Section C.3: Fisheries and Biodiversity

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SPECIALIST STUDIES – SECTION C

C3.1 Verification Survey Report: Fish Mammals and Seabirds

NAMIBIAN MARINE PHOSPHATE

VERIFICATION SURVEY

FISH, MAMMALS AND SEABIRDS

Prepared for:
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October 2014
This report has been undertaken independently under contract to Namibian Marine Phosphate by Capricorn Fisheries Monitoring cc (Cape Town). The verification programme relates to the original Environmental Impact Assessment (March 2012) to assess the potential environmental and operational impacts of the proposed offshore dredging of phosphate. This verification assessment relates primarily to the proposed first phase of dredging in an area within the Mining Lease Area known as Sandpiper-1 (SP-1).

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SUMMARY

Namibian Marine Phosphate (Pty) Ltd (NMP) has applied to dredge for marine phosphate in Namibia, approximately 40-60 km offshore from Conception Bay. The phosphate will initially be extracted from the target dredge area described as Sandpiper-1 (SP-1). NMP has been granted a 20-year lease to dredge phosphate in this area, subject to the issue of an Environmental Clearance Certificate following the approval of an Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP). The EIA was completed in March 2012, and, the EMP called for a Verification Programme to support the information used in the EIA and to address areas of uncertainty highlighted by the NMP appointed specialist consultants and in some instances by reviewing parties, including the authorities. The verification programme would also act as a reference or datum against which the actual impacts of dredging could be monitored in the future.

In the original EIA the impacts were interpreted at different scales to assist in gauging the potential significance of the impacts relative to the proximity of the actual dredging operations. This scaling included the following zonation:

- In the target dredge area known as Sandpiper-1 (SP-1);
- In an area immediately adjacent to SP-1 and within the Mining Lease Area (MLA); and
- Thereafter at a regular interval seawards (distance) from the perimeter of the MLA

Five likely impacts of marine dredging were identified and assessed. These were as follows:

- The impact on commercial fisheries;
- The impact on the main commercial and other fish species;
- The impact of the reproductive dynamics of the main commercial fish species and the potential impact on recruitment to the fisheries in the dredged area;
- The impact on biodiversity, in particular marine fauna; and
- The impact on seabirds and marine mammals.

To address levels of confidence in the original assessment and to expedite the verification requirements as detailed in the EMP (amended following consultation with MFMR and independent reviewers).

A Verification Programme consisting of several studies was undertaken. These studies and their outputs related to fish, mammals and seabirds, included the following:

1. An independent assessment of fisheries biomass in SP-1 and the MLA was conducted by Gaylard (Section C, Chapter 3.2), (Gaylard Chapter C 3.2): The report concluded that less than 0.2% of the biomass of each species assessed in Namibian waters (Merluccius capensis, M paradoxus and Lophius vomerinus) lies directly within the proposed SP-1 dredge site. The SP-1 site also makes no significant contribution to recruitment or spawner stock biomass for any of the species considered in the biomass assessment. Outside of SP-1 but still within the total MLA, the biomass of monk expected to contribute to the fishery recruitment was estimated to be 7%. It was emphasized that the broader impact is however likely to be negligible as the proportion of the potential biomass of hake and monk in SP-1 and recruiting to the commercial fisheries in the adjacent areas is extremely small when extrapolated beyond the actual area (a 60 km$^2$ portion of SP-1, (176 km$^2$) to be dredged.

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1 1/3 (approx. 60km$^2$) of SP-1 (176 km$^2$) is to be dredged in the 20 year mining licence period
2. A professional independent review of the likely ecosystem impacts in the context of dredging within the broader northern Benguela system was also carried out (Cochrane, Section C, Chapter 3.3). The overall conclusion was that the combination of the high uncertainty typically associated with projections by ecosystem models and the small area that will be affected by the proposed dredging means that it is unlikely that ecosystem modelling would expose any unexpected or highly significant threats that have not already been considered in the specialist studies.

3. A specific study on the reproductive dynamics of the main commercial fish species was also commissioned (Nadjula Section C, Chapter 3.4). With respect to the stock structure and gonad maturation of the main commercial species the data available showed that there were no special characteristics of their reproductive dynamics in the proposed dredging area (SP-1). Further, the study showed that there was no deviation expected that would make the area unique with respect to these reproductive biological characteristics. The study also considered cohorts for all the species analysed and showed that a mix of small and large fish for most of the Namibian EEZ was typical and that for the MLA there were no indications of any deviation from this norm. In addition the study showed that the MLA was not a unique spawning area that supported significantly different levels of recruitment of the main commercial species to the fisheries in the proximity of the MLA. Monthly trends also did not indicate any gonad development beyond “maturing stage” of the commercial species found in the MLA. This supported the suggestion that fish move in and out of such grounds over time. Annual maturity trends have also not shown repeated dynamics, implying that spawning grounds for these species are not localized. Multiple cohorts observed per year and by area suggest that high and low recruitment events are a normal occurrence. This again indicated the lack of a “homing behaviour” for adults, with the boundaries for recruitment and spawning grounds not clearly defined.

4. Together with the reproductive assessment described above a detailed review of the main historical information, regarding in particular the spawning areas, ichthyoplankton drift areas and recruitment grounds from the ICSEAF papers as well reference material associated with the historical SWAPELS programme, was conducted (Japp and Smith, Section C, Chapter 3.5). The main conclusions were that horse mackerel, anchovy and sardine spawned outside the MLA. A low abundance of hake eggs occurred near the southern borders of the MLA off Hollams Bird Island although typically fish larvae were found in the MLA as well as broadly in areas across the Namibian shelf. The historical data also showed that juvenile hake and monk occurred within the MLA and in adjacent areas and that goby larvae were also abundant in the MLA.

The main part of the verification programme was an eight day biodiversity survey (Section D, Appendix 2.1 and 2.2) of the proposed target dredge area (SP-1). From the 18th – 27th June 2014, a commercial monk trawl vessel, the FV Zeearend was chartered (Appendix 2.4 & 2.5) to sample 24 stations in and around the SP-1 target dredge area, in water depths greater than 200 m. Trawls (30-min tows) were carried out, twelve by day and twelve by night. Catches of fish, invertebrates and epifauna were sampled, counted, weighed and measured. Environmental parameters were measured at each station using a CTD (Appendix 2.3). Marine mammals and seabird sightings were made during daylight within 500 m of the vessel. The specific objectives for the biodiversity survey were to establish a baseline for future monitoring and survey assessments and to collect the following:

- Abundance (density) data for the main commercial species such as hake, monk and horse mackerel;
- Biological data (length, sex, maturity stage, stomach content) from the main commercial fish species;
- Epifauna from all trawl locations;
Environmental data (using visual observations and a CTD). To establish linkages between the environment and species distribution, recruitment and abundance; and

Marine mammal and seabird data in the area;

These data were used to verify the information assessed in the EIA (Japp in Midgley 2012) and provided comparative information regarding the:

- Biodiversity reported on in the EIA;
- Size structure of the main commercial fish species compared with areas outside of the MLA;
- Biological information on the main commercial species to verify if there are any notable deviations from the information and assumptions made in the EIA;
- The spatial distribution of marine fauna, in and adjacent to SP-1 to check if there are any significant deviations from what was expected; and
- Recruitment based on size and sex structure of the main trawled species, in and adjacent to, SP-1 and to test if the results deviated significantly from that determined by the EIA.

A total of 14 fish species including two squid species (Todarodes angolensis and Todaropsis sagittatus) and one shark (Hexanchus griseus) was identified. Cape hake dominated the catch, amounting to 40% of the total fish weight. This was followed by monkfish, 35%, rat tail (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 epifauna catch weight 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. Jellyfish, particularly Chrysaora fulgida (known locally as the red jelly) were also abundant in all trawl catches.

Fifteen species of seabird were recorded during the survey, of which 45% were White-chinned Petrel (Procellaria aequinoctialis), 20% Subantarctic Skua (Catharacta antarctica) and 12% Black-browed Albatross (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 only recorded along the eastern edge of the SP-1 area, whereas seals were observed throughout the survey area.

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.

In general, the conclusions of the verification programme were that the size distribution of the main commercial species likely to be impacted (i.e. monk and hake) are consistent with what is known and with what was assumed in the initial EIA. For the area there is no evidence of unique spawning and recruitment characteristics. For M. capensis, the abundance of juvenile and pre-recruiting hake is consistent with what is known. Further, the proportions of juveniles and sex ratios (males and females) suggests no irregularities that would make the area to be dredged unique. With regard to monkfish, as expected, the verification survey has shows a mix of juveniles, adults and pre-recruiting fish. As the survey used monk-directed gear with a cod-end liner (20 mm mesh) to retain as much as possible, the proportion of juvenile fish caught was higher than would be expected. This finding was consistent also with the
biomass estimates (Gaylard, Section C, Chapter 3.2). Both the verification survey outputs and the biomass estimates for SP-1 confirm that the limited extent of the dredging (in particular SP-1) is likely to have only a very small impact relative to the overall abundance of the monk and hake stocks in Namibian waters. The impact on monk reproduction and the recruitment to the commercial fishery as a whole in SP-1 will also be minimal. Sole were also caught in the verification survey, however their abundance was not high. Further, predominantly large sole were caught suggesting that the SP-1 area and adjacent grounds are unlikely to be a significantly recruiting area for sole to the monk trawl fishery.

The verification survey provided baseline data on biodiversity. In general fish diversity was lower than reported in the EIA. This is due to the fact that in the EIA data on fish diversity were consolidated from surveys using different gear types (hake, monk, midwater, purse seine). The fauna recorded in the verification survey was notably lower than reported in the EIA since the verification survey deployed dedicated monk trawl gear, no inference from the survey can be made regarding the availability and abundance of non-demersal species such as horse mackerel, sardine, mesopelagics and gobies (noting that both gobies and horse mackerel were, however, present in small numbers).

With respect to demersal fish species mammals and seabirds, no unique features were noted and the results are consistent with the initial assessment in the EIA (recognising that the abundance of some species, particularly sea birds and mammals will vary seasonally as well as spatially). Regarding mesopelagic species, none was recorded in the trawl catches. Mesopelagic species such as lantern fish are expected in the mid-water, however the gear used would not have targeted these species. Catches between night and day varied as expected and we assume normal diurnal behavioral patterns prevail with regard to fish and crustaceans.

With respect to epifauna (McClurg, Section C, Chapter 2.6) we noted the high abundance of ascidians. Based on the experience of the skipper this was not considered unusual and was typical of the substrate on which the trawls were made. The occurrence of these ascidians was not reported in the numerous surveys used in the EIA; however there were occasional observations of ascidians recorded from the recent macrofauna surveys (Steffani, Section C, Chapter 2.5). This species could have the potential to be used as a bio-indicator for future verification surveys. Their abundance may in part be due to the very low density of historical trawling of the region and in particular in SP-1: repeat trawling over the area is likely to systematically remove this species.

With regard to ecosystem impacts as a whole, the survey suggests that the area possesses no unique features and is consistent with the findings in the EIA. The primary issue in the ecosystem context is one of scale and it is the expert opinion that the area of impact (up to 3 km² annually and 60 km² for the 20 year mining lease period) is so small relative to the overall extent of the Benguela ecosystem that significant impacts on the ecosystem are unlikely. The current state of the modelling in both the northern and southern Benguela ecosystems is also unlikely to inform any differently from what is currently known on the likely impact on the broader ecosystem if dredging were to be undertaken in SP-1.

Mesopelagic fish, gobies and zooplankton were not recorded during the biodiversity survey, thus little is known about the potential effects of marine dredging on these fishes and the scattering layer in SP-1. (Weston, Section B: 2.7) Future verification surveys should attempt to track the scattering layer patterns using industrial or scientific echo sounders in order to infer the relative abundance of these species. Samples could also be taken if mid-water trawl gear were available on the survey vessel and if the vessel had adequate power to be able to tow such gear to nullify the avoidance behaviour of these species.

Interpretation of the geophysical data (Ludick, Section D, Appendix 3.2) conclusively indicated a flat, smooth seafloor with a homogeneous surficial sediment cover across the northern part of SP-1. No protruding obstacles were observed. The surficial sediment composition of the area was a muddy medium.
sand. This was further supported by the trawl surveys suggesting that the habitat was homogeneous and primarily of firm sandy gravelly (shell) character.

Previous studies of the potential impacts of sound from dredging vessels on a variety of species showed that sound levels in all cases are well below those known to cause damage to marine life. Thus, if we assume that the sound frequency and decibel level of sound emanating from a typical Tailer Suction Hopper Dredger (TSHD) is similar to the vessel to be used at the mine site (SP-1) then dredging noise can be assessed to be a low impact.

Overall, the verification programme for the fish, mammals and seabirds component of the NMP impact assessment process confirmed that the confidence levels of the assessment in the EIA (Japp in Midgley 2012) supports the core assumptions, thereby strengthening areas of weakness and improving the confidence of the original assessments. A summary of the assessment tables, after the verification programme, is presented below. Further, the verification programme strengthened the need to maintain the baseline information to be able to monitor for changes in the system around the area to be dredged. Continuation of the survey described in the verification programme should be an integral part of the NMP Environmental Management Plan. This will facilitate the ongoing management and monitoring of the dredging operation in SP-1 and can inform on the likely effects if the dredging activities were to expand beyond SP-1, into SP-2, SP-3 or indeed other areas.

<table>
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<th>Assessment criteria</th>
<th>Fisheries</th>
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<th>Reproduction</th>
<th>Biodiversity</th>
<th>Seabirds &amp; Mammals</th>
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<td>MLA</td>
<td>MLA</td>
<td>Specific dredge site (SP-1)</td>
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<tr>
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<td>Significance (with mitigation)</td>
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It is recommended that should an environmental clearance certificate be issued that monitoring through surveys continue. This should include a similar survey using similar design, gear and vessel annually. Further the monitoring of the baseline and knowledge base can be further strengthened if NatMIRC adapted their current hake and monk survey designs to incorporate the MLA and or SP-1 areas. This would also provide MFMR with an alternative independent estimate of conditions and changes that may occur in the dredged area over time.

