Independent Peer Reviews

Verification Studies

Sandpiper Project
Namibian Marine Phosphate (Pty) Ltd

November 2014

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Marine Ecosystems Management

EDUCATION DEVELOPMENT SERVICE

FOREWORD

Namibian Marine Phosphate (Pty) Ltd (NMP) commissioned J Midgley and Associates cc to project manage a marine verification work programme based on the NMP Environmental Management Programme (EMP) of the 2012 EIA, as submitted to the Environmental Commissioner on April 11, 2012. The verification programme as detailed in the EMP was expanded to include consideration of the comments on the EIA (2012) by the authorities, independent review parties (appointed by the Environmental Commissioner) and Interested and Affected Parties (I&APs).

J Midgley and Associates cc in consultation with the CSIR identified a review team with established relevant experience, high integrity and known independence from the NMP phosphate project. Their brief being to provide an independent peer review assessment of the studies that comprise of the verification programme (Appendix 4, terms of reference). In order to ensure that the reviewing parties could evaluate the reports in context of the Verification Programme they has prior access to key reports and correspondence (Appendix 1, list of review documentation), which they were required to assess prior to a two-day workshop in Cape Town (13 -14 August 2014). Their independent reports are provided herein.

The NMP specialist consultants responded to the peer review findings, and their response statements are provided (Chapter 1.2, responses).

Additionally, NMP commissioned the University of Namibia to provide an independent assessment of the processes (field work and analyses) followed during the 2013 – 2014 verification programme. The assessment was undertaken through the university's Central Consultancy Bureau (UCCB). Their report is provided herein. Their terms of reference are found in Appendix 4.

The contributions and findings of these independent reviewers, is significant, as it removes any consideration of bias that has been suggested by parties who are concerned as to the independence of the environmental assessments undertaken in the evaluation of the risks associated with the proposed phosphate project of ML 170.

J Midgley and Associates undertook the project management in collaboration with the CSIR, whose appointed representative, Mr P Morant, provided the services of Independent Programme Reviewer and Process Advisor. J Midgley and Associates compiled the report.

Jeremy Midgley (Pr.Sci.Nat)

November 2014

CSIR
our future through science

Patrick Morant (Pr.Sci.Nat)

November 2014

CONTENTS

PEER REVIEW REPORTS ON THE VERIFICATION PROGRAMME

Peer Review Report on Specialist Studies of the Verification Programme collated and compiled by Dr Andrew I. L. Payne

Dr Andrew I.L. Payne

Dr Barry Clark

Dr Michael J. O'Toole

Prof. Alakendra N. Roychoudhury

Independent review of the Verification Process compiled by Dr Samuel K. Mafwila

University of Namibia

PART 1: Peer Review Report on Specialist Studies of the Verification Programme

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EXECUTIVE SUMMARY

Peer Review Assessment of NMP Specialist Reports: Verification Programme.

Collated and compiled by Dr Andrew I. L. Payne, with input from Dr Barry Clark, Dr Michael J. O'Toole and Prof. Alakendra N. Roychoudhury

The review team (the authorship above) was contracted in mid-2014 to evaluate in an unbiased and scientifically robust manner, using their own specific scientific expertise, the various reports provided by local specialists in response to comments made on the original Environmental Impact Assessment 2012 (EIA) of Namibian Marine Phosphate (NMP) by stakeholders and reviewers. Two of the panel[1] are based in South Africa (Clark and Roychoudhury) and two are Europe-based (Payne and O'Toole), but had spent many years working off southern Africa, in both Namibia and South Africa. All four, though, have significant international experience, which they were able to bring to their expert evaluation.

The Terms of Reference for the study required that each of the appointed reviewers thoroughly read and assimilated the contents of the documentation prepared as part of the EIA (i.e. the EIA summary report, supporting specialist studies, comments from various reviewers and stakeholders, and the reports on verification studies undertaken to address comments from those reviewers (Appendix 1), to attend (Appendix 2) a two-day workshop in Cape Town (13th to 14th August 2014) where Namibia Marine Phosphate's (NMP's) appointed specialist consultants were required to present a summary of the work that they had done (Appendix 3), to prepare a report or statement (Appendix 4) on the quality and thoroughness of the various specialist studies, the relevance of datasets, opinions and conclusions of the NMP specialist consultants presented in their EIA assessments and the verification reports, and to identify if further work or assessments were required to quantify some of the risks and impacts associated with the proposed project.

A list of the specialist study topics, the lead authors, and independent experts appointed to review each topic is provided below.

[1] Consolidated CVs are presented in Appendix 5.

Topic	Lead author	Reviewers
Biomass and stock estimates Recruitment Jellyfish Ecosystem assessment	James Gaylard Dr Hilkka Ndjaula Prof. Mark Gibbons Dr Kevern L. Cochrane	Dr Andrew I. L. Payne (Team leader)
Water column and sediments	Dr Robin Carter (Lwandle Technologies)	Prof. Alakendra N. Roychoudhury
Fish, fishery, marine mammals and birds Jellyfish Ecosystem assessment	David W. Japp Prof. Mark Gibbons Dr Kevern L. Cochrane	Dr Michael J. O'Toole
Macrobenthos Meiofauna	Dr Nina Steffani Physalia, UK	Dr Barry Clark

Up front, it must be said that the client (NMP) and its supporting agencies and consultant specialists were totally open and frank about their aims and their work and were refreshingly receptive at the workshop to criticism and comment, positive and negative, about their overall *modus operandi* and findings. The target extraction area, Mining Licence Area 170, hereafter MLA 170) southwest of Walvis Bay on the Namibian shelf is an extensive one (2230 km^2), but the target area for phosphorite extraction (Sandpiper 1, hereafter SP-1) is much smaller (176 km^2), from which up to 60 km^2 will be dredged during the 20-year mine licence period. The extraction area is totally outside the 200 m isobath that limits any bottom-trawling activities on the Namibian shelf. It is also necessary here to stress that the proposed operation about which the reviewers are commenting is one of dredging of the seabed, not mining of the seabed, which by definition will include the onward processing of material extracted, in this case well away from the proposed dredge target area SP-1. Throughout the text that follows, the words "dredge" and "mine" are used alternately, but they all refer to the same activity, which is what we as reviewers were requested to evaluate, namely the dredging activity.

All four reviewers worked and provided their reports independently, though they did collaborate at the workshop and remotely subsequently. Each of the following sections were indeed drafted by each reviewer working independently, with the leader merely formatting the reports for consistency, correcting minor typographic errors throughout. However, all four reflect each named reviewer's own opinions and comments, not necessarily those of the whole team, and should not be amended in any way without their express permission. They are provided not necessarily to influence the result of the formal application, but to provide educated scientific back-up or criticism of the findings to date (August 2014).

The purpose of the Executive Summary is to provide an overview of the findings of the team at the time of writing. Some of the findings are generalities, but for ease of subsequent use and application, a bulleted list of recommendations and important suggestions drawn from each of the peer review reports is also provided. That list is made as the unanimous findings of the whole team, in other words, we support each other's views. To start, there are a few observations, including some proposals that we wish to share with the reader; these are provided below, in no particular order of priority.

- The whole expert evaluation process has, from a scientific perspective, been followed throughout its existence professionally, credibly and appropriately.
- Comments have been made in writing and verbally about the impacts of the more-extensive Namibian inshore marine diamond-extraction effort relative to that proposed in this application for phosphate mining. In our opinion, one needs to be cautious when comparing the two marine extraction exercises.
- It is gratifying to know that the positional accuracy of the dredge head and resolution of the extraction (dredging) process is (technologically) so good; being able to query the technology with the potential dredger operators present at the workshop was valuable.
- The overarching scientific disciplines covered in the specialist inputs and verification procedures are correct and complete.

- One will need to be alert to any cumulative (of mining and of mining plus other operational) impacts in future.
- Future monitoring of all key aspects including an analysis of the potential impacts on the seabed and surrounding areas of the dredging operation needs to be built into any forward-looking management plan, but it will be crucial in doing so to bear in mind potential seasonal effects and the need for consistency in the methodology, gear deployed and even the vessels used.
- Credible analyses of effect or impact cannot really be developed in opposition to or isolated from government scientists' opinions based on their official data (the latter data include the seemingly inaccessible Norwegian data collected for Namibia and stored in the database of the Nansen project). The relationship with state scientific institutions needs to be continually refreshed.
- It is recommended strongly that all specialists contributing data and analyses formally publish the outcome of their analyses as soon as feasible; peer-review adds to the scientific credibility and cannot be countered professionally.
- As with all such comprehensive and multi-disciplinary analyses as those presented to the review team here, regular, though infrequent, independent review will add to international scientific credibility.

Overall, the team finds that the response of the client to issues raised at the earlier review of the EIA through commissioning appropriate verification studies has been appropriate and laudable. The quality of those verification studies is covered elsewhere in this report, but collectively and independently, they have been carried out to the highest scientific and technical standards, using appropriate and up-to-date methodology. The results have almost without fail raised the level of confidence associated with the results in terms of likely impacts, and the team wholeheartedly confirms those analyses. A number of pertinent suggestions did arise through the course of the team's evaluation of the material presented and through discussion at the workshop. Some are mentioned in the observations above. However, for the sake of completeness, the proposals below are taken from the texts of each of the reviewing parties, and where appropriate commented upon, with their order here reflecting generally their mention in text. Some, of course, were mentioned by more than one member of this review team (i.e. appear in more than one review), meaning that suggestions had to be merged, so do not reflect a specific order of priority of either a specific review team member or the team as a whole. The client and his advisors are urged strongly to consider them carefully, either now or during implementation of any management plan established for consideration as part of the application by Namibian national decision-makers.

1. It is recommended that future dredging operations be authorized only within an adaptive management framework (i.e. coupled with intensive monitoring and careful scrutiny of such monitoring data by independent experts and the authorities) and that the authorities retain the right to require that the scale or scope of dredging be adjusted or that additional mitigation measures be implemented to ameliorate any unforeseen impacts that may arise.
2. Potential cumulative impacts arising from any future expansion in phosphate mining/dredging in the region will need to be considered by the authorities in their own right, or at the minimum a clear body of evidence will need to be presented that can confirm that the probability of there being a cumulative impact of all current plus extra activities is extremely low.
3. Monitoring surveys must be undertaken by NMP after dredging has commenced to confirm that the levels of impact do not exceed those predicted.
4. It is also crucial that, by way of mitigation of potential impact on the macrobenthos and to minimize the possibility of jellyfish polyps establishing in an area, a residual layer of sediment is left on the clay footwall underlying the mineral deposit. Further and if feasible, "lanes" or areas of sediment be left untouched; these two exercises will together facilitate the re-establishment of benthic macrofaunal assemblages on the substratum.
5. Although the current scientific output indicates no such likelihood that it will be a problem, any potential risks arising from ingestion by fish and other fauna of trace heavy metals bound to sediment or organic matter in the water column or on the seafloor should be evaluated by means of laboratory-based sediment toxicity studies.

