree required by the precautionary principle.

The review also suggests that the available scientific studies on this topic do not provide a strong case that there is a high *a priori* risk to fertilisation or coral larvae likely to occur near dredging in this area.

It is suggested that the API's current approach to evaluating the potential impacts of dredging on coral spawning has merit and could be integrated with the DEC recommendation on coral spawning management. The basis of the condition recommended by DEC is that dredging is managed to avoid the generation of turbidity which would impact adversely on coral larvae. That is also the focus of the modelling approach suggested by API.

Re-running the API spawning-turbidity model prediction with more appropriate thresholds and a dredging scenario based on a confirmed dredging schedule would allow API to identify whether planned turbidity generating activities had an unacceptable risk of impacts and should be shut down.

ABBREVIATIONS

APASA	Asia Pacific Australia Applied Sciences Associates
API	API Management Pty Ltd
DEC	Western Australian Department of Environment and Conservation
mg/l	Milligrams per litre
PER	Public Environmental Review/Draft Public Environmental Report
SSC	Suspended sediment concentration – used interchangeably with TSS by many studies
TSS	Total suspended sediments – used interchangeably with SSC by many studies

2.0 INTRODUCTION

2.1 BACKGROUND

API Management Pty Ltd (API) is undertaking an assessment of the environmental impacts of the West Pilbara Iron Ore Project's Anketell Point Port Development proposal (the Proposal). A Public Environmental Review/Draft Public Environmental Report (PER) has been prepared to evaluate potential impacts of the Proposal.

One component of that assessment is an evaluation of the potential for sediment plumes originating from the dredging operation to adversely affect coral spawn or newly settled corals at distance from the operation. Assessments by the Western Australian Environmental Protection Authority (EPA) of the environmental impacts of proposed dredging programs on the Pilbara coast since 2003 have all contained provisions requiring specific management of projects to avoid such impacts. Management prescriptions usually involve some period of stoppage of turbidity-generating activities during predicted spawning periods.

Section 9.3.2 pp 207-210 of the PER of the API assessment concluded that the potential for significant impacts of the current proposal was sufficiently low that a temporary stoppage was not justified. Neither has it proposed any alternate management actions.

In its submission to the EPA on the PER, the Western Australian Department of Environment and Conservation (DEC) has made the following recommendation:

Recommendation 19: That the proponent refers the coral spawning impact assessment on pages 9-207-9-210 and Supporting Study 7.1 to an independent expert to provide confidence that the predicted impacts from dredging on coral spawning and settlement, particularly coral spawning around Delambre Island, will not have significant detrimental impacts on recruitment in the local area.

Alternatively, the following environmental condition could be considered:
The proponent is required to develop a Coral Spawning Management Framework as a component of the Dredge Environmental Management Plan which:
1. identifies the predicted autumn coral mass spawning periods;
2. specifies procedures to determine when coral spawning will occur outside the autumn mass spawning period;
3. specifies procedures to ensure that turbidity-generating activities which may impact on coral larvae survival cease at least five days prior to the coral spawning events predicted in accordance with items 1 and 2 above, on the advice of DEC;
4. specifies procedures to ensure that turbidity-generating activities do not recommence until at least three days after completion of each of the mass spawning events to allow for fertilisation, larval competency and settlement; and
5. specifies reporting procedures and protocols.

Discussion: The proponent has predicted no locally or regionally significant effects on coral recruitment at Delambre Island will occur as a result of sedimentation effects (p. 9-209). However, the planned

occurrence of dredging over periods that coincide with optimum conditions for coral settlement and early survival is considered likely to lead to a significant delay in regeneration of corals and the coral reef assemblages around Delambre Island and other islands in the proposed DAMP.

This report provides the details of the review requested in that recommendation.

The review was undertaken by Dr James Stoddart of MScience Pty Ltd. Dr Stoddart completed a PhD in 1984 in an area of coral ecology with a strong focus on reproductive biology. He has published a number of papers on coral reproduction in peer reviewed scientific journals and books, including authorship on a recent comprehensive study of reproduction in Pilbara corals. He has been involved in the study of coral reproduction and its interaction with dredging on the Pilbara coast since 2003. He currently holds an appointment as Adjunct Associate Professor of Marine Science at the University of Western Australia.