Regarding noise emissions from dredgers, it is recommended that some acoustic monitoring at the target dredge site (SP-1) to determine the levels of dredging noise and to monitor whales and dolphins using Passive Acoustic Monitoring (PAM) devices should be undertaken. It is also recommended that marine mammal observers are trained to use such devices to be a part of a monitoring team on board the mining vessel or during dedicated monitoring surveys.
Little is known about the potential effects of marine dredging (in particular the potential impacts of sediment plumes) on scattering layers that include *inter alia* mesopelagic FISH species, gobies, plankton and zooplankton. Thus it is recommended that future monitoring surveys should attempt to track the scattering layer patterns and trends in order to infer the relative abundance and distribution of these species. This could be achieved using industrial or scientific echo sounders.
INTRODUCTION

Namibian Marine Phosphate Ltd (NMP) has applied to dredge for phosphate offshore on the Namibian continental shelf. The phosphate deposit lies approximately 60 km offshore from Conception Bay in water depths of 190 to 300 m and covers an area of 2233 km². The phosphate will be extracted by dredging in the target mine areas described as Sandpiper-1 (SP-1). SP-1 (176km²) lies in water depths of 200 to 225 m, up to 60km² will be dredged during the 20-year mine licence period. Subsequently, upon further assessment and approval dredging may be undertaken in SP-2 and SP-3 (Figure 1). NMP has been granted a 20-year mining lease area (MLA-170), subject to the issue of an Environmental Clearance Certificate following the completion of an Environmental Impact Assessment (EIA) and an approved Environmental Management Plan (EMP). The initial impact assessment was completed in March 2012 and the EMP called for an Verification Programme (environmental baseline) to be undertaken (established) prior to mining, to act as a reference or datum against which the actual impacts of dredging could be assessed. The scope of the Verification Programme described in the 2012 EMP was augmented by integrating the recommendations from independent reviewing parties and the Ministry of Fisheries and Marine Resources (MFMR) (Section D, Appendix 4.4).

We report here on the verification process for the fish, mammals and seabirds component (Japp, in Midgley 2012: Appendix 1a. Namibian Marine Phosphate – Environmental Impact Assessment of Fish, mammals and seabirds: Proposed monitoring and verification of Impacts in the proposed Mining Area).

ENVIRONMENTAL IMPACT ASSESSMENT OVERVIEW

The displacement of the commercial fishing activities and the redistribution, survival and recruitment of fauna (fish, seabirds and mammals) could be influenced by the dredging of phosphate in several ways. For the purposes of the verification programme we have summarised the original basis for the identification and separation of each impact.

As identified in the EIA, impacts can be interpreted at different levels and or at different distances from the dredging activity. For example:

- In the immediate area - the actual area to be dredged within each of the designated areas: SP-1, SP-2 and SP-3;
- In an area immediately adjacent to the dredging site - each of these areas proposed to be dredged falls within the overall Mining Lease Area (MLA); or
- Thereafter at some distance from the dredging site - the MLA falls within the Namibian Exclusive Economic Zone (EEZ).

To assist us with the implications of scaling, especially in an ecosystem context, we selected arbitrary scales or distances from the dredging location with which to gauge the potential impact relative to the distance away from the dredging operation. These scales were described in the EIA and have been reiterated here as they have relevance to the verification process (Figure 2). These scales had no ecological basis other than to assist in the interpretation and quantification of possible impacts at a range of distances away from the actual planned dredging locations.
Figure 1: Location of the proposed target dredging sites SP-1 (20 year mine plan established), SP-2 and SP-3 within the Sandpiper phosphate licence area (ML 170).
Figure 2: Illustration of zones and areas defined in the fisheries impact assessment (original EIA) (Japp 2012).
We also identified possible effects as either Direct or Indirect that broadly included the following:

**Direct effects:**
1. Exclusion of fishing to avoid dredging, and the loss of access to potential fishing grounds;
2. The removal of habitats (or disturbance of bacterial mats, if present) utilized by marine fauna;
3. The creation of sediment plumes (turbidity) that might affect species abundance (area avoidance, mortality, loss of feeding and spawning grounds);
4. Loss of biodiversity through direct physical removal of sediment and associated loss of fauna.

**Indirect effects:**
1. Displacing the normal behaviour of fish, seabirds and mammals due to the physical disturbance of the dredging activities (including noise from the dredging operation);
2. Disturbance of normal trophic interactions and the general ecosystem functioning.

In the context of the scaling we assumed that on average, demersal trawls are three hours long at 3.5 knots – or approximating 25 km long. Based on this assumption it is reasonable to assume that fishing operations in general will have to be altered from the historical norm (Figure 1).

### 3 IMPACT CATEGORIES

We categorized our Impact Assessment into five primary impacts as follows:

1. **Impact 1:** The likely impact of dredging **ON** commercial fisheries (hake and monk demersal trawl fishery, the hake longline fishery, the mid-water trawl fishery and the small pelagic purse seine fishery). The fishing sectors will not be able to operate effectively in SP-1. In addition there will be some disturbance on the fishing operations in SP-2 & SP-3 (if and when these areas are open to dredging) due to a) the disturbance caused from actual dredging operations; b) associated sediment plumes; c) exclusion zones around the dredging site; and d) increase levels of maritime traffic associated with the dredging operation;
2. **Impact 2:** The likely impact of dredging **ON** the main commercial and non commercial fish species (hake, monk, horse mackerel, small pelagics, sole, snoek and bearded goby). The fish fauna is a critical component of the broader marine ecosystem and may be displaced and/or redistributed by the dredging operation primarily because of the a) actual dredging activities; b) habitat disturbance; and 3) sediment plumes (turbidity);
3. **Impact 3:** The likely impact of dredging **ON** the recruitment (or on the reproductive dynamics) of commercially important species (hake, monk, horse mackerel and small pelagics). The dispersal and survival of juveniles, eggs and larvae will be affected by a) physical disturbance of the habitat and consequently the fishing grounds and b) sediment plumes (turbidity);
4. **Impact 4:** The likely impact of dredging **ON** the fish biodiversity. Dredging operations will result in a reduction or loss in biodiversity because of the a) actual dredging operations, b) the habitat destruction and c) sediment plumes;
5. **Impact 5:** The likely impact of dredging **ON** seabirds and marine mammals. Dredging operations will cause the displacement and/or redistribution of seabirds and mammals due to a) noise pollution b) artificial light intensity and c) disturbance of normal ecosystem processes.

**NOTE:** With respect to Impact 1 – the effect of dredging operations **ON** commercial fisheries is NOT a biological environmental impact and relates to disturbance of fishing industry operations.
4 VERIFICATION PROGRAMME

The programme was undertaken to address the levels of confidence raised by Japp (in Midgley 2012) of the original assessment, to expedite the verification requirements as detailed in the EMP (Midgley 2012) and to attend to the issues raised by the reviewers and other responses to the original EIA (Fisheries, Mammals and Seabirds), we undertook the following:

a) Review of information and references used as well as utilizing any new or other relevant information;

b) Commissioning an independent assessment of fisheries biomass in the MLA (Gaylard, Section C, Chapter 3.2). The main purpose of this was to obtain a realistic professional and independent estimate of commercial fish biomass in the MLA and target dredge area SP-1. This would be done in lieu of not being able to do a full standardized biomass assessment as suitable vessels and gear could not be accessed;

c) Commissioning of a professional independent review of the ecosystem issues in the context of dredging within the broader northern Benguela system (Cochrane, Section C, Chapter 3.3). In particular the assessment was to review the proposed dredging and uncertainty surrounding the ecosystem impacts in the context of the current resolution of marine ecosystem models;

d) Commissioning of a specific fisheries recruitment (reproductive dynamics) assessment (Nadjula, Section C, 3.4). Reviewers’ comments suggested that the impacts of dredging require a recruitment study, which would include long-term studies. Given that the data for a long term recruitment study were not available from MFMR, the verification strategy adopted was to initiate a scientific review of the current knowledge of recruitment of the main commercial fish stocks, review any associated biological information and to interpret the information in a scientifically rigorous manner in the context of the proposed dredging;

e) In addition to fish recruitment (reproductive dynamics) to the commercial fisheries sector study, we also undertook a detailed review of the main historical data, in particular the ICSEAF papers as well reference material associated with the historical SWAPELS programme (Japp and Smith, Section C, Chapter 3.5). The aim was to identify egg and larval distributions associated primarily with the demersal and small pelagic fisheries in Namibia prior to Namibian independence;

f) The historical and current information on the mesopelagic species and the pelagic goby were reviewed to investigate the likelihood of impacts related to the proposed dredging in SP-1.

g) An investigation of the habitat of SP-1 was conducted (Ludick, Section D, Appendix 3.2). Data were collected during a geophysical survey, the seabed topography and the distribution of seafloor surficial sediments was determined using side-scan Sonar (SSS) and Multi-beam Echo Sounder (MBES) equipment (Section D, Appendix 3.1). Specific objectives were to characterise the seafloor of the target dredge area within SP-1 and also identify any obstructions on the seabed in advance of the trawl survey.

h) A review of the available information of the effects of marine noise was carried with the intention of assessing the impacts of dredging noise on marine fauna in SP-1.

i) A biological (verification) survey (Section D, Appendix 2.1) of the proposed primary target area to be dredged (SP-1) was commissioned. This investigation is designed along the lines of a standard scientific biomass survey with randomly selected trawl stations. The area of this survey would be a very small part of the broader Namibian EEZ but would respond to the concerns expressed by reviewers that the data available and provided by NatMIRC for the EIA had few historical data points in SP-1, SP-2 and SP-3. This survey would serve as a baseline as needed prior to the approval of dredging and would provide comparative data on the following:

- The biodiversity reported on in the EIA (Japp in Midgley 2012);
Results of the Verification

5.1 Assessment of Fisheries Biomass and Stock Assessment

The biomass assessment focused on estimating the contribution of the MLA and surrounding areas to the biomass of three commercially exploited finfish species: shallow water hake *Merluccius capensis*, deep water hake, *M. paradoxus* and monk, *Lophius vomerinus*. The rationale for commissioning this work (Gaylard, Section C, Chapter 3.2) was:

- In response to the uncertainty regarding the likely impact of dredging on the biomass of commercial fish species in the area to be dredged, the study would contextualize the estimated biomass of monk and hake relative to biomass estimates for these stocks in Namibian waters;
- In lieu of not being able to standardize biomass estimates from the data collected during the biodiversity verification survey the approach used by Gaylard therefore was to use the available survey data from NatMIRC scientific surveys (depth stratified and random trawls using calibrated trawl gear) and apply standard statistical techniques to estimate the relative biomass proportions in the areas to be dredged; and
- Provide an estimate of pertinent biological components of each species, in particular stock structure related to juveniles, recruitment and spawner biomass.

Details of the methodology are given in the supporting paper by Gaylard (Section C, Chapter 3.2). The work commissioned is scientifically and statistically rigorous using standard fisheries modelling and stock assessment methodology. Demersal survey data for 2007 through 2012 provided by NatMIRC were used to estimate biomass in 28 spatial strata (7 depth divisions by 4 latitude divisions) within the Namibian fishery. Densities within these strata were appropriately weighted in proportion to the spatial contributions of these strata to the MLA in general and to the SP-1 dredge site in particular.

These calculations resulted in the following estimates of the contribution of the MLA (covering an area of 2233 km$^2$) and the SP-1 site (covering an area of 176 km$^2$) (Table 1) to the various components of the fisheries resources under consideration:

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2 The commercial vessel used for the Biodiversity Verification Survey was not calibrated with the vessel and gear used for the Namibian (NatMIRC) Surveys, thus a standardised biomass estimate could not be calculated from the data collected during the survey.

3 Note: Only up to 60 km$^2$ of SP-1 (176km$^2$) is targeted for dredging during the 20 year licence issue period.
The MLA is estimated to contain less than 1.6% of the Namibian biomass for *M. capensis*, which reduces to 0.14% if the SP-1 target dredge site only is considered. No notable departure from these proportions is estimated for either the recruits or the spawning adults. The 23° to 26° latitude band is a breeding ground for *M. capensis*, and contains a large proportion of juveniles. However, the overwhelming majority of these are at depths less than 200 m, whereas most (80%) of the MLA lies in water deeper than 200 m, and the mineral resource (phosphate deposits) area within SP-1 is in water deeper than 200 m.

*M. paradoxus* adults are scarce at depths of less than 300 m, and the younger fish (less than 27 cm) are predominantly found south of 26°S. Thus the MLA and in particular the SP-1 site have very little interaction with *M. paradoxus* (less than 0.2% of biomass is in the entire MLA).

For monk, the MLA is estimated to contribute about 2% to the overall biomass in Namibia. This is lower among the mature stock (0.8%), which tends to be in deeper water and further south within the MLA. The monk recruits however, are more prevalent in the MLA than those of hake, with an estimated 7% of recruits in the MLA. Most of this contribution to recruitment however, is in the 250 to 300 m depth range and is not in the target area to be dredged (SP-1). The SP-1 site is shallower than 250 m (the target dredge area is between 225 and 200 m), and so this is estimated to contribute only 0.2% of recruitment to the fishery. We stress also that recruitment will be affected by many factors, including fishing pressure and variability in environmental and oceanographic conditions and will not necessarily remain constant from year to year.

In conclusion, less than 0.2% of the biomass of each species considered lies directly within the proposed SP-1 dredge site. The SP-1 site also makes no significant contribution to recruitment or spawner stock biomass for any of the species considered in this assessment. Outside of SP-1 and within the larger MLA, the biomass of monk expected to contribute to the recruitment to the fishery is estimated to be 7%. Note that this estimate relates only to the spawner biomass in this total area and not to the spawner biomass in SP-1 (which is < 0.2%). Further, note that recruitment to a fishery is highly variable and dependent on many factors other than actual spawner biomass, including fecundity and conducive environmental conditions. This quantitative assessment can therefore not make any biological judgement on the possible impact of dredging on recruitment to the fishery in

### Table 1: Percentage biomass estimates for monk and hake in MLA and the SP-1 site

<table>
<thead>
<tr>
<th></th>
<th>MLA</th>
<th>95% Confidence Interval</th>
<th>SP-1</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Area</td>
<td>1.3%</td>
<td></td>
<td>0.11%</td>
<td></td>
</tr>
<tr>
<td>% of Biomass <em>M. capensis</em></td>
<td>1.6%</td>
<td>(1.3%, 2%)</td>
<td>0.14%</td>
<td>(0.1%, 0.18%)</td>
</tr>
<tr>
<td>% of Mature Stock <em>M. capensis</em></td>
<td>1.6%</td>
<td>(1.1%, 2%)</td>
<td>0.11%</td>
<td>(0.07%, 0.16%)</td>
</tr>
<tr>
<td>% of Recruits <em>M. capensis</em> (by No.)</td>
<td>1.6%</td>
<td>(1.1%, 2.2%)</td>
<td>0.20%</td>
<td>(0.12%, 0.28%)</td>
</tr>
<tr>
<td>% of Biomass <em>M. paradoxus</em></td>
<td>0.01%</td>
<td>(0%, 0.035%)</td>
<td>0.00%</td>
<td>(0%, 0.01%)</td>
</tr>
<tr>
<td>% of Mature Stock <em>M. paradoxus</em></td>
<td>0.001%</td>
<td>(0%, 0.003%)</td>
<td>0.00%</td>
<td>(0%, 0.001%)</td>
</tr>
<tr>
<td>% of Recruits <em>M. paradoxus</em> (by No.)</td>
<td>0.07%</td>
<td>(0%, 0.197%)</td>
<td>0.00%</td>
<td>(0%, 0.01%)</td>
</tr>
<tr>
<td>% of Biomass <em>L. vomerinus</em></td>
<td>2.0%</td>
<td>(0.9%, 3.1%)</td>
<td>0.06%</td>
<td>(0.04%, 0.08%)</td>
</tr>
<tr>
<td>% of Mature Stock <em>L. vomerinus</em></td>
<td>0.8%</td>
<td>(0.4%, 1.2%)</td>
<td>0.03%</td>
<td>(0.01%, 0.04%)</td>
</tr>
<tr>
<td>% of Recruits <em>L. vomerinus</em> (by No.)</td>
<td>7.0%</td>
<td>(1.8%, 12.3%)</td>
<td>0.20%</td>
<td>(0.07%, 0.34%)</td>
</tr>
</tbody>
</table>
SP-1 other than that the spawner biomass is extremely small and based on the available historical fishing effort in the area the likely impact of the proposed dredging in the area will similarly be extremely small. It is emphasized that the broader impact is also likely to be negligible as the proportion of the potential biomass in SP-1 and recruiting to the commercial fisheries in the adjacent areas is extremely small when scaled to outside of the dredged area.