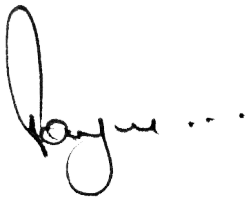
6. The review team is concerned at the absence of any in-depth analysis of the mesopelagic scattering layer in the MLA. Its presence needs to be confirmed either acoustically using a vessel echosounder or from upward-looking ADCP instrument data moored in the area. It is a phenomenon well known in Namibian waters, and some information needs to be provided in the documentary evidence to be provided in support of the application. The potential impacts of sediment plumes (physical and biogeochemical) on this scattering layer (which could comprise zooplankton, myctophids, other bathypelagic fish, bearded gobies and/or jellyfish) need to be evaluated now given the significant biomass of zooplankton that migrates through the water column and its importance in the ecological functioning of the pelagic environment off Namibia.
7. The water column report needs to include a preliminary model applicable to the SP-1 dredging area using data on current measurements and sediment properties that have already been collected in the vicinity, to demonstrate the distribution, dispersal and sinking rate of plume sediments. Such a model can be developed further as additional data are gathered during environmental monitoring and dredging operations.
8. The collection in future of site-specific sediment dynamics data would support a better understanding of how MLA 170 will be responding to cumulative anthropogenic and natural effects there.
9. Sulphide dynamics will be important, so a better understanding needs to be sought during the operational phase of how oxygen consumption will be affected by the reduced (dredged) sediment reservoir.
10. Attempts should be made to calculate a geo-accumulation index relative to average marine shale, in order to determine whether there is preferential deposition of trace and heavy metals in the target area.
11. In terms of confirming the reproductive dynamics of the commercially important demersal fish species in MLA 170, with focus on the target dredge area SP-1, it will be necessary to monitor on an ongoing basis the reproductive biology of hake and monkfish in the area, collecting appropriate samples as part of a future management plan that includes sample monitoring.
12. Consideration should be given to establishing a zooplankton time-series in and adjacent to SP-1; Such additional information is not crucial to the submission of a dredging application and management plan for SP-1, but would aid the evaluation of future applications in the same or adjacent areas.
13. Two of the review team are concerned at the high value of 7% (of all Namibian monkfish recruits) calculated for MLA 170. That value needs to be checked carefully, but in any case a sampling strategy needs to be devised to seek any evidence of there being a regular influx of young monkfish into the area (they do not appear to be spawning extensively there) to support such a high value calculated for the recent sampling years.
14. The recent CapFish biodiversity verification survey was well designed and fulfilled, but it used a net designed to catch bottom fish and particularly monkfish, so would not have captured many, if any, mesopelagic or bathypelagic fish. The same area in the 1970s was important for mesopelagic fish such as lanternfish, so the biodiversity report needs specifically to state that those fish were not available to the survey because of the selectivity of the monkfish-dedicated trawl sampling gear. Future sampling in the area (to be integrated into the monitoring programmes established for any operational phase) would benefit from at least a few samples being taken of fish scattering layers, deploying if feasible a research midwater trawl (RMT) to prove or disprove their presence in the area. Such information, positive or negative, would supplement the biodiversity baseline dataset compiled from the recent survey.
15. Acoustic monitoring needs to be integrated into future monitoring programmes and undertaken at the proposed extraction site to determine background noise levels and to monitor any local whale or dolphin populations. Ideally, this should be initiated before any dredging takes place, though not necessarily before submission of the revised application. Doing so with passive acoustic monitoring devices (PAMs) is a standard international technique when extraction or abstraction of water on an industrial scale is being considered for the marine environment.
16. Efforts must be redoubled to gain access to the valuable datasets collected off Namibia by the RV "Dr Fridtjof Nansen" programme. Some of those data (especially those collected around MLA 170) could be subjected to rigorous scientific analysis in future to support the current analysis; ideally too, the full

Nansen datasets should be made available to the marine science community of the Benguela region and also preferably released into the public domain.

17. In future, effort should be made in the impressively conceived reproductive dynamics work to follow annual cohorts through the samples. This may prove particularly rewarding in terms of pelagic fish, and will certainly enhance confidence in the conclusion currently drawn that marine resources are not being damaged by such industrial-scale activity on part of the Namibian shelf.
18. Although ecosystem modelling is in its relative infancy and in this context currently not able (for reasons of inherent modelling projection uncertainty given the scale of dredging, scarcity of data and their resolution) to evaluate the potential impact of the proposed dredging, its use should not be written off, especially if there is future expansion of phosphorus-mining. Monitoring data collected from this project should be earmarked for future contributions to input data for ecosystem modelling assessments, with the collection of high-resolution data.
19. In terms of the biodiversity survey, regularity and consistency of methodology, gear, vessel and season needs to be maintained and the survey established within the management plan proposed.
20. Effort should be redoubled to coordinate NMP-supported and official Namibian survey effort in future, if the licence to operate is granted.
21. For now, no further meiofaunal surveying is considered necessary, but baseline data have been established, so occasional sampling and comparison with these baseline data during a future operational phase could be revealing.
22. Perhaps in future, given the availability of these new data, the Namibian authorities will be able to commission an exercise to evaluate whether there are any specific lessons that can be learned about the ecosystem effects, including recolonization, plume dispersal and sedimentation rates, of marine industrial mining/dredging as an additional anthropogenic effect on the Namibian shelf.
23. Effort should be escalated in future to try to integrate any impact models from the current extraction proposal exercise with similar assessments undertaken on the fishing industry and the fishery, using industry, government and Nansen data. MFMR and/or the Benguela Current Commission could coordinate such an exercise, to the benefit of understanding water dynamics throughout Namibia.

To conclude, the review team is impressed by the quality of the information provided to it and believes that all avenues and disciplines of concern relating to the proposed operation in SP-1 have been addressed adequately. The policy decision on whether to proceed is a national one, but we can say that the information provided to us has convinced us that everything points to there being a minimal impact of the proposed operation, should a licence be granted, to the Namibian shelf ecosystem.

Finally, we thank the client and his advisors for entrusting us with this important evaluation and for allowing us to meet with the NMP-appointed specialists providing the background scientific information and to quiz them intensively at the two-day workshop in Cape Town.



Dr Andrew I.L Payne

August 2014

1.1 INDEPENDENT ASSESSMENTS

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Peer Review Assessment of NMP Specialist Reports: Verification Programme.
By Dr Barry Clark

Background

I (Dr Barry Clark of Anchor Environmental) hereby declare that, prior to being asked to review the specialist reports, I had no involvement with this project or the various surveys undertaken by the NMP-appointed specialists. I have not been involved previously with NMP in any capacity, and my review is provided in my capacity as a marine scientist. I understand that Namibian Marine Phosphate (Pty) Ltd (NMP) through their Sandpiper Project (SP-1) is seeking environmental authorization for recovery of phosphate-enriched sediments from Mining Licence Area 170 southwest of Walvis Bay, Namibia.

This chapter focuses on macrobenthos and meiofauna, but it also briefly addresses the other specialist studies that were undertaken as part of the EIA. Brief comment is also provided on the EIA as a whole, and specific comments on each component are included in the respective sections below.

General comments

It is my considered opinion that the quality of all of the specialist studies undertaken as part of the original EIA and of the verification study were of a very high standard and present a thorough and objective assessment of the likely impacts of the proposed mining project on the environment including all existing uses thereof within the limits of available information and knowledge, including that which can reasonably be obtained within the framework of such a study. This said, it must be acknowledged that the level of confidence pertaining to the assessment of impacts in many of the specialist studies prepared as part of the original EIA was limited by the paucity of information available from the mining site itself, and that the specialists were required to make inferences about conditions at the site and the attendant faunal communities present there, based on proxy-variables, data from nearby sites, and historical data. This was, almost without exception, clearly acknowledged by the authors of the original reports. Much of this uncertainty was, however, resolved through the verification surveys which, more than anything else, served to improve confidence levels in the assessments, and also provided a good deal of valuable baseline information on the site itself.

Collectively, this body of work has, in my opinion, confirmed that potential risks and impacts of phosphate mining *at the level proposed* for this project are within acceptable limits. However, given the sensitivity of the project it is recommended that any future mining operations only be authorized within an adaptive management framework (i.e. coupled with intensive monitoring and careful scrutiny of such monitoring data by independent experts and the authorities) and that the authorities retain the right to require that the scale or scope of mining be adjusted or that additional mitigation measures be implemented, to mitigate any unforeseen impacts that may arise.

The only aspect that I see has not been adequately dealt within the scope of this EIA study is the issue of cumulative impacts associated with phosphate mining. Such an assessment of cumulative impacts was, for

the most part, dismissed as being impossible without a rigorous assessment of the ecosystem impacts of fishing, the effects of which are felt throughout the region. Although I recognize that the impacts associated with commercial fishing operations in the region are not well quantified or necessarily well understood, this cannot be used as an excuse to avoid considering the issue. Potential cumulative impacts arising from any future expansion in phosphate mining in the region need to be considered in their own right, or at least a clear body of evidence needs to be presented that can confirm that the probability of there being a cumulative impact is extremely low (because of economic or logistical constraints for example).

Macrobenthos

Potential impacts on macrobenthos were addressed in specialist study reports prepared by Dr Nina Steffani commissioned as part of the original EIA and as part of the verification study. The specialist study report prepared as part of the original EIA was conducted primarily at a desktop level, but it included some data from a once-off survey undertaken in the SP1 target area (one of three target areas in the MLA). That report was reviewed by two independent experts, one of which was very complimentary ("an excellent specialist study") whereas the other was highly critical and highlighted numerous perceived deficiencies in the report ("severe lack of data needed for accurate impact assessment, the presence of unsupported concepts or claims, outdated methodology and terminology, misinterpretations, faulty logic, inconsistencies and a failure to consider key issues and concepts relevant to the assessment of phosphate mining impacts").

I acknowledge that there were some deficiencies in the original EIA report (mentioned below) and that the dataset on which it was based was somewhat limited, but I found the report personally to be of a high standard and believe that it represented a thorough and objective assessment of the likely impacts of the proposed mining project on benthic macrofauna communities in the MLA and surrounding areas. I am in agreement with key findings from the study that can be summarized as follows:

- Impacts on macrofauna populations are likely to be permanent (to last >20 years) owing to habitat loss (sediment removal) and changes in sediment structure associated with mining activities, which will, in all likelihood, result in residual sediments being colonized by a species assemblage that is different from that there currently. However, the extent of the affected area is small relative to the available habitat of this nature in the region, and macrofauna communities in the affected area are not unique (widely spaced samples showed a high level of similarly in terms of their faunal assemblages, and all species recorded are found elsewhere in the region, albeit in differing relative abundance).
- Ecosystem level impacts (through the foodweb) will to a large extent be ameliorated through "functional" recovery of the macrofauna communities (i.e. residual sediments are likely to colonized by different species that will fulfil the same role in the ecosystem). There is a good deal of evidence available to support this conclusion, some of which was cited in the report.
- The authors recommend that monitoring surveys be undertaken after mining had commenced to confirm that the levels of impact did not exceed those predicted in the report. The author also recommended that, by way of mitigation, a residual layer of sediment be left on the clay footwall underlying the mineral deposit and that, if feasible, "lanes" of sediment be left untouched, both of which would facilitate the re-establishment of benthic macrofauna assemblages on the substratum.