Dr Stoddart provided some advice to API during development of the PER but did not contribute directly to the assessment under review.

2.2 THE API APPROACH

API has approached the question as to whether the potential environmental risks of dredging during coral spawning are significant in two ways:

a. an assessment of the likely importance of a temporary decline in the reproductive success of local coral communities, based on the likely demographics of these communities; and

b. the prediction of how much of the outputs of a spawning event might be impacted by dredging-derived turbidity, using a numerical model predicting the occurrence of both turbidity and reproductive products during a simulated dredging event at the time of most likely coral spawning.

The basis of both approaches is examined in the following review. Where findings recommend a course of action, that recommendation is provided as guidance which should be taken into consideration in any future assessment. It is generic in nature and does not assume any specific reassessment will be undertaken.

3.0 BASIS OF THE PER ASSESSMENT

3.1 LIFE HISTORY STAGES

The "Coral Spawn" component of Section 9.3.2 of the PER follows Gilmour (1999) in categorising post-release stages into:

- fertilisation and embryogenesis;
- larval survival; and
- settlement and metamorphosis.

However, Table 9.3 of this section also presents some limited references to the potential for sedimentation to impact on gametogenesis (fecundity) and post-settlement survival. Those two aspects are not specifically addressed within the PER.

As the suggested activity stoppage contained within the DEC management recommendation, and past recommendations on this topic from EPA, focuses on a few days around the actual release of spawn, there is no capacity to affect gametogenesis (occurring over some months prior to spawning) or post-settlement survival (occurring in the months post spawning). Thus these topics appear to be outside the intent of the EPA (as judged from the content of past recommendations) and need not be discussed.

Equally, impacts on settling larvae are likely to be driven by sediment deposited prior to the spawning event: whether through the cover of settling surfaces with unconsolidated material, or the resuspension of loose sediments. Thus the proposed stoppage period would not be intended to mitigate these impacts.

The central argument within this section is based on Supporting Study 7.1 which examines the potential for elevated suspended sediment to impact on spawned gametes or coral larvae.

Finding: Based on the above reasoning, the study focus on fertilisation and larval survival is appropriate.

3.2 SUPPORTING STUDY 7.1

Supporting Study 7.1 contains a section (S.5.10) which uses a model of sediment dispersion from dredging sources to predict where suspended sediment levels will exceed nominated threshold concentrations during a period of predicted spawning. Then couples those predictions with a model of where coral spawn contained in surface waters would have travelled in the 6d post spawning.

Thresholds used here are applied at two stages. Firstly, the model of SSC identified areas in which the thresholds were predicted to be exceeded at some time within the model period [call these 'exceedence areas']. Secondly, the model of spawn movement was interrogated to determine what proportion of spawn remained within the exceedence areas for a minimum of the period specified within the threshold.

The thresholds used by the model specify an intensity-duration combination that may cause impacts for fertilisation or larval survival. These were:

> Acute impacts on fertilisation: TSS average over 3 hrs >50 mg/l;
> Chronic impacts on coral spawn: TSS average over 48hrs >25 mg/l.

The response to Query 3 (Appendix A) provides some further information on how these thresholds were derived by API/APASA. Based on that response, it appears that the intensity level of the thresholds is based on 50% of the SSC level at which impacts first appear in the two studies cited (See review Section 4). That would seem to be an acceptable precautionary approach.

However, the requirement for the impact to have a duration of 3 or 48 hours appears to be due to an incorrect interpretation of the studies cited (Gilmour 1999; Humphrey et al. 2008). For instance, the Humphrey et al. experiment was terminated 3 hr after commencing to allow sufficient post-fertilisation development such that viable embryos could be identified. There is no implication that the onset of the impact required 3 hours of exposure.

Similarly in Gilmour's study, the passage of time during the experiment on fertilisation effects serves to illustrate the impact as eggs develop to embryos rather than suggesting increasing duration of stress increases the effect. His study on larval survival shows impacts after 12 hours of exposure had reduced larval numbers by almost 90%. Continuing the experiment to 48 hours shows the loss of all larvae.