5.2 ASSESSMENT OF ECOSYSTEM IMPACTS

A review of the likely impacts of the dredging and related operations at the ecosystems level was commissioned (Cochrane, Section C, Chapter 3.3). The primary rationale for the review was:

- Responses to the EIA (Japp in Midgley 2012) referred to the uncertainty related to the effects the dredging may have on the broader ecosystem, raising the question that a precautionary approach was needed;
- Understanding the potential ecosystem impacts of the operation was a general weakness in the EIA (Japp in Midgley 2012). However, trophic modelling has been done on both the southern and northern Benguela systems (Heymans, et al. 2007, Roux and Shannon 2004, Shin et al. 2004, Travers et al. 2010, Travers-Trolet et al. 2014) and Namibia has advocated the application of an Ecosystem Approach to Fisheries (EAF);
- As it was difficult to contextualise the scaling effect (i.e. the extent to which dredging in a limited area may impact on the broader ecosystem) even though some complex modelling had been done on the system. The review was intended to provide a rational overview of these models and the extent to which they could respond to the assumptions and uncertainty made in the EIA (Japp in Midgley 2012), primarily for fisheries.

The overall conclusion of the review was that ecosystem modelling can be a valuable tool to investigate indirect and ecosystem impacts of natural or anthropogenic impacts on a part of the ecosystem. Spatially disaggregated ecosystem models have been applied in a number of localities and ecosystems around the world and have been found to be useful. In this case (phosphate dredging), however, the combination of the high uncertainty typically associated with projections by ecosystem models and the small area that will be affected by the proposed dredging means that it is unlikely that ecosystem modelling would expose any unexpected or highly significant threats that have not already been considered in the specialist studies.

That conclusion might not apply, however, if the area to be impacted by the dredging was found to be of particular importance in the ecosystem or in the life cycle of one or more key species. The assessment of the Verification Biodiversity Survey did not produce any results to suggest that the proposed target dredge (impacted) area has any unique or unusual features that would indicate such a disproportionate importance.

The expected ecosystem impacts of the dredging can be considered in the context of other actual or potential environmental impacts in the region, such as from trawling and other fishing impacts, diamond mining, and oil and gas exploration. At this stage, the only other anthropogenic activity taking place in the MLA is fishing with trawl nets, as reported in specialist report (Japp; Steffnie in Midgley 2012). The impacts of dredging in the specific area planned to be exploited can be expected to have considerably greater, and longer-lasting, direct impacts on the biota in that area than does bottom trawling. However, the limited area currently designated to be dredged means that, overall,
these impacts will almost certainly be considerably less across the northern Benguela shelf and southern slope environments as a whole than have been the impacts of trawling on these environments, noting that the impacts of trawling are well-managed and considered to be sustainable.

5.3 **ASSESSMENT OF RECRUIMENT**

As part of the verification programme a study on fisheries reproductive dynamics and stock distribution in Namibia was commissioned. The rationale for commissioning this work (Ndjuala, Section C, Chapter 3.4) was:

- There was uncertainty regarding the impact the dredging might have on recruitment of the main commercial fish species;
- The area to be dredged might be an important area for fish recruitment and this would have a negative impact on the commercial fishing sectors; and
- It was suggested that NMP should undertake studies on egg and larval distributions in the dredged area. Such studies were deemed impractical mainly because they required regular sampling (normally at monthly intervals) and to be of any value would need to be over a period of 10 years. The study commissioned aimed to collate the known and available information on fish recruitment in Namibia and to compare this with the likely distribution of recruitment in and around the areas to be dredged. The study would report on the likelihood that the spatial and temporal distribution of spawning and recruitment in the area to be dredged deviated from what was expected based on the historically and current knowledge.

This study combined analyses of fish size and maturity stages as a method of identifying recruits (juvenile fish) as well as spawners (adults or active gonad stage) and looked at these in spatial, depth and temporal gradients. Such analyses provide a three dimensional picture of fish distribution in terms of size and gonad maturation.

Survey data (1999 – 2012) from the Namibian National Marine Information and Research Centre (NatMIRC) were used for the following species: *Merluccius capensis*, *Merluccius paradoxus*, *Lophius vomerinus*, *Lophius vaillanti*, *Trachurus capensis* and *Sardinops sagax*. The information on the biological analysis of the gonad maturity stages and the gonad weight was recorded, together with fish size. Three approaches were taken:

1. Data were used to analyse stock structures for both spatial and temporal dynamics. Stock structure was also analysed for depth profiles;
2. Data were analysed for both spatial and temporal maturity development, and where necessary analysis for depth profiles was also undertaken; and
3. Where data were available, the Gonadosomatic Index (GSI) was evaluated for both spatial and temporal dynamics. However, due to the nature and interpretation of GSI in serial spawners (which is the egg production strategy used in hake and horse mackerel), the GSI results were not presented in this report as it would be a repetition of information gained from more reliable gonad maturity staging.

**Size distribution**

The results showed that no significant spawning areas for any species were observed, specifically not in the areas within the MLA. While the data showed there were certain dynamics relating to stock
Structure (mainly offshore-onshore and vertically with depth for all species analysed, as well as latitudinal for *M. paradoxus*), there seemed to be a wide range of growth rates and does not define the stock structure, as shown by the cohort indicators. It was determined that the area proposed for dredging has no special biological reproductive characteristics for the main commercial species found in the area compared with the rest of the Namibian waters. For example, there are no specific indicators suggesting that the dredged area is exclusively home to adult fish (spawner biomass), and has no pronounced recruitment of small and young fish.

Data for horse mackerel, hake and monk were available for the period 1999 to 2014, covering the entire Namibian coast (17°S to 29°S), whereas for sardine there were only data from 2007 ranging from 22°S to 25°S. In the case of all these species, the data suggested no unique reproductive characteristics particular to the area to be dredged.

This analysis also showed that for all species analysed their distributions were heterogeneous. Variation in population structure was also not indicative of defined recruitment grounds and in particular the area around 23°S to 25°S showed patterns just as complex and undefined as previously observed in historical studies. The results of this study did not show any special features of the proposed dredging area, with respect to the rest of the Namibian coast in both space and time. Cohort analyses for all the species analysed were a mix of small and large fish for most of the areas, and therefore lacked signs of well-defined spawning areas and/or recruitment of small fish.

**Gonad maturation**

Whilst hake with more advanced gonad maturity were present around the latitudinal area of interest (between 23°S to 25°S), they were found mostly at greater depths (>250 m) than that of the proposed dredging activities (200 to 225 m in SP-1). Monthly trends also have not indicated any progress (beyond a maturing stage) in gonad maturity in that particular area, suggesting that fish do move in and out of such grounds over time. Annual maturity trends have also not showed repeated dynamics implying that spawning grounds for these species is not localized. These multiple cohorts as observed per year and by area are suggestive of high and low recruitment events. This has again indicated lack of homing for adults and undefined recruitment and spawning grounds.

It is recommended that various ‘state of the stock’ monitoring surveys be built into the environmental management plan. The presence of phosphate as a resource in this area and given the importance of information needed on the dynamics of the commercial fish stocks in the MLA, it is worth noting that in future, the area should be included in the routine surveys undertaken by MFMR. Results of such studies will play an important part as a control measure from which necessary actions could be derived, as well as adding to the baseline for future monitoring and evaluation and possibly further development plans. Similarly, results from such monitoring programmes could indicate the extent of the impact of phosphate mining. The continuation of the annual biodiversity survey is highly recommended as it adds to the knowledge base of this study, by focusing in the proposed area of dredging activity (SP-1) at a high sampling resolution.

### 5.4 HISTORICAL ASSESSMENT OF SPAWNING AND RECRUITMENT (SECTION C, CHAPTER 3.5)

The preparation of this document preceded the verification studies. As a result of changes in the Benguela Ecosystem and also due to the collapse of some fish stocks e.g. sardine, there is likely to have been changes in the spatial and temporal dynamics of the key fish species. The EIA (Japp in
Midgley 2012) did report the current status of the commercial fish species. Characteristics such as spawning and recruitment areas are however not well reflected in the current literature, partly because for some species, there has been considerable resource shrinkage due for example to overfishing. A retrospective analysis of the historical information, in particular the work undertaken by the International Commission for South East Atlantic Fisheries (ICSEAF) is pertinent. In addition the material reviewed also reported on valuable research undertaken on the distribution of fish eggs, larvae and other ichthyoplankton (the SWAPELS project). The purpose of this historical assessment was therefore to review the spawning areas, ichthyoplankton drift areas and recruitment grounds from the historical and contemporary literature to support the fisheries EIA (Japp in Midgley 2012).

The review concluded the following:

- Aggregations of spawning horse mackerel and juveniles occur outside the MLA (Crawford et al. 1987, O’Toole 1977 and Boyer & Hampton 2001a) (Figure 3 in Section C, Chapter 3.5).
- Sardine spawn off Walvis Bay and further north near Palgrave Point. Only the northern extent of the MLA falls within the southern part of the spawning area (O’Toole 1977, Crawford et al. 1987) (Figures 4 – 6 in Section C, Chapter 3.5).
- Historically, spawning and larval distributions of anchovy took place north of Walvis Bay (outside the MLA) (Shannon & Pillar 1986, O’Toole 1977, Boyer & Hampton 2001a) (Figure 5 in Section C, Chapter 3.5).
- Snoek migrate southwards to spawn offshore and in deep waters near St Helena Bay and off the Cape Peninsula in South Africa. The MLA is at the eastern edge of the migration corridor (Boyer & Hampton 2001a, Crawford & de Villiers 1985, Griffiths 2002 and 2003) (Figure 8 in Section C, Chapter 3.5).
- Silver kob spawn very close inshore (<100 m) at Meob Bay and larvae drift northwards to the nursery grounds between Sandwich Harbour and the Ugab River mouth (Kirchner and Voges 1999, Van der Bank and Kirchner 1997, Holtzhausen et al. 2001, Kirchner and Holtzhausen 2001).
- A low abundance of hake eggs occurs to the south east of the MLA off Hollams Bird Island. Larvae are found in high abundance from Conception Bay to Palgrave Point in water depths between 100 – 300 m (Figure 9 in Section C, Chapter 3.5). A significant amount of juvenile M. capensis (<30 cm) occurs within the MLA (Sundby et al. 2001) (Figure 11 in Section C, Chapter 3.5), however according to the biomass estimates calculated by Gaylard (Section C, Chapter 3.2) only 1.6% of the juveniles occur in the MLA.
- According to the historical literature, juvenile monkfish occur within the MLA (Maartens 1999, Maartens and Booth 2005) (Figure 15 in Section C, Chapter 3.5). This is also reflected in the biomass estimates calculated by Gaylard (Chapter C 3.2) which showed that 7% of the monk juveniles could occur in the MLA.
- Goby larvae are in high abundance throughout Namibian coastal waters and in particular in the MLA. They also inhabit the bottom sediments and will be highly disturbed by the proposed dredging activity (Cruickshank et al. 1980, Cruickshank 1982 in Melo and Le Clus 2005, Utne-Palm et al. 2010) (Figures 18 and 19 in Section C, Chapter 3.5).
- Significant densities of west coast rock lobster occur far inshore and further south of the MLA but may be adversely affected by the sediment plumes (Cockcroft 2001, Pollock 1986). However, after a closer investigation of the extent of the sediment plume it was confirmed that the plume would be a maximum of 1.5 km long from the most southerly point of SP-1 and will not occur in the lobster distribution areas.
6 VERIFICATION BIODIVERSITY SURVEY

6.1 BACKGROUND AND OBJECTIVES

As part of the original baseline verification programme of the EIA (Japp in Midgley 2012), it was recommended that a structured biomass survey of the proposed dredging area (in particular the proposed target dredge area SP-1) be undertaken. However, following biomass estimate modelling using demersal survey data by Gaylard (Section C, Chapter 3.2) and a review of the ecosystem models by Cochrane (Section C, Chapter 3.3) as well as the spawning and recruitment statistical data assessment by Ndjaula (Section C, Chapter 3.4), it was recommended that a biodiversity survey (as opposed to a biomass survey) should be undertaken. For reasons previously indicated, research vessels equipped with standardised and calibrated trawl gear were not made available to NMP for a biomass (verification) survey.

The approach adopted therefore, was to focus on non-biomass estimates such as biodiversity, biological information, stock structure, recruitment, oceanographic parameters (measured using a CTD – Section D, Appendix 2.3) as well as epifauna, birds and mammals. The data collected would be used to verify as far as possible information assessed and determinations made in the EIA (Japp in Midgley 2012). The data collected would also be used as a baseline and information base for future surveys and would provide the opportunity to monitor and to track possible changes in the system associated with dredging.

Another criticism of the EIA (Japp in Midgley 2012) was that the NatMIRC data used had few locations within the MLA or areas to be dredged. It was considered optimal to undertake a biodiversity survey to verify the findings in the EIA (which used a desk-top approach) and to establish a baseline for future reference for biodiversity, fish abundance (density), recruitment (size distribution) and other biological aspects (spawning state of main commercial species etc.) within the actual MLA and SP-1 target dredge site. An industry-owned monkfish trawler, FV Zeearend, was used to undertake the biodiversity survey (Section D, Appendix 2.2). Specific objectives for the biodiversity survey were:

- Estimate the abundance (density) of the main commercial species such as hake, monk and horse mackerel;
- Collect biological information (length, sex, maturity stage, stomach content) from the commercial important/exploited species;
- Identify, collect and photograph epifaunal species and at the same time confirm the nature of the substrate and bottom profile;
- Collect environmental data (using visual observations and a CTD) to establish linkages between the environment and species distribution, recruitment and abundance;
- Record/identify the occurrence of surface species: marine mammals and seabirds in the area; and
- Establish a baseline for future monitoring and survey assessments.