I fully supported the recommendations presented in the EIA specialist study report but I do harbour some minor reservations relating to the fact that there was no direct evidence to substantiate conclusions regarding the low significance of impacts associated with the remobilization of nutrients, trace metals and hydrogen sulphide that may be present in the sediments.

Further surveys and assessments on the benthic macrofauna assemblages in the MLA were undertaken as part of the Verification study, which included the collection of an additional 15 samples from SP1, and analysis of fauna retained on sieves with a finer mesh than that used in the original surveys (designed to address concerns raised by the one reviewer). Data from the verification survey served to reaffirm conclusions

from the original assessment and improved confidence in most of the impact projections (mostly from other sampling activities undertaken as part of the verification survey including assessments of hydrogen sulphide and nutrient levels in sediment, and the bioavailability of trace metals in the sediment). The verification study showed clearly that there was little value in employing a set of sieves finer than that used in the original survey (1000 μm mesh) because the increase in the number of species collected as a result of this innovation was negligible.

Meiofauna

The absence of any data on meiofauna populations in the MLA was identified as a critical gap in the original EIA by one of the reviewers of the macrofauna specialist study. The rationale for this was that meiofauna reportedly often dominate (and can be considered more important than macrofauna) in oxygen minimum zones (OMZs) because of their small body size. Physalia, UK, were appointed to undertake a survey of the meiofauna in the MLA. Samples were collected form 26 sites in and adjacent to SP1, and all fauna were identified to Operational Taxonomic Units (OTUs) owing to the lack of taxonomic data for the region. The authors of that report examined patterns in community structure in relation to environmental variables (depth, sediment properties, trace metals) and compared the results obtained with those from the North Sea. Community structure of the meiofauna assemblages in the MLA were (unsurprisingly) different from those in the North Sea and appear to respond in a similar manner to prevailing environmental gradients, as did the macrofauna assemblages studied by Dr Steffani.

Although the study may have been a seminal study one on meiofauna in the region (given the dearth of work on this group in the region to date), it appears that few (if any) new insights were gained from the analysis. No comments were presented on the likely impacts of the mining activities on meiofauna, but the authors did express the opinion that meiofauna assemblages could provide a robust means of assessing and tracking any changes in the seabed habitats associated with the proposed mining operations. Personally, however, I remain to be convinced as to how this would add significant value over and above that which could be obtained from monitoring macrofauna populations, which have been much better studied in the region and, I suspect, can be monitored in a more cost-effective manner.

Jellyfish

Potential impacts of the project on jellyfish populations in the region and also of the potential impacts of jellyfish on operational activities were assessed in a specialist study prepared by Prof. Mark Gibbons from the University of the Western Cape as part of the original EIA. That study presented a thorough assessment of the potential risks and impacts of the project on jellyfish populations, and vice versa. The author concluded (correctly in my opinion) that the risks to the project operationally were in all likelihood greater than the risks to the jellyfish populations in the area.

Water column and sediments

A desk-level specialist study was commissioned on this subject as part of the original EIA (prepared by Dr Robin Carter) and additional field surveys and assessments were undertaken as part of the verification study (by the same author). In my opinion, the specialist study commissioned as part of the original EIA represents a thorough assessment of the potential impacts of the mining project on the water column and sedimentary environments in and around the MLA. I am comfortable with the main findings of this study (including the stated significance level of all impacts identified and the level of confidence expressed in the assessments). That notwithstanding, my level of confidence in the risks and impact as identified was limited by lack of data from the MLA particularly in respect of hydrogen sulphide levels in sediments (and the risks associated with their flux into the water column), the abundance of (and hence potential impacts to) sulphur bacteria in the sediments, and the levels of trace metals and nutrient in the sediments (and the risks associated with their release into the water column).

The field studies and analytical work undertaken as part of the verification study was designed to answer many of these questions. The study was well designed and well executed, and the data collected can assist in

resolving most of the concerns expressed already, greatly improving confidence in the assessments as presented. The author recommended that intensive monitoring be undertaken during the operational phase of the project (mostly of water column parameters), a notion that I support fully.

The only residual concerns or uncertainty I have with this specialist study pertains to the issue of the remobilization of trace metals from deeper sediments. Studies undertaken as part of the verification programme indicate that levels of trace metals in underlying sediments in the MLA are high (in excess of accepted guideline or even observed effect levels) but that the risks of these trace metals being released into water column is, in all likelihood, low (because of low solubility or the fact that these metals are rapidly scavenged by other species in the water column after their release). This study did not, however, adequately address the potential risks arising from ingestion of trace metals bound to sediment or organic matter either in the water column or on the seafloor by fish and other fauna. The only way to address this issue satisfactorily would be through laboratory-based sediment toxicity studies.

Ecosystem impacts

Dr Kevern Cochrane was commissioned to undertake a specialist study on the potential for using ecosystem models to assess the impacts of the proposed mining activities as part of the verification programme. This study was well executed. Dr Cochrane looked at a range of ecosystem models that had been applied in the region and was able to conclude that none of the existing models have the required level of resolution to assess impacts associated with this project (mostly because of the low resolution of data available for the region and the small size of the affected area). The models did, however, provide some comfort in that they indicated that impacts on "target" species (i.e. those that might be directly affected by the mining activities) are generally greater than on "non-target" species (i.e. that the impacts of the mining activities are likely to be "damped" rather than exacerbated as they propagate through the foodweb or ecosystem).

Dr Barry Clark

August 2014

1.1.2 Dr Michael J. O'Toole

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Peer Review Assessment of NMP Specialist Reports: Verification Programme.
By Dr Michael O'Toole

Background

I (Dr Michael O'Toole of Marine Ecosystems Management, Ireland) hereby declare that, prior to being asked to review the specialist verification reports, I had acted as external independent reviewer of the NMP specialist's EIA reports, appointed by the Ministry of Environment and Tourism. I have not been involved with or consulted on any of the various verification surveys or related assessments undertaken by the NMP-appointed specialists. I understand that Namibian Marine Phosphate (Pty) Ltd (NMP) through their Sandpiper Project (SP-1) is seeking environmental authorization for recovery of phosphate-enriched sediments from Mining Licence Area 170 southwest of Walvis Bay, Namibia.

Formally, I (Dr O'Toole) was asked to review the background and specialist reports on jellyfish, ecosystem assessment, and the all-embracing (Dave Japp *et al*.) fish, fishery, marine mammals and birds work. For the latter, it was necessary to look at the original and verification reports on higher taxa, including the reports on recruitment and on biomass, and also to review what was presented on biodiversity at the site. A short analysis of the ecosystem assessment report is presented, and although the jellyfish presentation is not concentrated upon *per se*, it is covered under the heading plankton, which was regrettably not highlighted as requiring great attention in the original request. Beyond these items, and because of its importance in the general ecosystem, comment is also provided on the water column and sediment work to supplement the analysis of other members of the team.

Water column and sediments (Lwandle Technologies)

This review provides an account of the results of the verification survey carried out by Lwandle Technologies (Pty) Ltd as a follow up to the Namibian Marine Phosphate (NMP) Environmental Impact Assessment (EIA) recommendations for a verification survey contained in the original marine ecology specialist report (Water Column Studies) submitted in 2012.

The need for the verification survey was viewed as essential to more accurately determine the risk assessment of mining/dredging activities on the water column and benthos and was also strongly advised by independent reviewers. The latest survey gathered further independent empirical data in the mining area on currents, water column characteristics and sediment properties including macrofauna and meiofauna and thiobacterial assemblages. Monitoring of environmental conditions included the deployment of an ADCP (acoustic Doppler current profiler) mooring at the site for a period of three months.

Results on current speed and direction supported earlier estimates, with northwest flows at the surface (peak 30 cm s^{-1}) and poleward/equatorward flows at the bottom with average velocities of 9 cm s^{-1} and 30 cm s^{-1}, respectively. Water masses in the region were dominated by South Atlantic Central Water with an upper mixed layer 20–30 m deep, weak thermocline and very low oxygen near the seafloor (hypoxic).

Turbidity levels were low in the upper water column and somewhat higher at the seafloor. Short-term high level turbidity events (>350 NTU) were recorded periodically at the bottom but were generated outside the

area and advected through the site. Nutrient concentrations in the water column were in line with those previously reported for the region with dissolved heavy metals close to detection levels.

Surface sediments throughout the survey area consisted of silty sand with silt dominating in subsurface layers. Inorganic nutrient levels in the sediments averaged 156 μg l^{-1} for nitrogen and 209 μg l^{-1} for phosphorus, with low overall water content. The oxidative state of the sediments showed that they were hypoxic with data analysis suggesting low sulphide fluxes.

High concentrations of heavy metals were found in surface and subsurface sediments with elutriation tests indicating that negligible proportions enter the dissolved phase and hence are not readily bioavailable. Iron was abundant in both sediment layers. The natural concentrations of metals in the sediment exceeded the sediment quality guidelines for the region but do not represent a toxicity risk either *in situ* or during physical disturbance.

Macrofauna and meiofauna were abundant in the overlying and subsurface sediment, quite typical of hypoxic sediments and inconsistent with sulphidic sediments. Benthic infauna such as *Prionospio* support a stable sediment environment despite periods of very low bottom oxygen. Large sulphur-reducing bacteria of the genera *Thiomargarita*, *Beggiatoa* and *Thioploca* were absent from bacterial assemblages found at sampling stations but smaller forms such as *Thiobacillus* with relatively low growth yields were present.

The report concluded that the main findings of the EIA produced in 2012 were supported by the results of the verification study which confirmed that the majority of the potential impacts associated with the dredging activities are likely to be physical rather than biogeochemical in nature. As a result, the level of confidence in relation to environmental impact assessment risks rises from a rating of medium-to-high to simply high.