In the case of both the Gilmour and Humphrey et al. studies there is no way to determine whether the impacts noted could have been the result of a single exposure to high SSC or whether some period of exposure was required. Postulated mechanisms of effect include those which require only a single exposure (e.g. coating of a sticky egg or sperm by fine sediment preventing fertilisation) and those which have a time basis to their action (e.g. different behaviour of gametes while in elevated SSC).

Were the model predictions of SSC dispersion extended to cover areas where spawn encountered any water with an SSC >25 mg/l or 50 mg/l for a single time, there might be greater overlap with the dispersed propagules. Figure 5-26 of Supporting Study 7.1 shows when the duration-based thresholds are applied to modelled SSC predicted exceedence areas are very small and occur many kilometres away from dredging or disposal.

The response to Query 2 (Appendix A) suggests that the larger exceedence areas are caused by resuspension of sediment during abnormal weather conditions. If sediments being resuspended originate from dredging, it is likely that the dredging activity which initially uplifted these sediments occurred well prior to the spawning event and could not be managed by a stoppage during spawning.

If the duration component is removed from thresholds, areas triggering the SSC elevation would be more extensive and be focussed around the dredging and spoil disposal grounds. Under that scenario, larval sources such as the corals fringing Dixon Island might also become relevant.

Finding: The durations of impact required by the thresholds used in Supporting Study 7.1 are likely to underestimate the area of occurrence of water quality conditions that impact on fertilisation or larval survival. Exceedence areas should be estimated from thresholds based on concentration alone.

Other Model Assumptions:

1. Only March needs to be modelled
March is the month most likely to contain the greatest number of species of corals spawning in this area. Corals spawning in February or April are likely to have conspecifics spawning in March, probably at greater frequency.

A few of the species in the study area will also have some individuals in their populations which undertake some spawning in late Spring. Some species may also spawn only at that time. Of these, *Porites lutea* which is a common, sometimes dominant, inshore Pilbara species appears to spawn primarily in early summer (Baird et al. 2010). Supporting Study 7.4 notes that species of the genus *Porites* may be dominant at some sites in the study area.

Finding: The API assessment should consider whether the model predictions provided for March would be similar to those for an early summer spawning.

2. Spawn are floating
The model assumes that spawn are all in the surface waters and models SSC and transport on that basis. Some species have neutral buoyant spawn which are retained near the seafloor. These would not disperse as widely as buoyant spawn, but would potentially be subject to higher SSC.

Finding: For the majority of coral spawn, this assumption should not compromise the model predictions.

3. Impacts on fertilisation are lumped with larval survival
The model assumes that wherever spawn are subject to breached thresholds they are all lost. With a 48 hr duration for exceedence of the trigger level, this is a correct interpretation of Gilmour's larval survival work. However, demonstrated effects on fertilisation do not show an effect greater than 50%.

As fertilisation events occur quite rapidly, they will be confined to the immediate vicinity of coral communities. Thus thresholds developed for fertilisation effects need only be applied at those sites.

Finding: The model should differentiate between fertilisation effects and larval survival effects to avoid overestimating impacts.

3.3 ARGUMENTS IN THE PER OUTSIDE THE IMPACT MODEL

Several points are developed within the Coral Spawn section of 9.3.2 which support a case that this project is unlikely to have a significant effect on local coral communities via impacts on their reproductive outputs. While these points are largely valid, there are instances where other interpretations of the argument are available. The following reviews those arguments and considers whether alternative views exist.

i) *"The coverage of hard corals within the region is therefore likely to be maintained by a relatively low rate of larval settlement."*

and

ii) *"...the supply and settlement of larvae to a reef under natural conditions may be both spatially and temporally sporadic..."*

It is not known whether coral populations in this area are sustained by a small amount of settlement each year (i), or the occasional dense settlement once every now and again (ii). In either event, the consequences of additional mortality cannot be simply dismissed as unlikely to be significant. In the first case, if the SSC-induced mortality acts incrementally to natural mortality, it may push the number of settled recruits below viable replacement rates. In the second case, if the SSC-induced mortality should occur in what would have been the only viable settlement year in a decade, the consequences may be severe.

iii) "...*unlikely that impacts will be significant on a local or regional level because, excluding the shallow reef flats surrounding Delambre Island (coral cover 10% to 20%) and the relatively narrow coral slopes surrounding Delambre Island, Bezout Island and Bells Reef and along the northwest coast of Dixon Island (hard coral cover greater than 20% and 60% or less), a relatively low cover (10% or less) of hard corals was recorded within the benthic primary producer habitats of the region.."*

Supporting study 7.4 states that approximately 33% of coral communities surveyed within the study area were classified as High cover and that communities at the northern end of Dixon Island (close to the proposed dredging), contained 15-30% cover. There is no necessary conclusion that disrupting the "normal' supply of new recruits to a community is less important if the community is sparse than if it is dense.