4 This was not considered a matter of significance when the EIA was undertaken. It is standard survey methodology in the marine environment to randomise sample stations and to extrapolate data on the basis of pre-determined assumptions e.g. that fish biomass is uniformly distributed by depth, or habitat type etc.
The survey design (Section D, Appendices 2.1, 2.4, 2.5) therefore aimed primarily at quantifying the biodiversity of the area and to compare this with the known information on the region. The survey also obtained commercial data on target catch (monk), hake and the other bycatch species. This allowed for a rough estimate of the abundance of spawning fish and recruitment creating a baseline for future surveys in the area if dredging proceeds.

Figure 3 shows the ML 170, the target dredge area (SP-1), the phosphate resource inside SP-1 (20-year mine plan) as well as the location of 24 sampling stations/trawl lanes of the biodiversity survey. The original locations of the stations were randomly selected such that a broad distribution of the entire SP-1, and just outside SP-1, would be sampled. However, given the conditions of the trawling permit limited the survey to waters deeper than the 200 m, most of the stations on the eastern side of SP-1 had to be randomly relocated westward to deeper water. The survey coordinates in decimal degrees of the start and end positions are given in Annexure 1. Of the 24 stations (each approximately 1.5 nm in length, with 30 minutes standard trawl time) 12 were sampled during the day and 12 during the night. The survey took eight days to complete.
Figure 3: Location of the 24 trawl lanes within ML 170 and SP-1. The station number (bold numbers) and depths (italic numbers) are also shown. Reference sites refers to the environmental sample sites, which were closed (2km around the sites) to the survey. Note all the stations are deeper than 200m.
6.2 METHODS AND MATERIALS

The survey took place from the 18th – 27th June 2014. A commercial vessel, the FV Zeearend, fitted with a double-belly monkfish bottom trawl net with a head length 86 m, footrope 108 m (0.108 km) and vertical net opening 45 m was used to sample 24 stations within, and in close proximity to, the target dredge area SP-1 (Figure 4). The distance between the wings during towing was approximately 40 - 50 m. The trawl was rigged with tickler chains along the footrope. The “Thyborun” trawl doors were 4.2 m square in size, weighing around 800 kg each. The codend mesh size was 120 mm but in order to retain small fish and epifauna, a 20 mm inner liner was integrated into the codend.

Trawl speed was an average of 3 knots, with trawl duration of 30 minutes (this being the time the net was in contact with the seabed). The fishing operation was in a north/south direction and the trawl distance covered at each station was approximately 1.5 nm. The survey took eight days (one day of no sampling, due to adverse weather conditions) to complete all 24 stations. Half the stations were sampled during the day (07h00 – 17h30) and the other half during the night (20h00 – 07h00) hours. Time, location and depth were recorded per station. Processing of the catches was achieved through integrated effort of the scientists and crew. Key components (principally fishes and jellyfish) were extracted first and the remaining material was then transferred to a sorting table where it was rigorously screened for epifauna (McClurg: Section C, Chapter 2.6 and Section D, Appendix 2.2).

The entire catch (or a subsample in the case of large catches) was sorted into species. Monk, hake, and sole were further sorted by sex. The total catch weights (kg) of each species (and sex where applicable) were recorded. Length frequency (total length) data were collected for all commercial species. For non-commercial species such as rat tails, only a sample of the fish were weighed and counted. If the catch was > 1.5 tonnes, the main fish species (hake, monk, sole and horse mackerel) were removed from the catch and the rest was sub-sampled by randomly selecting and measuring approximately 100 kg. Biological sampling of 15 fish per species (individual weight and length measurements, sex, maturity stage, and stomach contents) was done for hake and monk per station.

All invertebrate species retained by the net and landed as part of the catch were identified to the lowest possible taxon, counted and weighed. All large, whole epifauna species retained in the wings of the net were also included in the data counts. Photographs of invertebrates were taken for each trawl to provide an overview and a snapshot image of invertebrates occurring at each station.

---

5 There was a team of six scientists and professional staff as well as support from the vessel’s crew. Samplers included a specialist on epifauna (benthic), fish, environmental (CTD) and mammals and birds. In addition the team included two NatMiIRC scientists who provided local skills and experience related to Namibian species and conditions.

6 The sample weight and number were then used to extrapolate a total catch weight and number.
Figure 4: Configuration of the double belly monkfish trawl net fitted on the FV Zeearend
Not all the trawls were of exactly 30 minutes duration; therefore the data (weights and numbers) had to be standardized using the following equation:

\[ W = \frac{w}{t} \times 0.5 \]

Where \( W \) is the standardised weight (kg/0.5 hr), \( w \) is the measured weight per species and \( t \) is the duration of the trawl (hours).

Not all the trawls were of exactly 30 minutes duration; therefore the data for number had to be standardized using the following equation:

\[ N = \frac{n}{t} \times 0.5 \]

Where \( N \) is the standardised number (no/0.5hr), \( n \) is the number per species and \( t \) is the duration of the trawl (hours).

Density was calculated for each species per station using the swept area method. The swept area per hour at station, \( SA \), was calculated by:

\[ SA = d \times \left( \frac{b}{t} \right) \]

Where \( d \) is the trawl distance (km), a product of trawl speed and trawl duration multiplied\(^7\) by 1.852 km, \( b \) represents the footrope length (0.108 km); and \( t \) is the duration of the trawl. Species density is assumed to be proportional to the mean catch rate (kg/hour). Thus the density is equal to the catch per area swept at a specific station (kg/SA).

Marine mammal sightings (strategy was taken from the Marine Mammal Observation standard procedures, JNCC 2010) and seabird observations were carried out during the day by visually recording and identifying the number of species within a 500 m radius of the vessel. A sixty minute observation period was initiated from when the net was deployed for i.e. observations were done throughout the setting (15 minutes), trawling (30 min) and hauling periods (15 min) of the trawl.

Hydrological data (salinity, temperature and oxygen) were collected using a multi-probe internal logging Conductivity, Temperature and Depth (CTD) recorder, which was encased inside a stainless steel protective frame and specially designed net bag, and attached to the head rope of the trawl net, using shackles and cable ties (Section D, Appendix 2.3). At the start of the trawl environmental data such as air pressure, wind direction, wind speed (Beaufort scale), cloud cover and sea surface colour were also recorded using the electronic equipment on the bridge and visual observations.

Substrate and/or sediment type was also recorded from visual observations of retained material on the trawl doors and foot rope; this provided an indication of the habitat type.

---

\(^7\) 1.852 is the conversion from nautical miles to kilometres
6.3 RESULTS

Data were recorded on hard copies as well as entered electronically in a project specific Access database. Graphs, tables and spatial maps were created using Excel and ArcView GIS.

A summary of the entire catch weight (kg) and number of species standardized to 30 minutes per station is presented in Table 2. A total of 28 tonnes was caught with an average of 1.2 tonnes per station. Generally, catch weight was higher during day trawls than night trawls (Figure 5). Station number 11 was dominated by red jellyfish (*Chrysaora fulgida*) with 11 tonnes caught while the net descended and therefore does not show a true reflection of the catch composition for that station. Station 13 had the lowest catch (246 kg) whereas Station 11 had the highest. Ascidians (*Molgula sp*) were found in 21 out of the 24 stations but were particularly abundant at Station 20 with 1.1 tonnes. A full breakdown of species weight (kg) and number per station can be found in the cruise report (Section D, Appendix 2.2).

A total of 48 species of fish (including jellyfish), epifauna, seabirds and mammals were identified during the survey, of which 17 were made up of fish and 14 the epifauna species, 15 were seabirds and 2 were marine mammals (Table 3). In terms of total numbers the epifauna comprised 131,423 specimens and the fish 38,421. This figure excludes red jellyfish (*Chrysaora fulgida*) which were not counted. The epifauna clearly dominated in terms of number of individuals caught. The total overall biomass value for the epifauna was 5,587 kg vs. 23,124 kg for the fish/pelagic component. This, includes red jellyfish, of which one trawl alone yielded 11,860 kg.

The spatial distribution by weight and number of taxa (i.e. fish and epifauna species counts), showing a biodiversity index, per station is presented in Figure 6. Station 7 had the highest number of species (21) whereas Station 8 had the lowest (16). Both of these stations were within the 20-year phosphate resource target dredge area and both stations had low to medium size catches (<900 kg). Analysis of the data does not show any differences in species weights or counts between the target dredge area, SP-1 and surrounding areas.

---

8 Jellyfish were caught while the net was descending, this was confirmed from the echo sounder which showed a jellyfish layer in the midwater during the setting period. Further there were very few fish caught in the net because the jellyfish were already present when the net hit the sea floor (at the start of the fishing period).
### Table 2: Standardised weight (kg) and number of species caught in 30 minutes per station. Catch rate (CPUE) per hour is also shown. D = Day: N = Night trawls

<table>
<thead>
<tr>
<th>Trawl Number</th>
<th>Date Start</th>
<th>Fishing Time Start</th>
<th>Weight (kg) Standardised 30 mins</th>
<th>Number Standardised 30 mins</th>
<th>CPUE (kg/hr)</th>
<th>Density (kg/swept area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>18-Jun-14</td>
<td>18:05</td>
<td>576</td>
<td>8415</td>
<td>1152</td>
<td>960</td>
</tr>
<tr>
<td>D2</td>
<td>20-Jun-14</td>
<td>07:35</td>
<td>433</td>
<td>5049</td>
<td>867</td>
<td>869</td>
</tr>
<tr>
<td>D3</td>
<td>20-Jun-14</td>
<td>12:35</td>
<td>675</td>
<td>6287</td>
<td>1351</td>
<td>1125</td>
</tr>
<tr>
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<td>751</td>
<td>44953</td>
<td>1502</td>
<td>1377</td>
</tr>
<tr>
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<td>15:05</td>
<td>1261</td>
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<td>2522</td>
<td>2102</td>
</tr>
<tr>
<td>D6</td>
<td>21-Jun-14</td>
<td>07:13</td>
<td>1348</td>
<td>10736</td>
<td>2695</td>
<td>2171</td>
</tr>
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<td>1155</td>
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</tr>
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<td>2716</td>
<td>2263</td>
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<td>19747</td>
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<td>453</td>
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<td>10034</td>
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<td>622</td>
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<td>1041</td>
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<tr>
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<td>8616</td>
<td>1174</td>
<td>978</td>
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<td>375</td>
<td>4835</td>
<td>751</td>
<td>625</td>
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<td>TOTAL</td>
<td></td>
<td></td>
<td>28048.86</td>
<td>150658</td>
<td>47411.04</td>
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<tr>
<td>AVERAGE</td>
<td></td>
<td></td>
<td>1169.88</td>
<td>9470</td>
<td>2340</td>
<td>1975.46</td>
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</tbody>
</table>
Figure 5: Total catch weight (kg) per 30 minute trawl (bar graph) and total catch per swept area (line graph) per station. The day (grey bars) and night time (black bars) trawls have also been presented.
### Table 3: Number (and where applicable weight) for all the species identified and recorded during the biodiversity survey.

<table>
<thead>
<tr>
<th>No</th>
<th>Common name</th>
<th>Genus</th>
<th>Species</th>
<th>Weight (kg)</th>
<th>Number</th>
</tr>
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<td><strong>FISH AND PELAGIC COMPONENT</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Angelfish</td>
<td>Brama</td>
<td>brama</td>
<td>3.06</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Bonefish (long fin)</td>
<td>Pterothrissus</td>
<td>belloci</td>
<td>3.23</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Capensis</td>
<td>Merluccius</td>
<td>capensis</td>
<td>1920.89</td>
<td>13791.95</td>
</tr>
<tr>
<td>4</td>
<td>Goby (pelagic)</td>
<td>Sufflogobius</td>
<td>bibarbatus</td>
<td>56.20</td>
<td>6564</td>
</tr>
<tr>
<td>5</td>
<td>Gurnard Capensis</td>
<td>Chelidonichthys</td>
<td>capensis</td>
<td>0.60</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Jacopever</td>
<td>Helicolenus</td>
<td>dactylopterus</td>
<td>54.42</td>
<td>928</td>
</tr>
<tr>
<td>7</td>
<td>Jelly fish (purple)</td>
<td>Chrysaora</td>
<td>africana</td>
<td>0.05</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Jelly fish (red)</td>
<td>Chrysaora</td>
<td>fulgida</td>
<td>17722.98</td>
<td>0</td>
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<td>9</td>
<td>Jelly fish (white)</td>
<td>Aequorea</td>
<td>forskalea</td>
<td>405.24</td>
<td>1959</td>
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<td>10</td>
<td>Maasbanker</td>
<td>Trachurus</td>
<td>trachurus</td>
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<td>143</td>
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<tr>
<td>11</td>
<td>Mackerel</td>
<td>Scomber</td>
<td>japonicus</td>
<td>8.38</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Monk</td>
<td>Lophius</td>
<td>vomerinus</td>
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<td>3565.76</td>
</tr>
<tr>
<td>13</td>
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<td>Coelarichus</td>
<td>simorhynchus</td>
<td>672.48</td>
<td>9530</td>
</tr>
<tr>
<td>14</td>
<td>Shark (blunt nose sixgill)</td>
<td>Hexanchus</td>
<td>griseus</td>
<td>2.79</td>
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</tr>
<tr>
<td>15</td>
<td>Squid (Angola flying)</td>
<td>Todarodes</td>
<td>angolensis</td>
<td>174.29</td>
<td>1058</td>
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<tr>
<td>16</td>
<td>Squid (flying)</td>
<td>Toderopsis</td>
<td>sagittatus</td>
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<tr>
<td>17</td>
<td>West Coast sole</td>
<td>Austroglossus</td>
<td>microlepis</td>
<td>157.26</td>
<td>316.85</td>
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<td><strong>EPIFAUNA COMPONENT</strong></td>
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<tr>
<td>18</td>
<td>Hermit crab</td>
<td>Parapaguridae</td>
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<td>4.81</td>
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<tr>
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<td>Mantis shrimp</td>
<td>Squilla</td>
<td>sp</td>
<td>19.64</td>
<td>853</td>
</tr>
<tr>
<td>20</td>
<td>Prawn</td>
<td>Funchalia</td>
<td>woodwardi</td>
<td>0.06</td>
<td>6</td>
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<tr>
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<td>Prawn (Solnocera)</td>
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<td>africana</td>
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<td>Sea pen</td>
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<tr>
<td>24</td>
<td>Sea squirts</td>
<td>Molgula</td>
<td>sp</td>
<td>4616.91</td>
<td>108813</td>
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<tr>
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<td>Sponge (brown)</td>
<td>Porifera</td>
<td>sp</td>
<td>376.63</td>
<td>1334</td>
</tr>
<tr>
<td>26</td>
<td>Starfish (long armed)</td>
<td>Astropecten</td>
<td>sp</td>
<td>0.03</td>
<td>5</td>
</tr>
<tr>
<td>27</td>
<td>Starfish (short armed)</td>
<td>Odontaster</td>
<td>australis</td>
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<td>15</td>
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<tr>
<td>28</td>
<td>Swimming crab</td>
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<td>piperitus</td>
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<tr>
<td>29</td>
<td>Whelk (dog)</td>
<td>Nassarius</td>
<td>wolfii</td>
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<td>7</td>
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<tr>
<td>30</td>
<td>Whelk (sponge)</td>
<td>Facciolaridae</td>
<td>(plus sponge)</td>
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<td>25</td>
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<tr>
<td>31</td>
<td>Whelk (tulip)</td>
<td>Facciolaridae</td>
<td>lugubra</td>
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<td><strong>SEABIRD COMPONENT</strong></td>
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<td>Sub Antarctic skua</td>
<td>Catharacta</td>
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<td>33</td>
<td>Kelp gull</td>
<td>Larus</td>
<td>dominicanus</td>
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<tr>
<td>34</td>
<td>Tern</td>
<td>Sternidae</td>
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<td>Cape Gannet</td>
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<tr>
<td>36</td>
<td>Cape cormorant</td>
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<tr>
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<td>Shy albatross</td>
<td>Thalassarche</td>
<td>cauta</td>
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<tr>
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<td>Black browed albatross</td>
<td>Thalassarche</td>
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### C3.1 Verification Survey Report: Fish, Mammals and Seabirds