General comments

1) It is a high quality, well-written verification survey report that contains new and detailed information on the central Namibian shelf region and the dynamic processes affecting the marine environment within the MLA.
2) The rich benthic macrofauna, meiofauna and overall biodiversity (supported by trawl survey results) in the MLA indicate a stable benthic community. The absence of large sulphur-reducing bacterial mats in the region confirms that although the bottom levels of oxygen are low, it is not an anoxic environment as found further inshore in the "mud belt".
3) The heavy metal issue and biogeochemistry needs further clarification. Stakeholders need to be assured that once the sediment is disturbed by dredging, heavy metals will not enter the food chain. Simply saying that there is a low release of metals into the dissolved state or that they are not bioavailable for very long periods is insufficient; the issue needs to be clarified and quantified further. The statement that "although the natural concentrations exceed the sediment quality guidelines for the region…they do not represent a toxicity risk either *in situ* or following physical disturbance" is not that reassuring. Perhaps this should be stated in a different way or explained better. The heavy metal issue is potentially one of the most important environmental impacts associated with the mining activities and it needs evidence-based scientific findings to support the conclusions.
4) The occurrence of the scattering layer in the MLA needs to be confirmed either acoustically using a vessel's echosounder or from upward-looking ADCP instrument data moored in the mining area. This phenomenon is well known in Namibian waters. A paragraph or two on the scattering layer should also put the issue into context. The potential impacts of sediment plumes (physical and biogeochemical) on the scattering layer (zooplankton, myctophids, other bathypelagic fish, bearded gobies and jellyfish) does need to be addressed given the significant biomass of zooplankton that migrate through the water column and their importance in the ecological functioning of the pelagic environment.
5) The EIA water column report needs to include a model for the SP1 dredging area using the data that have already been collected to show the distribution, dispersal and sinking rate of the plume

sediments. The bottom sediment is known to consist of silty sand and silt and there are data on average current speed and direction and presumably sinking rates of various size fractions of sediment. A preliminary model could be constructed at this stage using the data collected at the proposed mining site and perhaps later re-adapted from one used in the diamond mining industry. Such a model can be developed further as additional data are gathered during environmental monitoring and mining operations. If such a model of plume dispersal and sinking rates is not included, stakeholders may conclude that the risk assessments are suspect.

Fish recruitment and stock dynamics (Ndjaula)

The study investigates the reproductive dynamics of six commercial fish species in Namibian waters and the potential importance of the Namibian Marine Phosphate MLA as a region of significant spawning and recruitment. The species considered are Cape hake and deep-water hake (*Merluccius capensis* and *Merluccius paradoxus*), monkfish (*Lophius vomerinus* and *Lophius vaillanti*), horse mackerel (*Trachurus capensis*) and sardine (*Sardinops sagax*).

The assessment examines the existing data collected on gonad maturity and spawning condition from Ministry of Fisheries and Marine Resources stock assessment surveys carried out from 1999 to 2012. The data analysed were collected throughout much of the region, including the MLA. The analysis includes temporal and spatial stock structure, maturity development and depth profiles where necessary. Gonadosomatic index (GSI) is used as a proxy for spawning and historical information is presented on the distribution and seasonal abundance of eggs, larvae and juveniles. Lengths and maturity stages of fish are presented by latitude and month using standard classification techniques for determining reproductive condition.

The results of the analysis indicate that sardine, horse mackerel and Cape hake spawn for the most part outside the proposed mining area farther north on the shelf. The data support historical information on the distribution and abundance of eggs and larvae and indicate that the MLA is not a significant spawning area for demersal species such as Cape hake and monk. There are also no indicators that suggest that it is a region of significant recruitment. Although Cape hake with more advanced gonads were present in the MLA, they were more widely distributed in deeper water outside the region. Further, gonad and length frequency analysis of commercial species from within the MLA showed no special reproductive characteristics relative to other Namibian waters where cohort analysis indicates a mix of small and large fish for most areas.

General comments

1) This is a comprehensive study that analyses large datasets on length frequency and stages of maturity of a number of commercially important fish species in stratified layers along the Namibian coast. The report is well structured and provides strong evidence-based findings that indicate that the NMP MLA does not feature as a significant spawning or recruitment site for pelagic species such as sardine, horse mackerel or anchovy or for demersal species such as hake or monk.
2) There may be some spawning of Cape hake and monk in the MLA depending on oceanographic processes and environmental conditions. However, the overall spawning intensity would be regarded as low relative to the amount of spawning taking place outside the MLA.
3) Historical information on the seasonal occurrence, distribution and abundance of fish eggs and larvae, i.e. the SWAPEL surveys, support the evidence derived from the reproductive dynamics analyses provided in the report. The MLA is located at the southern end of the Cape hake spawning grounds with the main breeding area to the north and the nursery grounds for larvae and juveniles being farther inshore.
4) Considerable changes in the pelagic ecosystem will have taken place in the northern Benguela Current region over the past decade following the collapse of the sardine and anchovy stocks. However, the main drivers of plankton production, i.e. upwelling in the south in winter and the mixing and southern movement of the Angola– Benguela front in summer/autumn, remain the same. Horse mackerel spawning probably still peaks from January to March in northern Namibian waters and the main Cape

hake spawning grounds are likely to be centred on the central Namibian shelf between Cape Cross and Conception Bay.

5) To my knowledge, little is known about the seasonal occurrence or distribution/ abundance of the early life stages of monkfish; very few larval stages of monkfish were identified in the SWAPELS samples of the 1970s. The reproductive dynamics suggest that adult monkfish spawn wherever they are distributed throughout the central Namibian shelf. Larvae may be carried inshore to nursery areas where they grow and later migrate as juveniles out to the grounds offshore.
6) Interannual environmental variability and decadal Benguela *Niño*s can play a major role in the reproductive dynamics and movement of fish, the timing of spawning events, the distribution of eggs and larvae and recruitment. Spawning patterns and the strength of recruitment to the fishery will change leading to fluctuations in year-class strength and biomass.
7) The author of the report highlights the need to continue to monitor the reproductive biology of hake and monkfish in the MLA as part of any future environmental management plan. I concur with this and suggest trying to incorporate such work routinely as part of the MFMR annual biomass surveys. Monitoring could also include the collection of zooplankton samples at some stations.

Biomass and stock estimates of hake and monkfish (Gaylard)

The report provides biomass and stock estimates of hake and monk in the NMP MLA. The study is designed as a supplement to support information provided by Japp and Smith (Capricorn Fisheries) in the original EIA (2012) submission. It focuses on estimating the fish biomass contribution of three important commercial species (Cape hake, deep-water hake and monkfish *Lophius vomerinus*) within the proposed MLA in relation to trawl catches over the rest of the Namibian demersal fishing grounds.

The biomass of the fish species was estimated using demersal survey trawl data provided by NatMIRC for the years 2007–2012. The data were extracted from 28 spatial strata over 7 depth divisions separated by 4 degrees of latitude within the fishery. The densities were weighted up in proportion to the areas of contribution of these strata to the area of the MLA and the SP1 mining site in particular.

The results of the analysis showed that the Namibian Marine Phosphate MLA contained <2% of the Namibian biomass of Cape hake; this reduces to <0.2% within the SP1 site. The greatest proportion of juvenile Cape hake were between 23 and 26°S, with most at depths of <200 m. Adult deep-water hake were scarce in waters <300 m, with younger fish south of 26°S. For the Cape monkfish, it was estimated that up to 2% of the Namibian biomass was in the MLA but that much of the mature stock was in deeper water farther south. It was estimated that up to 7% of young monkfish (recruits?) inhabit the MLA, most between 250 and 300 m deep. The SP1 site holds ~0.2% of the young monkfish.

The assessment concluded that the SP-1 mining site makes no significant contribution to recruitment of subsequent spawning stock biomass for any of the three species considered in the analysis and that the broader impact on the commercial fisheries for these species if scaled outside the mining area is likely to be tiny.

General comments

1) The report provides a robust analysis of the biomass and stock sizes of hake and monkfish in Namibian waters and the proportion of the fisheries that occur in the NMP MLA. The analysis of data is thorough and carried out in a professional manner using standard methodologies and approaches.
2) The findings and conclusions provide evidence that Cape hake and monkfish do live in the proposed dredging area but that they make up only a small proportion of the overall commercial stock of those target species in Namibian waters. The figures given in the estimate tables include 95% confidence intervals.
3) The estimate of 7% of monkfish recruits occurring in the MLA seems high. Monkfish are distributed widely over the central and southern Namibian shelf and the evidence of high influx of young monkfish into that particular area may need to be validated to ensure that the estimate is realistic.

4) It is likely that the MLA is not an important recruitment area for monkfish because young fish are found widely throughout other areas of adult distribution off Namibia. The process of recruitment *per se* can only be truly estimated if cohorts are followed through from monk spawning aggregations and the distribution of the eggs and larvae over time.

Plankton (Lwandle Technologies)

This report provides a comprehensive desktop literature review of plankton in northern Benguela Current continental shelf waters encompassing the proposed mining site of Namibian Marine Phosphate off central Namibia. It was produced in response to comments by independent experts that insufficient attention was paid to zooplankton and ichthyoplankton in the original Environmental Impact Assessment (EIA) submitted to the Namibian government.

The report compiles and collates available scientific information on the biological oceanography and the seasonality of phytoplankton, zooplankton and ichthyoplankton in the area. It describes the physical and biological processes involved in the seasonal production of plankton off the coast and provides separate summaries on historical research information on phytoplankton, zooplankton and ichthyoplankton populations both along the shelf, across the shelf and in the water column.

Within central Namibian waters, phytoplankton communities are dominated by diatoms and to a lesser extent by dinoflagellates. Diatoms tend to dominate the more inshore areas and dinoflagellates are more important offshore. Within the diatom group, the species *Chaetoceros* spp., *Rhizosolenia* spp., *Planktoniella* spp., *Nitzschia* spp., and *Asterionella glacialis* tend to be the most common. Other species such as *Delphineis karstenii, Thalassiosira* spp., and *Coscinodiscus* spp., are also present with some species blooming under favourable conditions. Within the dinoflagellate group, *Ceratium* spp. and *Peridinium* spp. Are the most common. Research shows a strong seasonal signal in terms of phytoplankton biomass, chlorophyll *a* levels and distribution, and the intensity of upwelling. Productivity increases during summer and early autumn off the coast of central Namibia and drops during the cooler upwelling months. In the MLA, low phytoplankton biomass would be expected in winter and spring, with an increase in productivity in summer and autumn following the reduction of upwelling and increased stratification in the upper layers

Zooplankton production peaks during summer from November to December and there is a secondary peak in autumn from March to June coinciding with maximum phytoplankton biomass. The dominant copepod species in the waters off central Namibia are *Metridia lucens, Rhincalanus nasutus, Calanoides carinatus* and *Centropages brachiatus*, all of which peak during later summer and early autumn. The euphausiid shrimps *Euphausia hanseni* and *Nyctiphanes capensis* also have similar seasonality and distribution. Seasonal zooplankton production is strongly linked to the slackening of upwelling and increased phytoplankton availability, with widespread interannual variation in patterns of distribution and abundance depending on oceanographic conditions and environmental variability. Farther south off the coast of Lüderitz, where upwelling is more perennial, there is less phytoplankton production and little seasonality in zooplankton biomass.

An account of the historical information on the seasonal occurrence and distribution of ichthyoplankton, particularly those of commercially important fish species, is given, describing key spawning and nursery areas. The monthly SWAPEL surveys of 1972–1974 indicated that small pelagic fish such as anchovy and horse mackerel spawned mainly in northern Namibian waters in late summer and autumn between 30 and 70 km offshore. Sardine spawned twice a year from August to April with the earlier spawning taking place south of Walvis Bay and later spawning in northern waters. The numerically dominant larvae of the bearded goby *Sufflogobius bibarbatus* were found mainly south of Conception Bay in the shallower waters between 5 and 20 km from the coast, with greatest spawning activity near Hollams Bird Island. It was widespread throughout the region with peak larval abundance in late spring and early summer. The West Coast sole (*Austroglossus microlepis*) supports a small but important local fishery and has a relatively short spawning season with a seasonal signal of larval abundance inshore from early spring to summer. Cape hake spawn

from spring to late summer with peak larval production from October to December on the central shelf between Cape Cross and Conception Bay.