Finding: The section's conclusion that "Impacts to one spawning event are unlikely to cause any detectable difference to coral recruitment and subsequent coral coverage" *may well be correct, however, the arguments put forward in this section of the PER are able to provide only partial support for that conclusion.*

4.0 DOES ELEVATED SSC CAUSES IMPACTS

In evaluating the level to which the PER can support an argument of 'no significant effect', it is relevant to evaluate the strength of the evidence supporting the case that elevated sedimentation does cause impacts to coral spawn.

The following discussion restricts its argument to the life history stages of gamete fertilisation and larval survival up to settlement, which are identified above as the focus of previous EPA recommendations for management. While there is considerable anecdotal studies and assertions that impacts are likely, there are only two published studies with an experimental basis for assessing impacts. These are discussed below.

Gilmour (1999) applied sediments from the Dampier Harbour to gametes and larvae from *Acropora digitifera* corals from Exmouth, WA. Sediment concentration was the only factor examined and application rates varied from nil (Control), to 50 mg/L (Low), to 100 mg/L (High). Responses examined were fertilisation success, embryonic development, larval survival and larval settlement.

Humphrey et al. (2008) studying *Acropora millepora* from the Great Barrier Reef applied a variety of sediment types at concentrations from nil to above 1000 mg/L in varying combinations with nutrient and salinity stresses. They examined impacts on fertilisation and embryonic abnormalities only.

Gilmour's study shows that both fertilisation and larval survival are strongly depressed by SSC of 50 mg/l or 100 mg/l, with no difference between the two treatments. Embryonic development was not affected by either treatment.

However, the Humphrey et al. study showed that only some types of sediment produced a decline in fertilisation rate, and then only when concentrations were above 100 mg/l. Sediments containing low levels of nutrients did not show an adverse effect on fertilisation in concentrations up to 512 mg/l. Organic levels in sediments targeted for dredging in this project (Supporting study 10.1) were generally similar to Humphrey et al.'s sediment type with the lowest nutrients, which showed no effects on fertilisation.

Both studies use larvae from species of the genus *Acropora*. Species of this genus are recognised as having life history strategies which rely on producing large numbers of reproductive propagules which suffer high mortality rates (Wallace 1985; Ramirez Llodra 2002). Wallace (1985) also notes that larval mortality of these species may be particularly high in nearshore locations. Thus the existing studies showing impacts of sedimentation on coral spawning products both target larvae from species which may be at the highest level of sensitivity to such impacts.

Finding: Evidence to support a conclusion that sediment elevation levels likely to occur at distances greater than a few hundred metres from dredging for this project have the potential to significantly impact coral larval supply is not strong.

5.0 DEC RECOMMENDATION

The alternative condition proposed by the DEC contains provisions that are not necessarily in conflict with the current view of the PER.

The PER suggests that dredging does not present a threat to coral communities through impacts on spawn if some conditions are met. However:

i. This review has suggested that the current justification for a "no significant effect likely" conclusion requires amendment based on altered thresholds and the season of spawning.

ii. The API response to review Query 1 (Appendix A) suggests that some assumptions of the PER and its model may not be able to be confirmed until quite close to the date of spawning (e.g. the spatial location of dredges and the weather).

Recommendation 19 suggests a set of conditions as a possible alternate to the 'no management' proposition. Clause 3 of that set of conditions contains a provision that would allow API to take no management action if it assessed that its specific turbidity-generating activities planned during coral spawning would not impact on coral spawn adversely.