#### Marine Mammal Component

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<th>No</th>
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<th>Species</th>
<th>Weight (kg)</th>
<th>Number</th>
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</thead>
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<td>pusillus pusillus</td>
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<td>73</td>
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<tr>
<td>48</td>
<td>Dusky dolphin</td>
<td>Lagenorhynchus</td>
<td>obscurus</td>
<td>-</td>
<td>250</td>
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</table>

Figure 6/...
Figure 6: Spatial distribution of all species by weight (kg/0.5min) per station
Note. The large numbers (red) refer to the number/counts of taxa (i.e. diversity) caught per station.
6.3.1 Fish

A total of 14 fish species, including two squid species (*Todarodes angolensis* and *Todaropsis sagittatus*) and one shark species (*Hexanchus griseus*), was identified and measured during the survey (Table 4). Note that in order to show a clear representation of the fish species composition, Epifaun (6.3.2) have been removed and a separate analysis below.

The shallow water hake (*Merluccius capensis*) dominated catches, amounting to 40% by weight of the total fish catch, followed by monk (*Lophius vomerinus*), 35%, rattle (*Coelorinchus simorhynchus*) 14%, sole (*Austroglossus microlepis*) 3% and goby (*Sufflogobius bibarbatus*) 2%. Horse mackerel (*Trachurus capensis*) 0.4% of the total fish catch. Figure 7 shows the weight of the fish component per day and night time stations. The number of fish taxa per station is also presented.

<table>
<thead>
<tr>
<th>No</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Weight (Std)</th>
<th>Number (Std)</th>
<th>Weight proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Angelfish</td>
<td><em>Brama brama</em></td>
<td>3.06</td>
<td>2</td>
<td>0.0006</td>
</tr>
<tr>
<td>2</td>
<td>Bonefish (long fin)</td>
<td><em>Pterothrissus belloci</em></td>
<td>3.23</td>
<td>17</td>
<td>0.0007</td>
</tr>
<tr>
<td>3</td>
<td>Capensis</td>
<td><em>Merluccius capensis</em></td>
<td>1920.89</td>
<td>13792</td>
<td>0.4020</td>
</tr>
<tr>
<td>4</td>
<td>Goby (pelagic)</td>
<td><em>Sufflogobius bibarbatus</em></td>
<td>56.20</td>
<td>6564</td>
<td>0.0118</td>
</tr>
<tr>
<td>5</td>
<td>Gurnard capensis</td>
<td><em>Chelidonichthys capensis</em></td>
<td>0.60</td>
<td>2</td>
<td>0.0001</td>
</tr>
<tr>
<td>6</td>
<td>Jacopever</td>
<td><em>Helicolenus dactylopterus</em></td>
<td>54.42</td>
<td>928</td>
<td>0.0114</td>
</tr>
<tr>
<td>7</td>
<td>Maasbanker</td>
<td><em>Trachurus trachurus</em></td>
<td>21.42</td>
<td>143</td>
<td>0.0045</td>
</tr>
<tr>
<td>8</td>
<td>Mackerel</td>
<td><em>Scomber japonicus</em></td>
<td>8.38</td>
<td>4</td>
<td>0.0018</td>
</tr>
<tr>
<td>9</td>
<td>Monk</td>
<td><em>Lophius vomerinus</em></td>
<td>1703.56</td>
<td>3566</td>
<td>0.3565</td>
</tr>
<tr>
<td>10</td>
<td>Rattail short nose rough</td>
<td><em>Coelorinchus simorhynchus</em></td>
<td>672.48</td>
<td>9530</td>
<td>0.1407</td>
</tr>
<tr>
<td>11</td>
<td>Shark (blunt nose sixgill)</td>
<td><em>Hexanchus griseus</em></td>
<td>2.79</td>
<td>2</td>
<td>0.0006</td>
</tr>
<tr>
<td>12</td>
<td>Squid (angola flying)</td>
<td><em>Todarodes angolensis</em></td>
<td>174.29</td>
<td>1058</td>
<td>0.0365</td>
</tr>
<tr>
<td>13</td>
<td>Squid (flying)</td>
<td><em>Todaropsis sagittatus</em></td>
<td>0.05</td>
<td>1</td>
<td>0.0000</td>
</tr>
<tr>
<td>14</td>
<td>West coast sole</td>
<td><em>Austroglossus microlepis</em></td>
<td>157.26</td>
<td>317</td>
<td>0.0329</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td>4779</td>
<td>35925</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

The proportion of hake, monk, sole and horse mackerel by weight per station is presented in Figure 8. Hake and monk were found in all the trawls whereas sole were found in 22 trawls. Hake were more abundant during the daylight trawls while monk and sole were more abundant during night trawls. Horse mackerel were found in five of the trawls, which were all daylight trawls and located along the eastern edge of the survey area i.e. inshore and in shallower water (less than 205 m). There is not much variation in catches of the main commercial species across the entire survey i.e. no difference in the proportion of fish caught inside the target dredging area (SP-1) when compared to the surrounding areas.
Figure 7: The weight of the fish per day (grey) and night (black) station. The number of fish taxa per station has also been presented.
Figure 8: Proportion of fish by weight at each station. Species include hake (*M. capensis*), monk (*L. vomerinus*), sole (*A. microlepis*) and horse mackerel (*T. capensis*) per station.
Goby (Sufflogobius bibarbatus) were found at all the stations. Slightly fewer goby on average (2 kg) were caught during the day trawls than during the night (3 kg) Figure 9. This was a surprising result as the goby were expected to rise up the water column at night and therefore would have been unavailable to the bottom trawl gear. An average of 2.3 kg of goby amounting to an average of 273 individuals was caught per station. Station 18 had the highest number of gobies and Station 11 had the lowest (Figure 10).

Figure 9: Goby weight (kg) per day (D) and night (N) station.
Figure 10: Spatial distribution of goby (*Sufflogobius bibarbatus*) by weight (kg) and number (red label) per station.
Fish length frequency

Length frequency distributions for monk, hake, sole, horse mackerel, squid and jacopever are presented in Figures 11 – 16. Sample size (n) and mean length per species are also shown. Adult hake and monk were split by sex during the survey whereas monk juveniles, sole and horse mackerel were recorded as combined sexes.

Figure 11: Length frequency distribution for monk. (split by male (blue), female (red) and juveniles (green))
Figure 12: Length frequency distribution of hake, split by male (blue) and female (red).

Figure 13: Length frequency of sole, split by male (blue) and female (red).
Figure 14: Length frequency of Angola flying squid, (both male and female combined).

Figure 15: Length frequency of horse mackerel, (both male and female combined).
Fish maturity

Maturity stages (1 – 5) and weight-per-stage was recorded for both monk and hake. Staging methods were adopted from Botha (1986) and are described in Table 5. Approximately 12 000 fish were staged, of which few Stage 4 (spawning stage) fish were recorded for both species. Almost 60% of the female monk was identified as stage 1 (immature) whereas only 1% of the female hake were immature. There were no stage 5 (spent) monk males recorded during the survey and the majority of the hake were stage 2 (active). The percentage maturity stage per length class for monk and hake are represented in Figures 17 – 20. Both male and female monk data suggested length at maturation from 32 cm and for hake from 22 cm.

According to scientific literature *M. capensis* spawn off central Namibia (25°S to 20°S), although the exact location varies between years (Assorov and Berenbeim 1983 cited in Sundby et al. 2001, Olivar et al. 1988, Sundby et al. 2001). It has also been suggested that *M. capensis* are serial spawners with females spawning numerous times a year (Osborne et al. 1999). Spawning appears to occur year round with peak spawning periods in occurring from mid-July to mid-September (Roux pers comm.). During this time *M. capensis* appear to move to waters <200m to spawn (Gordo a et al. 2006). Similarly, monk also spawns throughout the year with a peak spawning period in late winter and summer (Maartens and Booth 2005).

**Figure 16:** Length frequency of jacopever (both male and female combined).
Table 5: Number of samples per maturity stage for hake and monk males and females.

<table>
<thead>
<tr>
<th>Maturity stage</th>
<th>Number of samples (n)</th>
<th>L. vomerinus</th>
<th>M. capensis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Female proportion</td>
<td>Male</td>
</tr>
<tr>
<td>Stage 1 – Immature</td>
<td>935</td>
<td>0.59</td>
<td>536</td>
</tr>
<tr>
<td>Stage 2 – Active</td>
<td>559</td>
<td>0.36</td>
<td>944</td>
</tr>
<tr>
<td>Stage 3 – Ripe</td>
<td>43</td>
<td>0.03</td>
<td>237</td>
</tr>
<tr>
<td>Stage 4 – Ripe/Hydrated</td>
<td>26</td>
<td>0.02</td>
<td>9</td>
</tr>
<tr>
<td>Stage 5 – Spent</td>
<td>11</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1574</td>
<td>1</td>
<td>1726</td>
</tr>
</tbody>
</table>

Figure 17: The percentage maturity stage against length (cm) for monk females.
Figure 18: The percentage maturity stage against length (cm) for monk males.

Figure 19: The percentage maturity stage against length (cm) for hake females.
Stomach contents

Monk and hake (approximately 15 individuals per species per station) were dissected for stomach content analysis (Figures 21 and 22). Prey items (number and length) were measured as well as stomach state, stomach fullness and digestion state. For monk most of the prey items were juvenile hake followed by goby. Ascidians were found undigested in the stomach of the monk suggesting that the ascidians were eaten accidentally while the monk was in the net. For hake the majority of the prey items were euphausiids (krill) and goby.
Figure 21: Number of prey items found in 337 monk individuals.

Figure 22: Number of prey items for 324 hake individuals.
6.3.2 **Epifauna**

The epifauna were assessed by McClurg, and reported in more detail in Section C, Chapter 2.6. The benthic environment within SP-1, where dredging is scheduled to commence, has been a particular area of focus. Studies there have included two detailed surveys of benthic fauna (Steffani 2010; Section C, Chapter 2.5). Project reviewers have expressed concern that these surveys, which were based on traditional grab sampling, were not fully comprehensive, in that the larger organisms inhabiting the sea bed (epifauna) were not adequately sampled. Epifaunal organisms tend to be larger, more mobile and occur in lower densities than their infaunal counterparts and may accordingly be missed in grab-based surveys. Partly in response to this criticism an additional survey, which focussed on epifauna, was performed in June 2014. This study formed part of a wider trawling survey aimed at further elucidating the biodiversity and fishery potential of the proposed dredging area and environs. Epifauna (sometimes referred to as megafauna) includes the larger, and typically more mobile, organisms that dwell on the sediment surface. It was determined that trawling, using the technical skills of local trawler-men, was the most appropriate route for the collection of the epifauna of this region. This epifauna survey could then be linked logistically to a broader biodiversity and fishery survey which comprises part of the verification programme.

The identities and weight of the epifauna organisms collected during the survey are listed in Tables 6 and 7. Ascidians are considerably the most dominant species of the epifauna component thus in order to show a clearer representation of the other epifauna species, ascidians, jellyfish and brown sponges data have been removed from Table 6 and a separate analysis is presented Table 7.
Table 7: Relative proportions of jellyfish, ascidians and sponges

<table>
<thead>
<tr>
<th>No</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Weight (Std)</th>
<th>Number (Std)</th>
<th>Weight proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jellyfish (purple)</td>
<td>Chrysaora africana</td>
<td>0.05</td>
<td>1</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>Jellyfish (red)</td>
<td>Chrysaora fulgida</td>
<td>17722.98</td>
<td>0</td>
<td>0.7665</td>
</tr>
<tr>
<td>3</td>
<td>Jellyfish (white)</td>
<td>Aequorea forskalea</td>
<td>405.24</td>
<td>1959</td>
<td>0.0175</td>
</tr>
<tr>
<td>4</td>
<td>Sea squirts</td>
<td>Molgula sp.</td>
<td>4616.91</td>
<td>108813</td>
<td>0.1997</td>
</tr>
<tr>
<td>5</td>
<td>Sponge (brown)</td>
<td>Porifera sp.</td>
<td>376.63</td>
<td>1334</td>
<td>0.0163</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td>23122</td>
<td>112106</td>
<td>1</td>
</tr>
</tbody>
</table>

The results are presented for both counts and weights using the non-standardised results. In numerical terms the Ascidiacean sea squirt (Molgula sp.) was, by far, the most prolific, having contributed 60% of the total catch. This was followed by the Pennatulid sea pen (family Veretellidae) at 37%. The remaining 12 taxa were relatively insignificant and comprised only 3% of the total catch.

In terms of contributions to the total weight, Molgula sp. was again the highest contributor at 85% followed by Porifera (sponge) and then sea pens (Veretellidae) at 5%. The remaining taxa were again relatively insignificant in their weight contributions. A summary description of each epifaunal taxon encountered in the survey is given below.