Later work on fish egg and larva abundance by Spanish and Norwegian researchers in Namibian waters confirm the general seasonal trends in spawning patterns although it is recognized that the ichthyoplankton community assemblages can be complex and composition and seasonality driven by environmental conditions and hydrological factors.

The author highlights the interannual variation in phytoplankton biomass, but notes that it is not very significant over time. However, interdecadal environmental variability, i.e. Benguela *Niños*, can have significant effects on productivity resulting in a reduction in the abundance of phytoplankton. The interannual variability in zooplankton is also influenced by the intensity of upwelling as well as the size and abundance of the foraged prey items. Warm-water intrusions from Angola associated with Benguela *Niños* can also have a marked effect on the variability on abundance, distribution and diversity of zooplankton species.

In addition to long-term variability as a result of changes in environmental conditions, the overexploitation of many of the commercial fish stocks off the coast of Namibia has influenced long-term variability in ichthyoplankton abundance and community composition, resulting in regime shifts in the northern Benguela ecosystem. Environmental anomalies together with overfishing of pelagic stocks such as sardine and anchovy as well as heavy exploitation of hake (to a large extent by foreign fishing vessels) during the 1970s and 1980s resulted in a collapse of those stocks. In recent years, hake stocks have begun to improve as a consequence of more effective and cautious management. Horse mackerel stocks have also steadily increased, but sardine and anchovy biomass remains at a very low level. Given the significant changes that have taken place in fish populations within the northern Benguela over the past few decades, corresponding changes are bound to be reflected in the structure of the ichthyoplankton fauna.

The review also points to the complexity of ecosystem functioning and the importance of phytoplankton, zooplankton and ichthyoplankton in the Benguela system where the upper levels of primary and secondary consumers are entirely dependent on the planktonic communities. However, many of the trophic studies and models for ecosystem functioning have been derived from inshore water, where production and consumption estimates are a lot higher than offshore.

In the summary, it is concluded that northern Benguela upwelling off Namibia supports a productive ecosystem with a great abundance of phytoplankton, zooplankton and ichthyoplankton. The distribution of the species differs with temporal and spatial variations affected by the occurrence and intensity of upwelling (especially off Lüderitz) in the south and the mixing and interaction of the Angola–Benguela front in the north. It is also pointed out that much of the plankton biomass is inshore and that there is a gradual decrease in the production of phytoplankton and zooplankton farther offshore.

In relation to the proposed MLA, it is concluded that the region is not an important spawning or nursery area of commercial fish. Zooplankton tend to peak at the shelf-edge and may be seasonally abundant locally depending on oceanographic conditions. However, the species in the area are likely to be widespread through the central Namibian shelf region and not particularly unique.

General comments

1) The report provides a comprehensive review of information on phytoplankton, zooplankton and ichthyoplankton in the northern Benguela Current. It also describes the oceanographic processes that drive plankton productivity and presents data on the temporal and spatial distribution of plankton over the central Namibian shelf. The review is well researched and referenced, drawing on much of the key historical work in relation to plankton in the region.

2) The conclusions that the plankton population within the MLA is typical of the region with species widely distributed throughout the northern Benguela is supported by historical research findings published in the peer-reviewed literature
3) Evidence that the MLA is not an important spawning and nursery area for commercial fish is also strongly supported by the results of historical plankton surveys carried out off the Namibian coast. This is especially true for pelagic species such as horse mackerel, anchovy and sardine as well as for demersal species such as Cape hake, monkfish and West Coast sole, which spawn closer inshore and farther north and south.
4) Scattering layers comprising dense concentration of copepods, euphausiids and jellyfish as well as bearded gobies and myctophid lanternfish are common through the northern Benguela especially in deeper waters and along the shelf edge. These members of the zooplankton community form an important component of the pelagic ecosystem and undergo diurnal vertical migration through the water column to upper layers at night and sink deeper by day. These scattering layers have strong acoustic signals and can be observed by echosounders. It is likely that they occur throughout the MLA at night and that they will be impacted locally by dredging or mining operations, especially sediment plumes. It is also worth noting that the larval stages of the lanternfish *Lampanyctodes hectoris* were common along the shelf edge during the SWAPEL surveys and were particularly common in the MLA. However, the trophic structure of the northern Benguela ecosystem may have changed significantly since these surveys were conducted in the 1970s and the larvae of this species may no longer be common there.
5) Given the importance of the scattering layer and the potential impact of sediment plumes on these concentrations of zooplankton and bathypelagic fish, I suggest that a paragraph or two be added to the report to provide further information on the zooplankton scattering layer.
6) In the event of the licence being approved, any future environmental monitoring plan should include the collection of zooplankton at a few selected stations some of which should be outside the area being dredged. Samples can be taken in the upper 50 m using Bongo nets and analysed elsewhere in southern Africa if NatMIRC does not have the capacity to do so. The samples would serve as a baseline on composition and biomass and need only be collected during routine fish biomass estimate surveys and can be done in partnership with NatMIRC aboard their own vessel (NMP providing equipment and scientific personnel).

Fish, marine mammal and seabird verification report (CapFish)

This report relates to a follow-up verification process that was recommended in the original Environmental Impact Assessment undertaken by CapFish in March 2012 and supported by the independent review process to assess the potential environmental impacts of the proposed offshore extraction of phosphate from the Namibian shelf.

The report consists of a number of components, including the following, each submitted and presented separately:

1) An assessment of Fisheries Biomass and Stock Assessment (Gaylard 2013). This work estimates the contribution of the MLA and surrounding waters to the Namibian biomass of Cape hake, deep-water hake and monkfish (*Lophius vomerinus*).
2) An assessment of Ecosystem Impacts (Cochrane 2013). This review examines the likely impacts of dredging and related operations on the broader Benguela Current ecosystem within the context of trophic modelling.
3) An assessment of Recruitment (Ndjuala 2014). This study analyses the size and maturity stages of some commercial fish i.e. sardine, horse mackerel, Cape hake and monkfish as a way of identifying recruits (juvenile fish) as well as spawners. It also looks at the reproductive dynamics in relation to spatial and temporal gradients as well as depth.

A brief review of the above assessments together with some comments has already been provided as part of this Chapter.

The main part of the verification report is devoted to a Biodiversity Verification Survey, which focuses on biological information, fish stock structure, recruitment, physical and oceanographic parameters, as well as seabirds and marine mammal occurrence and abundance both within the SP1 target site and the overall MLA. The survey's main aim was to collect data to verify as far as possible information provided in the EIA and to establish a useful baseline for future surveys and to track possible changes within the system associated with the proposed dredging/mining activities.

In all, 24 trawl stations were carried out in the SP1 mining site or the overall MLA but were constrained to depths of 200 m or greater because trawling in shallower water is prohibited under Namibian legislation. Trawls (30-min tows) were carried out by day and night and catches of fish, invertebrates and epibenthic animals were subsampled, counted, weighed and measured. Environmental parameters were measured at each station using a CTD and marine mammals and seabird sightings were made by day visually within 500 m of the vessel.

A total of 14 fish species including two squid species (*Todarodes angolensis* and *Todaropsis sagittatus*) and one shark (*Hexanchus griseus*) was identified, with Cape hake dominating the catch, amounting to 40% by weight of the total. This was followed by monkfish, 35%, rattail (*Coelorinchus simorynchus*), 14%, West Coast sole, 3%, bearded goby, 2%, and horse mackerel, 0.4% of the total fish catch. Cape hake, monkfish and gobies were found in most of the trawls and there was little variation in the catches of commercial species across the survey area. Most female monkfish were immature, but many of the female Cape hake had active developing gonads.

In all, 14 taxa of epifauna were collected by the bottom trawl, including crabs, ascidians (sea squirts), brown sponges, sea pens, mantis shrimps, starfish and whelks. The colonial ascidian (*Molgula* sp.) was numerically the most dominant bottom living organism, contributing to 60% of the catch during the survey. This was followed by the pennate sea pens (family Veretellidae), which made up 37%. Both these groups were found widely distributed over the area surveyed. The low biodiversity in epifauna including crustaceans and echinoderms may indicate poor tolerance to oxygen-depleted bottom water.

Jellyfish, particularly *Chrysaora fulgidia* (known locally as the red jelly) were very abundant in some trawl catches.

Fifteen species of seabird were recorded during the survey, of which 45% were white-chinned petrels (*Procellaria aequinoactialis*), 20% subantarctic skuas (*Catharacta antarctica*) and 12% black-browed albatrosses (*Thalassarche melanophrys*).

Only two species of marine mammal were observed during the survey, the Cape fur seal (*Arctocephalus pusillus pusillus*) and the dusky dolphin (*Lagenorhynchus obscurus*). Dolphins were most abundant found along the eastern edge of the SP1 area, whereas seals were less abundant but widely distributed.

Hydrological data collected during the survey indicated a well-mixed layer of South Atlantic Central Water with typical winter values for temperature and salinity and low oxygen levels near the seafloor.

General comments

1) The report is very professional, comprehensive and useful, providing a wealth of baseline data in relation to fish stock biomass and structure, recruitment, benthic biodiversity and the presence of seabirds and marine mammals in the MLA and particularly SP1 site.
2) The methodology used, the results and the deductions made from the findings in terms of stock structure, recruitment and biodiversity and potential impacts of mining on the biota are credible and

supported by evidence-based scientific data collected during this survey and supported by other studies. These include:

- The impact of the dredging process on key commercial species is estimated to be low given that the proposed dredging area is small relative to the known distribution and biomass of these species, particularly of Cape hake and monkfish over the rest of the central Namibian shelf.
- The MLA and SP1 contain some juvenile hake and monkfish that ultimately would have entered the main fishery in the region, with greater numbers of young monkfish than of hake. The data are consistent with what is known and there appears to be no unique spawning and recruitment characteristics. Impacts on hake and monkfish recruitment and the fishery as a whole is regarded as low.
- Fish biodiversity at the MLA is generally low relative to other areas of Namibia and there is a paucity of species especially in the case of small pelagics, i.e. sardine, anchovy and horse mackerel, which are usually not abundant anyway in the region.