API's modelling approach used in the PER provides one potential mechanism for making that assessment. However, any future application of that model would require the predictive model of impacts to be corrected for i & ii above. The revised model could be run using specific dredging details to ensure that the "turbidity-generating activities" planned for that period would not impact on 'coral larvae' as in the existing clause 3:

3. specifies procedures to ensure that turbidity-generating activities which may impact on coral larvae survival cease at least five days prior to the coral spawning events predicted in accordance with items 1 and 2 above, on the advice of DEC;

Some amendment to clause 4 is required to align it with clause 3. A suggested amendment is underlined below.

4. specifies procedures to ensure that <u>the turbidity-generating activities specified in 3</u> do not recommence until at least three days after completion of each of the mass spawning events to allow for fertilisation, larval competency and settlement; ....

While some uncertainty will remain in the model predictions of impact, its outputs will be no more uncertain than the current evidence that elevated SSC damages fertilisation or larval survival at concentrations under 100 mg/l or more. At the time of assessment there may also be improved information to validate the model predictions on the decay rate of dredging plumes over time or distance from dredging.

6.0 REFERENCES

Baird A, Blakeway D, Hurley T, Stoddart J (2010) Seasonality of coral reproduction in the Dampier Archipelago, northern Western Australia. Marine Biology 158: 275-285 doi 10.1007/s00227-010-1557-7

Gilmour J (1999) Experimental investigation into the effects of suspended sediment on fertilization, larval survival and settlement in a scleractinian coral. Marine Biology 135: 451-462

Humphrey CL, Weber M, Lott C, Cooper TF, Fabricius K (2008) Effects of suspended sediments, dissolved inorganic nutrients and salinity on fertilisation and embryo development in the coral *Acropora millepora* (Ehrenberg, 1834) Coral Reefs

Ramirez Llodra E (2002) Fecundity and life-history strategies in marine invertebrates Advances in Marine Biology. Academic Press, pp 87-170

Wallace CC (1985) Reproduction, recruitment and fragmentation in nine sympatric species of the coral genus <i>Acropora</i&gt. Marine Biology 88: 217-233 doi 10.1007/bf00392585

APPENDIX A QUERIES SENT TO API

Query 1 & 2 - 28 April 2011

1. In making the predictions shown in Figure 5-26, what dredges were assumed to be working immediately prior to, and during March of each year, where were they working, and what guarantee is there that they will be working in those locations during spawning periods in the actual project?

ANSWER

Refer to Appendix 2, Attachment 3 of the APASA report. Given the nominated September start, then from mid-February (week 23) the 10,000m3 TSHD will be in area (section) 1, and the CSD and the 20,000m3 TSHD will be in area (section) 2. In mid March the CSD & 20,000m3 TSHD move to area 2.
See Figure 2.7 of PER for channel sections.

Disposal to DMDA 1 and DMDA 2 (inshore & mid).
The actual timing likely to be completely different – impossible to confidently predict at this stage.

For worst-case sediment fate modelling we're re-run with December start which gives us dredging of berth pockets during calm autumn period and dredging close to Bezout during prevailing easterlies.

However, the approach to the spawning impact assessment was meant to show that even during energetic conditions (scenario 1) with a high rate of resuspension, the nominated thresholds were not often exceeded, and therefore the risk of significant impacts is low.

2. How is it possible that in Fig 5-26 both TSS thresholds are exceeded adjacent to Legendre Island, but not where the dredge is actually working or anywhere between those points?

This would be a product of the high rate of resuspension included within the initial model run (and recently removed). Scenario 1 includes multiple cyclones, so the zones around Delambre would represent exceedance of the thresholds following resuspension of settled dredge material during an 'extreme' weather event. The take home message would be that under 'normal' conditions (i.e. those in which a dredge could safely operate) surface TSS generally don't exceed the nominated thresholds (there is a small area of exceedance within DMDA2).

Query 3 – 3 May 2011

3. What was the basis of the durations of the thresholds applied to elevated TSS levels impacting spawn (p 9-208) for 3 hours (acute) and 48 hours (chronic)?

Thresholds were developed based on the best available literature.
A 48 hour threshold was developed based on the data presented in Gilmour 1999, in which impacts over this time frame are presented.
Similarly a 3 hour threshold was developed on the basis of the data presented within Humphrey et al. 2008, in which impacts to larvae development after 3 hours was determined.
The two were applied together to take account of potential short term and longer term impacts.