**Ascidiacea** (sea squirts or ascidian tunicates). A single species (Molgula sp.) was encountered at 21 of the 24 stations, often in large numbers. Ascidians are widespread and common, they have several life forms which include solitary anchored individuals, and compound colonies. Ascidians are filter feeders and assumed to play an important role in nutrient recycling. Their tough leathery exterior “tunic” may render them unattractive to many potential predators. There was, incidentally, no evidence of digested Molgula sp. remains in any of the fish stomach contents that were examined in this survey. Discussions with Mr Malakia Shimhanda (on-board technician from NatMIRC) revealed that Molgula sp. is widely known in Namibian fishing areas. However, he remarked that, in 25 years at sea, he had never seen them recovered in such large numbers. It is likely that the reduced mesh size (20 mm), that was used to line the cod end in this survey, played a significant role in boosting catches of Molgula sp.

**Pennatulacea** (sea pens, Family Veretellidae, Phylum Cnidaria). The Cnidaria (which includes jellyfish, anemones and hydroids) comprises a diverse, abundant and widely distributed group of marine organisms (Branch et al., 2010). Only one member of this group was encountered in the epifauna survey, namely a sea-pen which was assigned to the family Veretellidae. Sea pens have a fleshy body covered with polyps and a soft unbranched peduncle that anchors the colony in mud or sand. The specimens recovered in this survey were generally small (2 to 3 cm) so would not be expected to be readily caught in the trawl. Interestingly, none was encountered in the cod-ends while relatively high numbers were consistently retained in the net wings. Veretellidae were also recorded in the benthic faunal surveys (Steffani, 2010; Section C, Chapter 2.5).

**Porifera** (sponges). Sponges are simple, primitive, and somewhat characterless organisms. As a result, they have been very poorly described. One unidentifiable species was recovered at 20 of the 24 stations in numbers ranging between 1 and 285.
**Gastropoda (whelks).** Whelks are commonly recovered in bottom trawls. They are active predators or scavengers. Eight specimens of *Nassarius wolffi* (dog whelk) were recovered at station 13. Somewhat more common was the “tulip whelk” (*Fasciolaria lugubris*) which was found at 16 of the 24 stations, in numbers ranging between 1 and 98.

**Crustacea.** Crustacea are usually common in bottom trawls. This survey yielded six species, two of which are widespread and relatively abundant. A swimming crab (*Bathynectes piperitus*) was present at all stations in numbers ranging between 31 and 212. Mantis shrimp (*Pterygosquilla armata capensis*) was absent only from station 11 and was recorded in numbers ranging between 2 and 124. The remaining four crustacean species were present in relatively small numbers and at only a few stations. Two specimens of mud prawn (*Callianassa australis*) were recovered at station 8. It was also recorded in the SP-1 area by Steffani (2010). Eight specimens of unidentified hermit crabs (*Paguridae*) were recovered at station 13, while three specimens of the prawn *Funchalia woodwardi* were present at station 12. Finally, the prawn *Solenocera africana* had a slightly higher presence with recoveries at four stations in numbers ranging between 3 and 32. It is evident that, apart from the swimming crabs and mantis shrimps, crustacean numbers in the study area were exceedingly sparse.

**Echinodermata.** Echinoderms are usually well represented in bottom trawls, globally, with urchins and starfish being particularly prominent. In the SP-1 study area they were virtually non-existent. The total recovery for 24 trawls was 20 starfish (*Asteroidea*) and 43 sea cucumbers (*Holothuroidea*). The starfish were divided between two taxa, namely an unidentified species of *Astropecten* and *Odontaster australis*. The sea cucumber was identified as *Pseudocnus thandari* (Moodley, 2008; Thandar *et al.*, 2010).

**Jellyfish, sponge and ascidians.** Three species of jellyfish (*Chrysaora fulgida, Aequorea forskalea* and *Chrysaora africana*) were identified during the survey. The abundance of *C. fulgida* in particular was the highest for all stations; this was removed from the catch, weighed and discarded, before sorting the remainder of the catch.

**Comparisons with other trawling surveys**

Drawing direct and valid comparisons between epifaunal catches in disparate bottom trawling surveys is fraught with difficulties. There have been no similar surveys on the central Namibian continental shelf. However, in recent years there has been renewed interest in the benthic ecology of the southern Benguela Current region, driven by a need to evaluate the impacts of trawling (Atkinson, 2009; Atkinson *et al.*, 2011). These studies have focussed on the deeper waters (roughly 350 to 450 metres) between Cape Point and southern Namibia. While there are significant differences in location and depth between the two studies, a broad comparison would appear to be justified, both studies were based on 24 trawls so they may be directly compared.

Atkinson *et al.* (2011) recorded a total of 81 epifaunal taxa in their study, which is far in excess of the 14 recorded in this study. Echinoderms and crustaceans were particularly well represented in their samples, whereas they are very poorly represented here. The epifauna in the SP-1 area would thus appear to be highly impoverished, particularly in terms of crustaceans and echinoderms.

**Environmental Drivers**

Apart from station 11, where a massive catch of jellyfish was made, and counts of other organisms were suppressed, there was notable uniformity in the epifauna across the study area. This is in line with a geophysical survey (Ludick, Section D, Appendix 3.2) which confirmed that sediment type and sedimentary conditions were also uniform. Other factors which might be considered to influence the
epifauna include water depth, salinity and oxygen concentration. The depth range was 198 to 255 metres, which would seem to be sufficiently narrow to be of little consequence. Salinities and oxygen concentrations were continuously monitored during trawling through a CTD that was attached to the tow line. The detailed results are presented in an accompanying report (Section D, Appendix 2.3). The salinity and temperature readings were within expected ranges and indicated the presence of South Atlantic Central Water (SACW) in the study area for most of the survey. However, dissolved oxygen concentrations were in many instances significantly depressed towards the seabed. The link between impoverished crustacean and echinoderm communities amongst the epifauna and oxygen depletion seems obvious. Periodic hypoxia may not be problematic for mobile organisms that are capable of avoiding low oxygen conditions. However it may impose severe limitations on those that lack this ability or are not physiologically pre-adapted to a low oxygen environment. The presence of high numbers of sea squirts (*Molgula* sp.) and sea pens (Veretellidae) suggests that they are able to tolerate occasional hypoxia and maintain significant populations. On the other hand, portunid crabs (*Bathynectes piperitus*) and mantis shrimps (*Pterygosquilla armata capensis*), which were the only other taxa present in significant numbers, are strong swimmers and presumably capable of avoiding hypoxic conditions. Most of the remaining taxa, notably the gastropods, echinoderms, the sponge, the mud prawn and the hermit crab, have relatively limited mobility and would thus be vulnerable to the negative effects of oxygen depletion.

**Concluding remarks**

While there was a significant presence of epifaunal organisms in the SP-1 area, there was low diversity. This may be ascribed to the chronic effects of periodic hypoxia on the less mobile and more vulnerable taxa. The fauna was numerically dominated by ascidians (sea squirts) and pennatulids (sea pens), which are presumably capable of tolerating periodic hypoxia. Relatively high numbers of portunid crabs and mantis shrimps were also observed. These are strong swimmers and thus capable of circumventing periodic hypoxic events. The information gained in this survey may serve as a baseline for future impact monitoring. Of particular interest, in this survey, was the widespread abundance of ascidians (*Molgula* sp.).

### 6.3.3 Seabirds

A total of 15 species of seabirds was recorded during the survey (Table 8). Of these, 45% were White-chinned Petrels (*Procellaria aequinoctialis*), 20% Sub-Antarctic Skua (*Catharacta antarctica*), 12% Black-browed Albatross (*Thalassarche melanophrys*) with the remaining species making up 23%. Not all the birds were identified to their species level.

Spatial distribution of seabird numbers per station is presented in Figure 23. Station 6 and 17 had the highest number of birds but Station 9 had the highest bird species counts. Seabird observations were only carried out during daylight trawls.
### Table 8: List of seabird sightings during the survey

<table>
<thead>
<tr>
<th>No</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Adult</th>
<th>Juvenile</th>
<th>Unidentified</th>
<th>Total</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sub Antarctic skua</td>
<td><em>Catharacta antarctica</em></td>
<td>436</td>
<td></td>
<td>436</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kelp gull</td>
<td><em>Larus dominicanus</em></td>
<td>1</td>
<td>1</td>
<td></td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Tern</td>
<td><em>Sternidae</em></td>
<td></td>
<td>1</td>
<td>1</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cape Gannet</td>
<td><em>Morus capensis</em></td>
<td>12</td>
<td>1</td>
<td>13</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cape cormorant</td>
<td><em>Phalacrocorax capensis</em></td>
<td>1</td>
<td></td>
<td>1</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Storm petrel</td>
<td><em>Hydrobatidae</em></td>
<td>18</td>
<td>57</td>
<td>75</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Albatross</td>
<td><em>Diomedeidae</em></td>
<td></td>
<td></td>
<td>33</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Shy albatross</td>
<td><em>Thalassarche cauta</em></td>
<td>135</td>
<td>25</td>
<td>160</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Black banded albatross</td>
<td><em>Thalassarche melanophrys</em></td>
<td>235</td>
<td>18</td>
<td>253</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Yellow nosed albatross</td>
<td><em>Thalassarche chlororhynchos/carteri</em></td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Pintado petrel</td>
<td><em>Daption capense</em></td>
<td>2</td>
<td>17</td>
<td>19</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Petrel</td>
<td><em>Hydrobatidae</em></td>
<td>10</td>
<td></td>
<td>10</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>White chinned petrel</td>
<td><em>Procellaria aequinoctialis</em></td>
<td>12</td>
<td>987</td>
<td>999</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Shearwater</td>
<td><em>Puffinus spp.</em></td>
<td>8</td>
<td>8</td>
<td></td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Sooty shearwater</td>
<td><em>Puffinus griseus</em></td>
<td>2</td>
<td>102</td>
<td>104</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>2196</strong></td>
<td></td>
<td></td>
<td><strong>1.00</strong></td>
<td></td>
</tr>
</tbody>
</table>
Figure 23: Spatial distribution of seabird number and species counts (red labels) per station.
6.3.4 Marine mammals

Two species of marine mammals were identified during the survey, namely the cape fur seal (*Arctocephalus pusillus pusillus*) and the dusky dolphin (*Lagenorhynchus obscurus*) (Table 9). Marine mammal observations were only carried out during daylight trawls. Seals were present at all stations and the dusky dolphin was observed at Station 7 and 9, where 100 and 150 individual dolphins were recorded, respectively.

The spatial distribution of mammal numbers is presented in Figure 24. Seal numbers were highest along the western edge of the target dredge area (in deeper water). Dusky dolphin was observed twice inside the target dredge area (SP-1).

<table>
<thead>
<tr>
<th>Station number</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Cape fur seal</td>
<td><em>Arctocephalus pusillus pusillus</em></td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Cape fur seal</td>
<td><em>Arctocephalus pusillus pusillus</em></td>
<td>7</td>
</tr>
<tr>
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<td><em>Arctocephalus pusillus pusillus</em></td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Cape fur seal</td>
<td><em>Arctocephalus pusillus pusillus</em></td>
<td>4</td>
</tr>
<tr>
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<td><em>Arctocephalus pusillus pusillus</em></td>
<td>4</td>
</tr>
<tr>
<td>7</td>
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<td><em>Arctocephalus pusillus pusillus</em></td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Dusky dolphin</td>
<td><em>Lagenorhynchus obscurus</em></td>
<td>150</td>
</tr>
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<td>8</td>
<td>Cape fur seal</td>
<td><em>Arctocephalus pusillus pusillus</em></td>
<td>9</td>
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<tr>
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<td><em>Arctocephalus pusillus pusillus</em></td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Dusky dolphin</td>
<td><em>Lagenorhynchus obscurus</em></td>
<td>100</td>
</tr>
<tr>
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<td>4</td>
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<td>3</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>323</strong></td>
</tr>
</tbody>
</table>
Figure 24: Spatial distribution of marine mammal numbers per station.
Station numbers have also been shown.
6.3.5 Hydrography and environment

The CTD with its temperature, salinity and oxygen sensors was attached to the trawl net to allow for sampling during trawling. The CTD report is presented in Section D, Appendix 2.3. In summary, 22 of the 24 trawls undertaken during the biodiversity verification survey provided acceptable results for temperature (with the exception of trawls 23 and 24) and 19 trawls yielded reasonable salinity data (exceptions being Trawls 13, 14, 17, 20 and 21). The trawls where successful temperature and/or salinity data were recorded can be compared with the fisheries and biodiversity data from the respective trawls.

Temperature profiles showed a well-mixed upper water column in most instances, with slight stratification occurring from Trawl 10 onwards (Figure 25). This is to be expected as the survey took place just after an extended period of rough seas with considerable wave action in the survey area. The weather conditions calmed significantly from trawl 5 onwards and this may be the cause of slight stratification of the upper layers of the water column. In general the upper water column was approximately 2.5 to 4°C warmer than the near seafloor temperatures (>200 m). The temperature on or near the sea floor throughout the survey averaged 10.68°C. This is within the range of expected winter values for the region (Shannon and Nelson 1996).

Salinity and temperature data indicated the presence of South Atlantic Central Water (SACW) for the majority of the survey. SACW upwells from approximately 200 m below the surface with a salinity of 34.7 to 35.65 PSU and temperatures between 8 and 16°C (Shannon and Nelson 1996, Mohrholz et al. 2001, Duncombe Rae 2005). The dissolved oxygen levels near the seafloor for most of the trawls were reasonably low (approx. 3 to 10%) as can be expected in the continental shelf zone offshore of Namibia (Monteiro PMS & van der Plas AK. 1996).
### Table 10: Summary statistics of the ‘Trawl section’ (excluding up and down casts) of each trawl

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Temperature (°C)</th>
<th>Dsvl. Oxygen (%)</th>
<th>Salinity (PSU)</th>
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<td></td>
<td></td>
<td></td>
<td>Day/Date</td>
<td>Mean</td>
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<td>26-Jun-14</td>
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</tr>
</tbody>
</table>
Figure 25: Down cast data for Station 6 in a cross-section view. Temperature, dissolved oxygen and salinity data are shown. Note the very low oxygen concentrations.
6.4 DISCUSSION AND CONCLUSIONS OF THE BIODIVERSITY SURVEY

Typically, because of the extent of the offshore environment, surveys undertaken for fisheries, benthic sampling and other biological and oceanographic processes are sub-samples and are randomised, requiring extrapolation of information across wide areas (normally including the entire continental shelf). It was mostly for this reason that information used in the EIA (Japp in Midgley 2012) was based almost entirely on historical survey data provided by NatMIRC. This data and its assessment formed the initial baseline for the fisheries impact assessment of the EIA (Japp in Midgley 2012). The target dredge area (SP-1) within the MLA is relatively small, and as expected, information provided using exact station locations did not necessarily coincide with the area (SP-1) targeted for dredging. The main objective for the verification survey was therefore to gather quality in situ data specifically from inside and just outside SP-1 (within the MLA) to verify the EIA determined baseline, which was established on the available data.