3) The survey report recorded no mesopelagic fish species in trawl catches and therefore concluded that they were of no consequence in a risk assessment. However, this deduction is misleading. SWAPELS ichthyoplankton data of the 1970s showed that the MLA was a region of especially high abundance of the myctophid lanternfish *Lampanyctodes hectoris*. This species was concentrated in the upper layers at night and formed an important component of the scattering layer along with gobies and euphausiid shrimps. They would not have been caught with the monkfish gear used for the survey! To sample them, it would be necessary to deploy a midwater trawl with fine mesh or an RMT (research midwater trawl), Methot or Bongo net at night. Although the trophic structure of the northern Benguela has undergone massive change over the past few decades, bathypelagics (gobies + euphausiids) are probably still fairly widespread through the MLA and would need to be taken into account in any assessment of the impacts of sediment plumes from mining operations.
4) With regard to the biodiversity (demersal fish species, epifauna, mammals and seabirds) and ecosystem impact as a whole, the results of the survey suggested no unique feature. Jellyfish were common and abundant in the water column and ascidians (sea squirts) were frequently abundant on the seafloor, which is typical for the area. Interannual and seasonal variation in the abundance of species is likely through the region, depending on fluctuating environmental and oceanographic conditions.
5) The survey has strengthened the need to maintain a baseline dataset and to monitor it to detect any possible changes in the system around the area to be dredged. This suggestion is strongly supported and should form part of any future environmental plan in the event of a licence being issued for the area. Negotiations could be held with MFMR to incorporate such baseline monitoring into their annual hake and monkfish stock assessment surveys.
6) In my earlier review of the CapFish EIA Report (2012), I stressed the need to undertake some acoustic monitoring at the site to determine background levels of noise and to monitor whales and dolphins using passive acoustic monitoring devices (PAMs). Marine mammal observers could be trained to use such devices and could be a part of a monitoring team on board the mining vessel or during dedicated monitoring surveys.
7) The impacts and ratings given in the report for the effects of mining operations on commercial fisheries, fish recruitment, ecosystem trophic functioning, benthic biodiversity, seabirds and mammals are considered to be appropriate. Raising of some of ratings to a higher level of confidence relative to the earlier EIA report would seem to be justified based on the result of this verification survey.
8) The extensive data collected by the RV *Dr Fridtjof Nansen* surveys off the Namibian coast over the past decade provide a valuable record of pelagic and demersal fish distribution, abundance and biomass. Epibenthic fauna taken in bottom trawls were also recorded on those surveys and entered into the Nansen database. Efforts should therefore continue to allow these data to be released for future scientific analysis and if possible made available in the public domain. Future cooperation with NatMIRC would probably go a long way to opening up this treasure trove of information on the pelagic, demersal and epibenthic communities of Namibian shelf waters.

Ecosystem impacts (Dr Kevern L. Cochrane)

This short study provides an expert opinion on some of the models currently being used in the Benguela for ecosystem-based management (EBM). It also reviews their effectiveness and use for assessing possible effects of dredging/mining activities on the broader ecosystem as a whole. It was carried out in response to the need to include an understanding of ecosystem impacts of dredging activities, which was a weakness identified in the EIA (2012). Trophic modelling and integrated assessments are also important to consider given the fact that an EBM strategy has been agreed by the countries of the region through the Benguela Current Commission (BCC), which views the implementing of an Ecosystem Approach to Fisheries Management (EAF) and the adoption of the Precautionary Principle as key policy objectives. Understanding the trophic interactions of various components of the ecosystem and the assessment of the impacts of anthropogenic activities on trophic functioning are therefore an important overall objective. They include the assessment of the impacts of fishing, seabed mining and oil and gas extraction on the ecosystem as well as proposing ways to ameliorate their effects.

The assessment of ecosystem impacts is a complex process that needs to take into account both direct and indirect effects of mining activities on all the biota in the immediate environment and surrounding ecosystem. This includes top predators as well as species lower in the food chain than target fisheries resources, including benthic organisms removed by the dredging. It also requires detailed understanding of the trophodynamics of the foodweb as well as knowledge and understanding of the possible impacts of other activities taking place nearby including trawling, seabed mining for diamonds, and oil and gas exploration and extraction.

A short review is given of some of the current trophic models developed and used in the Benguela Current ecosystem (Roux and Shannon 2004, Heymans and Sumaila 2007, Shannon *et al*. 2000, Shin *et al*. 2001) including Ecopath with EcoSim and OSMOSE. Limitations and shortcomings in some of the models are also highlighted, especially in relation to fisheries.

Although some trophic modelling has been done that can be applied to the Benguela system as a whole, much of the development and application work has centred on the southern Benguela. It is also pointed out that regarding the status of modelling in Namibian waters, no conclusive models or data are available yet that can be used to obtain a more-informed assessment of the impacts of anthropogenic activities on the ecosystem.

The report points out that ecosystem modelling can be useful in investigating ecosystem impacts by either natural or anthropogenic activities on a part of the ecosystem. However, there are significant limitations with regard to interpreting impacts attributable to the scaling effect and the extent to which dredging in a limited area may impact on the broader ecosystem.

It is concluded that the combination of great uncertainty typically associated with projections by ecosystem models and the small area that would be impacted by the proposed dredging operations means that it would be unlikely that ecosystem modelling could expose any unexpected or highly significant threats that have not been already been considered in the specialist studies.

General comments

1) This is a very useful overview of the status of trophic modelling in the Benguela system and highlights some current limitations with respect to their application in an assessment of ecosystem impact in relation to proposed seabed dredging. The modelling typically done is unlikely to provide any useful direction on either a large scale or localized impacts as determined by the EIA. The change in rating proposed by Japp and Smith (2014) for ecosystem impacts from low–medium to high based on this report seems fully justified.
2) Further work needs to be done in relation to the development and application of trophic modelling in the Benguela system in order to improve EBM and to more adequately assess the impacts of fishing,

mining and offshore oil and gas exploration and production on the integrity of the broader ecosystem as a whole.

3) Lessons learned from the marine diamond mining industry off the west coast of South Africa and off Namibia need to be evaluated and made more readily available. De Beers, Namdeb and other companies have had seabed mining activities in the Benguela system for well over a decade. There must be a wealth of information on ecosystem impact, recovery rates for recolonization by benthic organisms, plume dispersals and models, sedimentation rates and various oceanographic data. Environmental monitoring, audits and reporting to government will have been part of environmental management plans as part of conditions for licence approvals. Such information if made available in future can be integrated with similar assessments undertaken to date on the fishing industry and the fishery, using industry, government and Norwegian-collected Nansen data. MFMR or indeed the Benguela Current Commission would be best positioned to coordinate such an undertaking.

4) In the longer term, the cumulative effects of seabed dredging for phosphorite (in the context of and considering other anthropogenic activities) on the trophic structure of the northern Benguela ecosystem would need to be addressed should licensing for phosphorite along the Namibian coast be approved on a larger scale.

Dr Michael O'Toole

August 2014

1.1.3 Dr Andrew I. L. Payne

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Peer Review Assessment of NMP Specialist Reports: Verification Programme.
By Dr Andrew Payne

Background

I (Dr Andrew Payne of A&B Word Ltd (UK) and an associate of the UK's Centre for Environment, Fisheries and Aquaculture Science (Cefas)) hereby declare that, prior to being asked to review the specialist reports, I had no involvement with this project or the various surveys undertaken by the NMP-appointed specialists. I have not been involved previously with NMP in any capacity, and my review is provided in my capacity as a marine scientist. I understand that Namibian Marine Phosphate (Pty) Ltd (NMP) through their Sandpiper Project (SP-1) is seeking environmental authorization for recovery of phosphate-enriched sediments from Mining Licence Area 170 southwest of Walvis Bay, Namibia.

I, (Dr Andrew Payne) was contracted to lead a team of expert reviewers tasked with evaluating specialist studies developed and carried out to supplement earlier work that provided the basis of an Environmental Impact Assessment of Namibia Marine Phosphate's (NMP) application to dredge for phosphorite in MLA 170 southwest of Walvis Bay, Namibia.

In addition to leading the team and chairing the workshop convened to consider the recent specialist studies, I also had to familiarize myself fully with the tranche of documentation that had already been produced, in terms of both the formal application developed by NMP and the initial studies of 2012. This proved to be quite challenging, because although I have broad knowledge of Namibian fisheries and southern African marine science in general, gained from 30 years spent in the region, as a researcher and subsequently research leader and policy advisor in both Walvis Bay and Cape Town, much of the documentation was outside my own specialist field of fisheries and ecosystems. Notwithstanding, I was asked specifically to focus on four areas, biomass and stock estimates, recruitment, jellyfish, and ecosystem assessment. All four of these works had been commissioned as supporting evidence to the initial EIA, largely because of suggestions made by the two independent reviewers contracted to consider the scientific validity of that work, and especially the confidence associated with the findings. They also feed into and are taken up in other recent work commissioned for the same purpose, so unsurprisingly I also make a few comments on other studies in the suite.

This brief report contains my own views and its content should not be ascribed to any other author nor altered substantively without my consent.

General

I was impressed with the scientific rigour and appropriateness of the recently commissioned work. It was all well-conceived and planned, always conducted using the best methodology currently available, and delivered impressively within a short space of time. However, this short space of time within which the work was conducted might be creating false comfort for the applicant and ultimately the decision-makers in that the marine environment (and its resources) is always dynamic and hence regularly changing; off Namibia,

the dynamicism is in fact greater than in many other geographic areas worldwide. Therefore, all of the results of the recent work have to be considered as applicable to the window of time during which the surveys and deployments were undertaken rather than as exemplifying the situation off Namibia generally. Seasonal, annual, decadal and even longer-term changes will occur in such a dynamic environment, and will continue to do so even during the operational period should the licence be granted. Some support for the conclusions can be gleaned from the impressive historical data for Namibia collected during the 1970s (e.g. SWAPEL surveys within the Cape Cross Programme) and subsequently by NatMIRC and the Norwegian Nansen Programme during regular trawl and environmental surveys of the Namibian shelf, but it is well documented that historical changes have been taking place there over thousands of years, even preceding anthropogenic activities (e.g. see the analysis of seabed cores for fish scales carried out in the late 20th century).

Notwithstanding what is said above, it is my overall opinion that the output from the work demonstrates that the risks to the ecosystem and Namibian fished and non-fished marine resources generally of undertaking phosphate dredging in the area proposed (a very small part of MLA 170 known as SP1) are small. Succinctly, therefore, and with the supportable levels of confidence stated in the recent works, the impacts of the dredging activity on the Namibian marine environment generally will almost certainly be insignificant in the greater scheme of things on the Namibian shelf.

I note, though, that the effects of anthropogenic activity should be considered cumulatively if further industrial-scale activity is proposed for the Namibian shelf. There is already an established and mature fishery (for pelagic fish, for demersal fish and for crustaceans such as rock lobster), a part of the shelf inshore off southern Namibia is being mined for diamonds, and another potential area of seabed has provisionally been assigned to another applicant to extract phosphorus-rich sediments. All except the last of these three uses of the shelf are ongoing, i.e. their effects can be taken into future consideration cumulatively with that of the current application although evidence currently is that the ecosystem can entertain allowing the two current ones plus the new single use associated with phosphorite extraction, but if further phosphorite extraction is licenced in another area of Namibian seabed, then the cumulative effect of the added disruption to the ecosystem may provide a tipping point beyond which the authorities would not wish to, or should not, move. I am aware that market forces themselves (i.e. there is an upper point not much greater than the current world levels of production at which phosphorus extraction will become subeconomic) may limit future expansion of the extraction currently proposed, but the Namibian authorities will need to be sensitive to cumulative impacts if further activities of this nature are proposed in future.

I now provide brief comments on the four studies assigned to me for consideration, along with a few brief comments on the other ones for which I have the necessary expertise.

Biomass and stock estimates (Gaylard)

The author focuses on the two species of hake and the main species of monkfish. All are subject to rigorous stock assessment by Namibian scientists and managed by the authorities according to strict guidelines on sustainability. That is appropriate because, although none of the stocks are currently certified by the Marine Stewardship Council (MSC), they may wish to seek such certification in future in order to gain greater formal entry to the lucrative European markets some of the production currently targets. That is how the South African deep-sea trawled hake gets into the European markets.

The report provided for consideration is based on the analysis (by formal strata – 28 over seven depth divisions) of the data collected for formal stock assessment during the years 2007–2012, i.e. not collected specifically for the purpose of the exercise here. Nonetheless, the analysis is, in my opinion, appropriate for the task in hand, and, although some of the assumptions made may be open to question, the best possible use of the data is made. An inherent assumption made in the work is that the distribution of the resources off Namibia are fairly uniform and that they can be adequately sampled by means of a random stratified sampling survey, which is the methodology used by Namibian scientists.

Nonetheless, the numerical basis for the assessment is acceptable scientifically – other algorithms could have been used for the analysis, but they would have been subject to similarly questionable assumptions of appropriateness. However, given that no "hotspots" of the target resources were found in the biodiversity survey of Japp and Smith, a "quasi-uniform" distribution assumption is feasible in this case. That Cape hake and monkfish do live in the MLA and even in SP1 is not questioned, but the assessment clearly shows that the proportion of the Namibian stocks of each that do so is small, although the 7% monkfish calculation for MLA 170 would seem to be rather high. This value needs to be checked, though it could be the result of the uniform distribution assumption across the southern Namibian area.

In all respects, however, it is my opinion that the results of the analysis show that dredging in area SP1 will not have an undue effect on any of the main commercial species analysed here. The Cape hake stock is anyway protected by fishing being constrained by law to deeper than 200 m, and deep-water hake do not comprise a large resource except in southern Namibia.

Reproductive dynamics and stock distributions (Ndjaula)

This report was commissioned under the title "Recruitment", noted as an important issue by the reviewers of the first EIA in 2012. However, the author was immediately forced to define that term and presents three definitions before engaging in a discussion of the reproductive dynamics of six species off Namibia, two species each of hake, two of monkfish, and one each of horse mackerel and sardine. As a practitioner of fisheries science, I should point out that the definition of recruitment strength as the number of fish of an annual cohort entering the fishery is the only one that should be entertained, however, because it is on that basis that fishery management decisions are taken. While the term "recruitment" may be used widely in the scientific literature, it is difficult to evaluate except through a formal stock assessment process based either on cohort progressions or independent survey results, so the best value of this type of work in the context of the current application is in its focus on the general ecological processes associated with the reproductive dynamics of the target species.

The report analyses official data for the whole of Namibia for the six species listed from 1999 to 2012 in terms of spatial (including by depth) and temporal trends in stock structure and maturation stage, using the gonadosomatic index as a proxy for spawning state. The output is presented as length/maturity plots by month and latitude over the study period. The results are credible and useful for the decision-making process here. Again, however, it must be stressed that the resource dynamics now (i.e. 1999–2012, the years for which the data were analysed in this report) may well be different from the historical situation, even as recently as the 1970s and 1980s, when vast quantities of very good scientific data were being collected off Namibia. Natural resources fluctuate naturally over time, and what was apparent even 20 years ago may not be applicable now.

In any case the conclusions of the work are that horse mackerel, sardine and Cape hake currently spawn north of MLA 170 and that none of the target species use the proposed dredging area currently as a focus for spawning activity. That is not to say that mature fish of some of the species do not occur there, indeed mature hake and monkfish are found, but the contribution such fish make by reproduction to the pool of juveniles that will ultimately recruit to the fishery is tiny. The area should not, therefore, be categorized as a focus spawning area for any of the species. No spawning of deep-water hake has yet been identified off Namibia, so that species' reproductive dynamics will almost certainly not be affected by seabed dredging.

Looking at the data presented, the quantity and quality of which are impressive, I would suggest that future work look at following annual cohorts through the annual samples. Doing such an analysis now will not add much to the conclusion that dredging in MLA 170 and especially the target site SP1 will have little effect on the spawning populations of any of the species analysed, but in time (particularly for pelagic fish) could strengthen further the conclusion.

Jellyfish (Gibbons)

Jellyfish, mainly the two large species *Chrysaora fulgida* and *Aequorea forskalea*, are common in Namibian waters, and estimates have been made that their combined biomass exceeds that of all finfish in the region. It is the free-swimming medusa stage that is best known and seen, and they are most common inside the 200 m isobath, generally in the upper 50 m of water. They are present year-round but peak in late winter/early spring, when finfish spawn (the medusa feed on the products of fish spawning).

The author of this impressive overview report makes some valid comments. First, to minimize the likelihood of jellyfish populations burgeoning, it is important that a soft layer be left on the seabed after any dredging, so that the polyp phase cannot establish itself (it requires hard substratum to do so). Second, evidence that jellyfish populations are "controlling" the populations of target finfish populations is circumstantial, but there are many in the fishing industry who believe this to be true, so every effort to minimize population growth should be made. Finally, and most important, the proposed extraction operations will almost certainly have a minimal effect on jellyfish populations generally, but the jellyfish populations may well have an influence on the operational aspect of at sea work. Succinctly, large concentrations of jellyfish may have to be avoided by the dredger if its cooling systems are to function optimally. It was gratifying to be told by the dredge operators that this issue is under control in the plans they have drawn up in the case of the application being successful.

Ecosystem considerations (Cochrane)

Any marine operation these days has to consider the ecosystem, and specifically any possible negative effects that may be promoted by anthropogenic activity in the sea. That statement applies as equally to fishing, where an ecosystem approach to fisheries management (EAFM) is being widely promoted as the optimal way to go, as it does to other marine operations. The precautionary principle too is broadly applied in fisheries management decision-making worldwide, invoking ecosystem aspects as well as direct resource considerations. Although ecosystem models have not yet made it into mainstream fishery decision-making, as the author of the report acknowledges, they are a crucial consideration in any MSC-certification exercise, and their various outputs are also cited broadly and hence considered carefully in most reputable fisheries decision-making that takes place in the developed world.

There are several ecosystem models in existence for the Benguela, but the most advanced have been developed for the southern Benguela off South Africa. Namibian waters have as yet some way to go to be able to say that the ecosystem is being managed optimally through the application of such technology. All such models are data-hungry, and the resolution of such data ideally needs to be high for the conclusions to be able to withstand robust perusal. Appropriate ecosystem data from Namibia are sparse anyway, and even rarer for the area around MLA 170. The author of the thorough report therefore reaches some telling conclusions with which I concur:

- ecosystem modelling, including spatial forms such as those he considers (e.g. Ecopath with Ecosim, and OSMOSE), can be used to investigate ecosystem impacts in the area;
- however, all such models have great uncertainty and the small area being impacted and the very small direct impacts of the proposed operation means that it would be very unlikely that any such model currently available would be able to produce reliable information on indirect impact;
- the ecosystem impacts of dredging operations in the MLA will be small in the general scheme of things relative to the direct impacts of the activity, but if direct impacts are scaled-up by future expansion of dredging for phosphate, the ecosystem impacts will be too, with possible disproportionately severe (maybe unknown) consequences;
- the direct impacts of mining in MLA 170 will be substantially greater than equivalent fishing impacts there, but far less than the current fishing impacts across the whole of the northern Benguela ecosystem.

Succinctly, therefore, current ecosystem modelling capability and the data available for the target area and even the broader Namibian shelf are unlikely together to be able to provide evidence either for or against the

effects of the proposed dredging activity. However, given the size of the area being targeted, it would be a reasonable conclusion to reach that at currently proposed levels, the effects (negative or positive) will be small.

Other reports (various authors)

An impressive volume of pertinent information has been acquired through the investigatory process undertaken to develop an acceptable EIA, and specifically recently to verify and supplement some of the findings of the initial investigations. Although not specifically required to do so in terms of my specific knowledge-base, I have made a few observations to supplement those of my fellow reviewers on the other reports presented to the workshop. These summary conclusions are listed beneath.

Marine resources, i.e. fish marine mammals and seabirds (Dave Japp and Melanie Smith)

- The baseline, i.e. the knowledge base, for Namibian seas generally is excellent, but as realized, for MLA 170 and SP1 in particular, a sound information base is crucial to generate increased confidence in impact management.
- The design of the recent biodiversity/verification survey meets international best standards and was seemingly designed to answer questions even before they were asked; the survey *has to* form part of ongoing monitoring effort, but gear or vessel modification of the survey going forward has to be minimized.
- The Namibian official surveys have a different aim (they are for stock assessment purposes) and should not be recommended for modification by proponents of the current exercise; the biodiversity effort of the recent survey should be viewed as localized and complementary to official Namibian survey effort.
- Notwithstanding the above, collaboration at the highest level with Namibian resource survey effort going forward is crucial.
- Elsewhere in the world, disruption of resources by noise/sonar is often an issue raised; this subject needs to be addressed in future planning and, if appropriate, monitoring (using passive acoustic monitoring devices (PAMs).
- The data presented in the report, and in its feeder reports (by Ndjaula and by Gaylard) indicate a limited impact of the proposed dredging activity on local resources, and even less impact on Namibian fish resources generally.

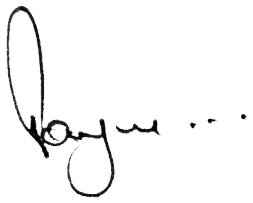
Water column and sediments (Lwandle Technologies)

- Professionally, this is a very comprehensive analysis made at both initial expert review stage and more recently at the stage of verification, with the new on-site monitoring activity.
- It is gratifying that vast quantities of data have been collected that support other aspects of the scientific evaluation, e.g. the upward-looking sounder data to support analysis of the scattering layer.
- It seems for statements made that some official (Namibian government) data are being withheld internally, perhaps for later analysis internally (e.g. scientific papers or theses). It is not for an outsider to comment upon national policy, but the international norm for release into the public arena of such data is a maximum of two years, and in most developed countries one year. Analysis of such data, particularly those relating to the water column and the sediments off Namibia, are likely going to be critical to the decision-making process of the proposed operation in MLA 170.
- Plume effects appear not to be extensive or long-lasting, and the impacts of the release of sediment heavy metals and other content is in my opinion going to be small.
- Ongoing monitoring surveys to support the assumptions and statements made in the current evaluation report are going to be crucial.

Marine benthos (Nina Steffani) and Meiofauna (Physalia, UK)

- Generally in my opinion on the basis of the report presented, marine benthos issues arising from dredging operations are likely to be localized and not critical to diversity and general abundance. However, forward monitoring (of dredged habitat and the fauna) is essential.
- Meiofauna are expensive to monitor (though not necessarily to survey), but they have the

advantage of being effective indicators of system status and change especially in oxygen-low sediments, such as those in the target area. It may well be that regular monitoring can be dispensed with, but we now have the benefit of having some good baseline data on which to evaluate changes in future, so consideration should be given to occasional (not annual) monitoring to assess changes in the meiofauna in future.