The execution of the designed biodiversity survey was successful and all of the designed work scope was accomplished. The survey was designed to identify and quantify the biodiversity of epifauna, demersal and pelagic fish, seabirds and mammals in the area to be compared with the known information from the region. The survey also obtained data on commercial species such as monk, hake and the other bycatch species to allow for rough estimates of, for example, spawning and recruitment, size distribution and other biological parameters. The sampling approach mirrored typical offshore fisheries survey sampling design with the exception of a standardised swept area biomass estimate (due to the non-availability of a suitable calibrated vessel and gear). The survey however, allowed for substantive verification and confirmation of the main determinations and data extrapolations from historical survey information that was used in the EIA (Japp, in Midgley 2012). This verified information provides a baseline of data from the target dredge site and increases the confidence levels of the assessment significantly, when compared with the original EIA assessment associated with data extrapolations.

Biodiversity

A total of 48 species of fish, jellyfish, epifauna, seabirds and mammals was identified during the survey. Of this, 14 fish species (including shark, squid and jellyfish) were identified which is relatively low when compared to the cumulative survey data from the combined hake, monk and small pelagic research cruises where approximately 40 fish species were identified in and immediately adjacent to the MLA. The primary reason for this difference is associated with the gear deployed – a larger number of pelagic species would for example have been recorded on pelagic-directed surveys. The species complexity obtained in the verification survey therefore reflects the availability of species typically caught in commercial monk and/or demersal trawl nets. The verification data therefore are a subset (indicator) of the total biodiversity.

Bird observations were carried out during daylight stations for 60 minutes during the entire trawling operation (i.e. from the setting to the end of hauling). Fifteen (15) species of seabirds typical to this area were identified. Of these, 54% of the species are considered Endangered, Threatened and Protected (ETP) namely, the White-chinned Petrel, Shy Albatross, Cape Gannet, Yellow-nosed Albatross and the Cape Cormorant. Their occurrence on the survey was expected and consistent with the known range of these species.
Two species of mammals were identified, the Cape fur seal (found at every station) and the dusky dolphin (at two stations only), both of which are common to the region. We conclude that there is a likelihood that numerous seabird and mammal species will occasionally be found in or near the MLA (target dredge site SP-1) and that impacts on these species will relatively be minimal.

**Species Availability and Catch Levels**

A total of 28 tonnes was recorded by the survey with an average of 1.2 tonnes per station. Trawls were 30 minutes and generally catches in day trawls were larger (by weight) than night trawls. These results are not dissimilar to the catch weights caught by the MFMR research surveys for monk (Kathena *et al.* 2010) and hake (Kainge *et al.* 2004) along the entire Namibian coast. Hake dominated the catches in the verification survey, amounting to 40% by weight of the total fish catch, followed by monk with 35%, rattail 14%, sole 3% and goby 2%. Horse mackerel constituted 0.4% of the total fish catch. A high abundance of red jellyfish was found at all the stations but particularly at Station 11, where 11 tonnes were caught. Similarly, ascidians were also in high abundance at all the stations but particularly high at Station 20.

**Recruitment**

To determine a rough estimate of recruitment the length frequency data as well as maturity stage were recorded for the main commercial species such as monk and hake. The mean length of monk and hake was 29 cm and 26 cm, respectively. The size distribution pattern is consistent with what is expected for juvenile hake and monk with depth-related recruitment. Typically recruiting fish are found in relatively shallow water (<200 m) and then migrate deeper as they mature.

Monk juveniles were in high abundance contributing to 45% of the total sampled monk catch. Approximately 62% of the monk were smaller than the length at 50% maturity (34.5 cm). These results are comparable with the conclusions made by Gaylard (Section C, Chapter 3.2) in that monk recruits are expected to be prevalent in the MLA. For monk the results for length at 50% maturity (34.5 cm females and male 27 cm) were similar to Maartens (1999) in that juveniles in her study reached sexual maturity at 32.1 cm for females and 23.7 cm for males.

Fewer than 6% of the sampled and staged hake were juveniles and fewer than 8% were smaller than the length of 50% maturity (21 cm). Juvenile hake are therefore expected to be displaced from the dredging area, but their mobility should limit the likelihood of mortality. The distribution of stage 4 adult hake is an indicator that these fish are not commonly spawning in the SP-1 and its immediate vicinity. Hake recruitment therefore, is not expected to be impacted significantly. We note however that maturity estimates and spawning activity estimates are constrained by the data limitations i.e. to survey periods.

Horse mackerel juveniles (<21 cm) were not observed during the survey. They occur mostly northwards of the MLA (Zone 2 and beyond). The impact on the recruitment of horse mackerel is therefore expected to be negligible.

**Trophic structure**

---

9 An estimated 7% of monk recruits were in the MLA and 0.2% in SP-1.
No direct conclusions could be made with respect to trophic structure. Stomach samples were taken and typically reflect the presence of the species composition in the trawls. These data however will form a baseline for future surveys. For hake the majority of the prey items were euphausiids and gobies. These results are comparable with diet analyses carried out by (Maartens 1999, Singh and Johannis 2013). For monk the main prey items were hake and gobies.

In conclusion, this initial baseline survey is a “snapshot” compared with historical data gathered in and around SP-1 of the MLA. This survey has proven to be a suitable sampling platform for monitoring the changes in fish availability, abundance, recruitment, biodiversity, marine mammals, seabirds and other fauna. Additional sampling stations can be included if necessary in subsequent surveys and changes in the parameters measured can be tracked over the lifetime of the exploitation of marine phosphate. This information can then be used to fine tune the management of dredging operation including possible future expansion of the operation.

7 A REVIEW OF THE MESOPELAGIC FISH AND PELAGIC GOBY

Among the largest potential commercial fishery stocks are the vast numbers of mesopelagic fish that are found in the mid-layers of the world ocean, typically from 100 to 1000 metres below the surface. While there are many species from many families that constitute this fauna, the lanternfish or myctophids of the family Myctophidae such as (Lampyrius hectoris and Maurolicus muelleri) and the pelagic goby (Sufflogobius bibarbatus) are perhaps the most widespread and ubiquitous (Figures 26 and 27) occurring on occasions in great abundance.

Both mesopelagics and gobies play an important role in this ecosystem (Staby and Krakstad 2008). They feed mostly on plankton and convert this energy to provide an important component, as a lower level trophic species, to species higher in the food chain (i.e. birds, mammals, pelagic and demersal fish).

Mesopelagic fish

In the northern Benguela region off the Namibian coast Rubies (1985) reported on a total of 41 lanternfish species. Of these, 25 originated solely from the Valdivia Bank 400 miles offshore on the Walvis Ridge, 10 were specific to the northern Benguela area, and six were common in both areas (Rubies 1985). Two species belonging to the oceanic lanternfish genus Symbolophorus and the pseudo oceanic warm-water genus Diaphus were also common off the coast of Namibia (Prosch et al. 1995). Of the 14 species of sternoptychids (hatchet fishes) found in South African waters, 11 have been recorded in the eastern south Atlantic (Prosch et al. 1995). Hulley (1991) gives a general account of 28 genera, comprising 125 species, of the lanternfish most likely to be found in the southern African region. This account covers a detailed description by Hulley (1986) of the distribution of lanternfish occurring in the southern Benguela.

Recent surveys undertaken by the Norwegian research vessel R.V. Dr. Fridjof Nansen and reported by Staby and Krakstad (2008) showed a similar distribution pattern of mesopelagic species to that reported by O’Toole (1977) in Figure 28. The data indicated that L. hectoris and M. muelleri were more abundant in the region compared with the other mesopelagic families however Yarella blackfordi and Photichthys argenteus (Photichthyidae) were also widely distributed and abundant in
trawl catches. Little however is known about their biology, ecology, vertical distribution and behaviour, life history parameters, or abundance of these mesopelagic species. The same can be said about *Stomias boa boa* (Stomiidae) and the bristlemouth fish *Triplophys hemingi* (Gonostomatidae).

![Map of mesopelagic fish species in the Benguela region](image)

Figure 26: Distribution of main commercial mesopelagic fish species in the Benguela region. Myctophidae (Lanternfish)
The reported historical distribution and abundance of larvae and early juveniles of lanternfish (Ahlstrom 1976) were reviewed with reference to the proposed marine phosphate dredging area.
(ML 170). The data for lanternfish larvae (*Lampanyctodes hectoris*) from the Southwest African Pelagic Egg and Larval Survey (SWAPELS) indicated that these species were widely distributed between latitudes 19° and 25°S (Figure 28). Larvae were found at distances of 8 – 112 km from the coast but were most abundant in offshore waters especially between Mowe Point (20°20'S) and Cape Cross (22°S) and between Walvis Bay (23°S) and Hollam’s Bird Island (25°S). The occurrence of high density sites of larvae at the southern limit of the sampling grid suggested that considerable spawning of these species is likely to occur off Hollam’s Bird Island. The main spawning period was understood to be from spring to early summer (between August and November), which coincided with the peak upwelling periods in the area.
Figure 28: Distribution and abundance of larvae of lanternfish (*Lampanyctodes hectoris*) from SWAPELS data. Numbers represent cumulative standard haul totals (adapted from O'Toole 1997).
Pelagic goby

The pelagic goby (*Sufflogobius bibarbatus*) also occurs extensively throughout Namibian waters generally in water depths of between 200 and 1000 m. According to Staby and Krakstad (2008) the goby stock is much smaller than previously reported by O’Toole (1977) (Figure 29). However, there is still a lack of knowledge regarding the seasonal dynamics, and spatial and temporal variations in fish size distribution and the life history parameters of the species although a recent study (Melo and Le Clus 2005) has expanded our knowledge on reproduction. Melo and Le Clus (2005) suggested that the pelagic goby might be a serial batch spawner, based on the extended spawning season from July to April, and the presence of more than one batch of yoked oocytes in the ovaries. They also showed that gobies mature late at 2-3 years of age, and males mature at a greater size and age than females.

Figure 29: Distribution of *Sufflogobius bibarbatus* in the Benguela. The figure represents a measure of mean relative abundance of gobies from all trawl hauls captured by the RV *Dr. Fridtjof Nansen* between 1985-2005.
The historical distribution and abundance of larvae and early juveniles of pelagic goby (O'Toole 1978) were reviewed with reference to the proposed marine phosphate dredging area (ML 170). During two ichthyoplankton surveys off South West Africa (Namibia), pelagic goby larvae (S. bibarbatus) was found in abundance and were widely distributed along the Namibian coast in the upper 50 m layer (O'Toole 1977). From all the larval organisms collected during these surveys (SWAPELS) goby constituted 61% (Figure 30).

The main spawning season has been reported to be from July to February, with a peak in late winter to early spring (O'Toole 1977). Spawning has been reported to be most intense in coastal waters south of Walvis Bay, but with less intense spawning over a more extended area during summer (O'Toole 1977).
Figure 30: Distribution and abundance of goby larvae during SWAPELS survey 1 (left) and survey 2 (right). Values represent cumulative standard haul totals for all cruises (adapted from O'Toole 1977)
Conclusions

Mesopelagic fish and gobies are well known for their diurnal vertical migrations producing strong “scattering” layers that are typically seen on echo sounders. During daylight hours most species remain within the light-limited bathypelagic zone. At sundown, as the surface light intensity diminishes, these species begin to rise towards the surface (but still remain well below the sea surface). They are thought to do this to avoid predation, and also because they are following the diurnal vertical migrations of zooplankton upon which they feed (O’Toole 1977, Crawford et al. 1985, Prosch et al. 1995).

*L. hectoris* is the only mesopelagic fish species that has been targeted and caught in reasonable amounts by the purse seine fishery in South Africa (Crawford 1980; Crawford 1987). This species has also been recorded in catches in Namibian waters but only as a bycatch in the purse seine fishery. Not only are these mesopelagic species numerous they are also found across the entire shelf of the Benguela ecosystem. Areas of abundance cover the mid-shelf areas that include the MLA. Research on this group suggests that these species are an important prey species for many top predators, including the deep water hake *Merluccius paradoxus* (Staby and Krakstad 2008).

Little is known about the potential effects of marine dredging (in particular the potential impacts of sediment plumes) on these scattering layers that include mesopelagic species, gobies, plankton, zooplankton. As the available information on the precise distribution of these species in the MLA and specifically in SP-1 is data deficient, no clear inference can be made on the impact dredging may have other than the dredging operation is likely to disrupt aggregations of mesopelagic species and the scattering layers of which they are a part.

The biodiversity verification survey, which used a net designed to catch bottom fish and particularly monk, did not capture any mesopelagic fish. The high mobility of this group of fish has been the primary reason why the commercial fishing sector has been unable to target them. Obtaining scientifically defensible indices of abundance of mesopelagic species in and around SP-1 would require a sophisticated research vessel with purpose built fishing gear. Future monitoring surveys should attempt to track the scattering layer patterns in order to infer the relative abundance of mesopelagic species, gobies and zooplankton. This could be achieved using industrial or scientific echo sounders with the frequency resolution suitable for the target strengths of the most commonly expected species. Samples of the species indicated on the acoustic scattering layers could also be taken if mid-water trawl gear were available on the survey vessel and if the vessel had adequate power to be able to tow such gear to nullify the avoidance behaviour of these species. The acoustic tracks would nevertheless provide adequate information on which to gauge the presence of these species and can be used as a baseline to monitor responses of this group of species to dredging operation.

8 GEOPHYSICAL SURVEY AND HABITAT MAPPING ASSESSMENT

The Namibian marine habitat is characterised by widespread areas of low oxygen waters overlying the diatomaceous mud-belt on the central Namibian shelf (Chapman and Shannon 1985; Dingle and Nelson 1993). Methane and hydrogen sulphide are reported to accumulate over large areas under this mud belt (Emeis et al. 2004). Blow outs of these toxic gases are frequently recorded at the ocean surface, affecting the movement and distribution of many pelagic and demersal species (Weeks et al. 2008).
However, despite its widespread occurrence across the Namibian shelf, the reported distribution of the mud belt indicates that it does not overlap with the proposed area for phosphate dredging i.e. the MLA (Figure 31, Emeis et al. 2004).