Dr Andrew I.L Payne

August 2014

1.1.4 Prof. Alakendra N. Roychoudhury

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Peer Review Assessment of NMP Specialist Reports: Verification Programme.
By Prof. Alakendra Roychoudhury

Background

Namibian Marine Phosphate (NMP) proposes to mine an offshore marine phosphate deposit. As part of the requirements, an extensive EIA for the proposed activity was prepared by the proponent and submitted to the appropriate authorities. Various concerns were raised on different aspects of the EIA report, including a lack of measurement of environmental parameters within MLA 170. As a consequence, further field-based verification surveys were conducted on different aspects, including on water column and sediment characteristics, to understand the possible impact these might have on the environment during the mining process. The data collected and their impact assessment were submitted as a specialist report in a fully referenced, scientific document format.

As part of the process, I (Prof. Alakendra Roychoudhury) was appointed to provide an independent review of the specialist report on the water column and sediments in the context of the EIA and previous concerns raised by the stakeholders and interested parties. I hereby declare that, prior to being asked to review the specialist report, I had no knowledge of this project or the survey undertaken by Lwandle Technologies (Pty) Ltd (henceforth LT). I have not been involved with NMP or LT in any other capacity and the following review is provided in my personal capacity as a Marine Biogeochemistry specialist. I have more than 20 years of experience in the field of biogeochemistry in aquatic environments including a PhD from Georgia Institute of Technology (Atlanta, USA) in marine biogeochemistry and I have published >50 articles in reputable international journals in the field. Having worked in Namibian and South African offshore environments, I am fully aware of the Benguela system and the processes therein. I have acted, for extended period, as an associate editor of the international journal "Applied Geochemistry" and have graduated a number of PhD and Masters students in the field.

My review is based on:

- a thorough reading of the report submitted by LT,
- a two-day workshop organized by NMP where the water column and sediment report and other survey reports were presented by specialist representatives followed by question-answer sessions,
- other specialist reports and the project description provided by NMP,
- various correspondence from the Ministry of Marine Fisheries and Marine Resources, Namibia, outlining their concerns to NMP.

This review report may not be modified without my consent.

Review

The report is a follow-up from a previous desktop study conducted by LT as part of the EIA. From the desktop study, it was concluded that sediments in the target mining area are predominantly of muddy sand texture. Hydrogen sulphide, methane and other chemical flux measurements are low, because particulate organic matter (POM) does not accumulate on these sediments. It was concluded that the predominant sources of sulphur in the ore body itself would be pyrite, which has low rates of dissolution; therefore sulphide would not

be readily available for formation of hydrogen sulphide. On that basis, the water quality and associated environmental risks in the MLA were considered to be mainly physical as opposed to biogeochemical.

Interested parties in Namibia raised concerns, however, that muddy sulphidic sediments would be exposed during dredging/mining with important consequences for water quality in oxygen minimum zones (OMZs) and the surrounding biota. Concerns were also raised because the previous study depended on data from regions outside the area of concern and that the MLA was within a dynamic system with variations common, both longitudinally and zonally. Other concerns pointed to a required study to assess year-long seasonal signal on water and sediment quality, exact measurement of hydrogen sulphide in sediments and of the secondary impact of the release of hydrogen sulphide, the impact of phosphate ore-dredging on the Redfield ratio of surface waters, the impact of heavy and trace metals on the foodweb over extended periods, and the behaviour of the sediment plume caused by dredging over time.

To allay these fears, a verification study was undertaken in the SP1 target area within MLA 170, offshore Namibia, to generate key sediment and water quality empirical data. The results of the survey are presented herein. Additional supporting documents, e.g. details of the analytical methods used, were also supplied for review.

The report presents the results for an elaborate set of variables measured in the water column and sediment. Water quality was measured in samples collected during six CTD deployments to produce depth profiles for nutrient, turbidity, salinity, temperature, dissolved oxygen, phytoplankton biomass and heavy metals within SP1. A mooring was also deployed to produce high-resolution time-dependent measurement over 90 days for ocean currents, temperature, salinity, dissolved oxygen and turbidity. Without access to an appropriate multicorer, sediment properties were determined in surface grab samples, and depth samples were collected using a gravity corer from 26 different sites within the target area. The suite of analyses carried out on sediment samples included tests for particle size analysis, %moisture, %loss on ignition, organic carbon, total nitrogen, heavy metals, AVS (acid volatile sulphides), SEM (simultaneously extractable metals), and porewater ORP (oxidation reduction potential), nitrate and phosphate concentrations. In addition, elutriation tests were conducted in the laboratory to determine the potential for heavy metal release from the sediment. The bacterial population was analysed using qPCR.

Although limited in time and space, significant quantities of baseline data in the target area were generated through this work. Data quality is generally good and the standard methods used for measurement provide confidence in the data. Some of the concerns raised by interested parties may not be answered with this set of data, but in my opinion, what was being requested is no simple feat to produce and in some cases impossible to achieve within a reasonable time-frame. I believe that the data request on ecotoxicity and its impact on the foodweb is unreasonable given that these are metal- and species-specific and in regions as biodiverse as the Benguela would require extensive laboratory-based experimental work over many years on each individual biological and metal species. A comparison with the sediment quality guideline for the Benguela Current system depicted in this report is the only reasonable way of understanding the impact of heavy and trace metals on the biota. It is clear that the study has produced an enhanced understanding of the biogeochemical dynamics of the system, but long-term monitoring is strongly advised so as to scrutinize the environmental impact of dredging/mining in the region.

General comments and analyses

Measurements reveal complex current patterns with velocity and dominant directions varying with depth and indicate possible changes in water masses over time. The target area is in the region influenced by both South Atlantic Central Waters that are cool, oxygenated and nutrient-rich, and warm, high salinity equatorial water. These water masses move in and out of the system and impact bottom water oxygen concentration. The 90 days of observation did not show such a phenomenon, a possible reason being some probes on the mooring not functioning during the latter part of the observation period. CTD profiles show fairly low oxygen concentration in the bottom waters (average 0.3 mg l^{-1}) in the region. If high salinity Angolan waters indeed

result in widespread OMZs, then exposure to dredged reduced sediment may further influence the consumption of oxygen in the water column.

Current velocities decreased with depth through the upper water column, but bottom currents have a velocity as high as 18 cm s^{-1}. One advantage of these high-energy currents is that they may remove surface productivity away from the area, making a pool of carbon-poor sediment in the area. One could believe that sediment biogeochemical processes under these circumstances may not be an important impact factor, as asserted previously. However, measured average carbon content of 7% and a C : N ratio varying between 11 and 19 suggests a sufficiently reactive carbon pool to be ignored. Infrequent turbidity events related to fast-moving currents were also observed. Given these high-energy currents and their ability to move sediment, the suspended sediment produced during dredging may be moved greater distances, thereby impacting larger parts of the water column. Although analyses from nearby show that the sediment-plume effect may be limited, interpretation using current measurements and sediment properties in the target area may be helpful in fully understanding the impact of the sediment plume generated during dredging, i.e. how long these sediments remain suspended and how far the sediments may be mobilized. Subject to plume sustenance, changes in redox and through biogeochemical transformation, trace and heavy metals associated with the sediment may also be mobilized along the sediment plume.

Within the period of observation in the target area, the water mass was dominated by fresh, cool, oxygenated waters. Sulphide was not measured either in porewaters or in the water column because of a lack of infrastructure on the vessel used. The oxic-anoxic dynamics is therefore not well constrained. The water column varies from oxic surface waters to fairly low oxygen conditions in bottom waters. The low bottom-water oxygen can arise as a consequence of the degradation of biomass or oxygen reacting with reduced elements refluxing into the bottom waters from the sediments. AVS measurements show low solid phase sulphide in surface sediments, but no data are available for pyrite because an assumption was made that pyrite is fairly insoluble and hence not measured. During early diagenesis in productive systems, although not as reactive as AVS, pyrite does oxidize and may be playing a role in bottom water oxygen consumption. Even though there is no benthic dissolved sulphide flux, a sufficiently large solid phase sulphide pool can have a significant impact on bottom water oxygen, another reason to understand plume dynamics in the region better. The method followed to measure AVS might also have affected the data, because it is possible that some of the AVS pool might have oxidized even before measurement as a result of the addition of oxygenated water. Although the method would have no impact on the measurement of SEM, less AVS would have been detected. I do not believe that dredging will have a significant impact on the water column Redfield ratio, and only minor phosphate enrichment will take place.

Given the Eh-pH conditions, it is no surprise that elutriation tests show little release of trace and heavy metals. If bottom waters on site remain fairly oxygenated, it would mean that metals would only be mobilized with the sediment plume, and readily available soluble trace metal will not be an issue. Their impact on the biota will only be seen if these sediment/carbon particles are directly ingested as food.

The qPCR results show the presence of diverse bacterial consortia. Both sulphide oxidizers and sulphate reducers were observed, with some facultative in nature. These bacteria can function well within a fluctuating redox environment. Even within hypoxic conditions, therefore, active sulphur dynamics can be maintained. *Thiomargarita* were not observed in the target area sediments.

Final comments

The LT team should be congratulated for producing a wealth of data from an environmentally important area. The work is scientifically sound and was performed with due care. This was not an easy task and it has considerably advanced our understanding as a basis for making informed decisions for impact assessment.

The physical nature of the sediment suggests limited impact to a wider area as a consequence of the proposed mining activity. Unfortunately, the sediment dynamics are extrapolated from observing the plume

behaviour in adjacent areas. It is important that site-specific sediment dynamics be better understood. Much of the narrative above regarding biogeochemical dynamics and their impact, to a large extent becomes significant depending on the behaviour of the sediment plume generated during the mining activity. In addition to impacting the wider area, prolonged sustenance of the plume will make biogeochemical processes important within the water column by modifying the redox status and mobilization of trace metals. Sulphide dynamics will only become important under those conditions and will require a better understanding of oxygen consumption by the reduced sediment reservoir. Then, a back-of-the-envelope calculation of the reduced sediment reservoir and corresponding consumption of available oxygen can easily be performed with the available data. I do not believe that ecotoxicity issues can easily be deciphered for the area concerned, but it may be a good idea to calculate the geo-accumulation index relative to average marine shale to determine if there is preferential deposition of trace and heavy metals in the area. The phase association of trace metals in the sediments would have improved understanding of their dynamics under changing redox conditions.

Prof. Alakendra Roychoudhury

August 2014

1.2 RESPONSES: EIA SPECIALISTS

1.2.1 Introduction

This section provides a summary of the responses of the EIA Specialists to the issues raised by the Peer Review Team. The full details of these responses are integrated into the specialists' reports, which are presented in the Verification Programme Report: Namibian Marine Phosphate Sandpiper Project Marine Licence area No. 170. November 2014.

1.2.2 Letter from Dr A.I.L. Payne