The geophysical survey

A geophysical survey was undertaken over a period of five days during September 2013 in the SP-1 area with the purpose of mapping the habitat and to determine the distribution of seafloor surficial sediments (Ludick: Section D, Chapter 3.2). The vessel, MV DP Star was fitted with Sidescan-Sonar (SSS) and Multi-beam Echo Sounder (MBES) equipment with the objective of characterising the seafloor of the target dredge area SP-1.

A block of 4 x 5 km², covering the proposed first 10 years of dredging inside SP-1, was selected as the survey location. A series of parallel north-south lines were run with side scan sonar and/or multi-beam echo sounders.

From the data, a 5 m x 5 m bathymetric digital terrain model grid was produced from the processed bathymetry and colour-shaded by water depth (Figure 32). This figure shows an overall flat seafloor
with depths ranging between 204 and 220 m. The 1 m isobaths contoured from the data, to a vertical resolution of 20 cm, strikes north-south with an eastward dip of around 0.3 degrees. A single, shallow depression (less than 1 m deep) in the sediment however was identified and appeared to be an exception to the rule. No positive relief features in the form of reef outcrops or shipwrecks of any kind was present in the data.

The backscatter image (called the Pseudo-backscatter mosaic) (Figure 33) with a 50 cm pixel resolution produced from the MBES data showed a featureless, homogeneous surficial seafloor, indicating a medium muddy sand surface (Ludick: Section D, Chapter 3.2). This was determined by applying the automated surficial seabed classification Angle versus Range Analysis (ARA). Further, the Sidescan Sonar (Figure 34) also confirmed a smooth seafloor with an absence of any features or variance. The ARA result indicated a medium sand surface for all of the mosaic, which is consistent with the Backscatter result.

The biodiversity survey (trawl verification survey)

In addition to the data provided by the geophysical surveys, the semi-random sampling methodology using bottom trawl gear provided no evidence to suggest that the substrate type was mud. Further, throughout the trawl survey, a homogenous bottom type was noted. There was no evidence of reef structures or areas with irregular bottom types. No mud was noted on trawl doors or footropes and the species trawled were consistent with a firm sandy / gravelly (shell) substrate amenable to trawling, as was expected. In some areas large numbers of typical substrate residing species were recorded. These include, for example, the ascidians and the sea pens, which together constituted for 76% of the overall epifauna component. Typical bottom-dwelling fish species recorded such as monkfish and sole are known to have sand and mud substrate preferences although no inference on habitat could be made on the availability of these species to the trawl gear as they could equally have occurred over muddy, sandy or gravelly substrate types.

Conclusions

The geophysical data conclusively indicated a flat, smooth seafloor with a homogeneous surficial sediment cover across the entire survey block. No protruding obstacles (natural or artificial) were observed.

The surficial sediment composition of the area was well known through a large amount of gravity cores that were taken across SP-1 for the purpose of resource development. The top few centimetres consists of a mixture of silty sand particles, with typically dense shell (Section D, Chapter 3.2). This confirms the muddy medium sand conclusion reached with the various images produced by the geophysical survey and is further supported by the trawl surveys suggesting habitat was homogeneous and primarily of firm sandy gravelly character.
Figure 32: Multi-beam Echo Sounder and Sidescan Sonar coverage within SP-1. Red shading shows shallow water, while blue is deeper water.
Figure 33: Multi Beam Echo Sounder bathymetry data.
Figure 34: Sidescan Sonar mosaic image.
9 ASSESSMENT OF THE EFFECTS OF DREDGING NOISE ON MARINE FAUNA

Sounds can have a variety of effects on marine fauna, ranging from subtle to strong behavioural reactions such as startle response or even the complete avoidance of an area. It is well documented that short and implosive sounds such as those produced from pile driving strikes, seismic airguns and military sonar can cause behavioural reactions by fishes and cetaceans up to distances of several tens of kilometres from the sound sources (OSPAR 2009, Robinson et al. 2011, for example). Certain sounds can also mask biologically important signals such as communication calls between baleen whales or fish. If the sound level that the animals receive is high enough, sound can affect hearing either temporarily or permanently and extremes can lead to injury or even death. The latter, however, usually occurs only in the case where animals are very close to very high intensity sounds, without having the opportunity to first move away. Research on the effects of underwater sound on marine fauna has increased over the last decade, but there are still many unanswered questions, especially with regards to the significance of sound impacts for conservation objectives. In particular, the translation of individual effects into consequences at the population level involves significant uncertainty.

Notwithstanding, marine dredging operations typically produce regular and continuous low frequency sound below 1 kHz with estimated source sound pressure levels ranging between 168 and 186 dB re 1 µPa at 1 m (Thomsen et al. 2009). Looking at these relatively high sound pressure levels, dredging noise has the potential to affect on marine fauna (fish, invertebrates and marine mammals) by inducing adverse behavioural reactions and by causing physiological damage (Thomsen et al. 2009). Previous studies indicated that dredging can trigger avoidance behaviour in marine mammals, and that marine fish can detect dredger noise over considerable distances (Richardson et al. 1995; Defra 2003). Despite these initial results, there are essential questions remaining on the potential effects of dredging noise. Studies to date have been sparse, undertaken on a few dredgers and at a very limited number of sites.

The few studies however, that have been conducted regarding the potential effects of dredging on marine fauna have predicted that vibration and frequency levels close to the dredger are relatively low and the data available indicate that dredging is not as “noisy” as for example seismic surveys, container ships and/or tankers; but are louder than for example most fishing vessels and whale watching vessels (Table 11). A detailed assessment of the potential impacts of sound from dredging vessels on a variety of species showed that sound levels in all cases are well below those known to cause damage to marine life (EIA Don Diego Technical Report unpublished). Thus, given the sound frequency and decibel level of sound emanating from a typical Tailer Suction Hopper Dredger (TSHD) intended to be used in this project, the dredging noise impact can be assessed as low.
Table 11: A comparison of the average sound emitted by various relevant vessels including this used for whale watching (EIA Don Diego Technical Report unpublished)

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<th>Vessel</th>
<th>Ref Frequency Hz</th>
<th>Amplitude dB at 1m</th>
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<tr>
<td>Container ship</td>
<td>20Hz – 10 kHz</td>
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<tr>
<td>Tanker</td>
<td>20Hz – 10kHz</td>
<td>186dB</td>
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<td>250Hz – 4kHz</td>
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<td>Fishing vessel</td>
<td>100 Hz – 4kHz</td>
<td>170dB</td>
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<tr>
<td>Whale watching boat</td>
<td>100Hz – 20.3kHz</td>
<td>146-160dB increasing with speed.</td>
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## 10 OVERALL CONCLUSIONS OF THE VERIFICATION PROGRAMME

The verification process for the fish, mammals and seabirds component of the NMP impact assessment process has confirmed the following:

1. The verification programme has increased the confidence levels of the determinations in the EIA (Japp in Midgley 2012), supporting the core assumptions, thereby strengthening areas which were of concern and or uncertainty in the original assessment.

2. The verification programme aimed to address several key issues, in particular the concern that the proposed dredging will have a significant effect on fisheries. The verification programme has confirmed the following in this regard:
   a. The biomass of key commercial fish species likely to be impacted by the dredging of phosphate will be low, particularly as the dredging process is confined to a proportionately small area relative to the known biomass of these species (hake and monkfish in particular). It is our considered opinion that the impact on the commercial fishery biomass will be low;
   b. With regard to recruitment, the verification programme has confirmed our initial assessment that the impact of dredging in SP-1 is of moderate intensity and medium significance. However, the area to be dredged (SP-1) is generally understood to be in the “usual” distribution of the main commercial species and that their size distribution and their general biological dynamics are what was to be expected;
   c. The verification survey programme has shown that the size distribution of the main commercial species likely to be impacted (monk and hake) is consistent with what is known and with what was assumed in the initial EIA. There appears to be no unique spawning and recruitment characteristics. For hake, the abundance of juvenile and pre-recruiting hake (*M. capensis* only) is consistent with what is known and the proportions of juveniles and sex ratios (males and females) suggests no irregularities that would make the area to be dredged unique. With regard to monkfish, as expected, the verification survey has shown a mix of juveniles, adults and pre-recruiting fish. We note that as the survey used monk-directed gear and since it used a cod-end liner to retain as much as possible, it is expected that a higher proportion of juvenile fish would be caught. The area does therefore have a higher proportion (than hake) both of juvenile and pre-recruiting monkfish. The biomass estimates of Gaylard (Section C, Chapter 3.2) confirm this as well, but also that the scale of the dredging (in particular SP-1) is extremely limited when compared to the abundance of the monk resource. The impact on monk recruitment and the fishery as a whole will be low.
d. Sole were also caught in the verification survey. Abundance was not high and is in all likelihood consistent with what is expected (as a proportion of a monk-directed catch). Further, predominantly large sole were caught suggesting that the SP-1 area and adjacent grounds are unlikely to be a significant recruiting area. The area is nevertheless an extremely small proportion of the overall distribution of the stock.

e. The general fish diversity is low – no inference from the verification survey can be made regarding non-demersal species such as horse mackerel and gobies. Both of these species were found in small quantities. Part of the verification programme incorporated historical spatial and temporal distributions of small pelagic species as well as the assessment done by Ndjaula (Section C, Chapter 3.4). We note that the resource has reduced to such an extent that it would be irrational and illogical to assume that the location of the MLA and in particular SP-1, that small pelagic species would be impacted by either the dredging operation or by the plume so generated. The plume effect has been shown to be relatively limited in extent (Section C, Chapters 2.1 and 2.2).

f. With regard to mesopelagic species, none was noted in the trawl catches. Catches between night and day varied as expected and we assume normal diurnal behavioral patterns prevail with regard to fish and crustaceans. Mesopelagic species such as lantern fish are expected in the mid-water and the monk gear used would not target these species. We would expect however if mesopelagic species were abundant in the area that they would be recorded in small quantities either in the trawls or in the wings of the net. This did not occur.

3. The verification survey also provided baseline data on biodiversity. The diversity of fish is low compared with the EIA – this is expected as the EIA consolidated information on all the species and all the surveys (types) in and around the proposed dredging area. With respect to fish species, epifauna and mammals and seabirds, no unique features were noted and the results are consistent with the initial assessment (accepting that abundance of some species, particularly sea birds and mammals will vary seasonally as well as spatially).

4. With regard to the oceanographic conditions (Section D, Appendix 2.3) as derived from the CTD measurements we make no inference other than that no unusual conditions were noted that would result in uncertainty in interpretation of the data on marine fauna;

5. With regard to ecosystem (Section C, Chapter 3.1) impacts as a whole, the survey itself suggests that the area possesses no unique features. We noted that there are occasional large catches of jellyfish as well as of ascidians. This is typical of the area inside and near the MLA and the skipper of the monk trawl survey vessel (a regular trawler skipper) confirmed that this is consistent with what would be expected for that area.

6. Further, with regard to ecosystems (Section C, Chapter 3.1) as a whole, the uncertainty stated in the original EIA is supported. The primary issue is one of scale and it is the considered view that the area of impact (up to 3 km$^2$ annually and 60 km$^2$ for the 20-year mining lease period) is so small relative to the overall Benguela ecosystem that significant impacts on the ecosystem are unlikely. Typical ecosystem modeling which has been done on both the northern and southern Benguela is unlikely to provide any useful guidance on either the large scale or localized impacts as determined by the EIA. The verification process has strengthened the need to maintain a baseline and to monitor this for changes in the system around the area to be dredged. This will facilitate management of the process and inform the likely effects if these activities were to expand and if incorporated into the management plan for the area, will allow for appropriate responses to any changes.

7. Mesopelagic fish, gobies and zooplankton (Section C, Chapter 2.7) are well known for their diurnal vertical migrations producing strong scattering layers that are typically seen on echo sounders. Little is known about the potential effects of marine dredging (in particular the
potential impacts of sediment plumes) on these scattering layers. Obtaining scientifically defensible indices of abundance of these species in and around SP-1 would require a sophisticated research vessel with purpose built fishing gear. Future monitoring surveys should attempt to track the scattering layer patterns using industrial or scientific echo sounders in order to infer the relative availability of these species. Samples could also be taken if mid-water trawl gear were available on the survey vessel and if the vessel had adequate power to be able to tow such gear to nullify the avoidance behaviour of these species. The echo-sounder tracks would nevertheless provide adequate information on which to gauge the presence of these species and can be used as a baseline to monitor responses of this group of species to dredging operation.

8. The geophysical data (Section D, Appendix 3.2) conclusively revealed a flat, smooth seafloor with a homogeneous surficial sediment cover across the entire survey block. No protruding obstacles were observed. The various images produced by the geophysical survey show that the surficial sediment composition of the area was a muddy medium sand. This was further supported by the trawl surveys, suggesting that the habitat was homogeneous and primarily of firm sandy gravelly (shell) character.

9. Previous studies of the potential impacts of sound from dredging vessels on a variety of species showed that sound levels in all cases are well below those known to cause damage to marine life. Thus, if we assume that the sound frequency and decibel level of sound emanating from a typical Tailer Suction Hopper Dredger (TSHD) intended to be used in this project, then dredging noise impact can be assessed as low.

11 RECOMMENDATIONS

i. It is recommended that should an environmental clearance certificate be issued that monitoring (baseline time series) continues. This should include a similar survey using similar design annually. For continuity similar vessels and gear should be used such that results are comparable and so that a baseline biomass index can be further developed.

ii. There is a lack of specific mine site information on noise emissions from dredgers and their potential effects; thus it is recommended that some acoustic monitoring at the target dredge site (SP-1) to determine the levels of dredging noise and to monitor whales and dolphins using Passive Acoustic Monitoring (PAM) devices should be undertaken. It is also recommended that marine mammal observers could be trained to use such devices and could be a part of a monitoring team on board the dredging vessel or during dedicated monitoring surveys.

iii. Future surveys should attempt to track the scattering layer patterns in order to infer the relative availability of mesopelagic species, gobies and zooplankton. This could be achieved using industrial or scientific echo sounders. Samples of could also be taken if mid-water trawl gear were available on the survey vessel and if the vessel had adequate power to be able to tow such gear to nullify the avoidance behaviour of these species. However, echo-sound data should be adequate to gauge the presence of these species, which can be used as a baseline to monitor responses of these groups of species to dredging operation.

iv. The monitoring of the baseline can be strengthened if NatMIRC adapted their current survey design for both the monk and hake annual surveys. For relatively low additional cost and effort the MLA and or SP-1 areas can be incorporated into these surveys. This would strengthen the baseline as well as providing MFMR with an alternative independent estimate of conditions and changes that may occur in the dredged area.
ACKNOWLEDGEMENTS

Thanks are due to Jeremy Midgley and Mike Woodborne for solid logistical and technical support, to fellow scientists; Kate Munnik, Victor Ncongo, Dr Robert Williamson, Malakia Shimhanda and Ester Nangolo for great team work and to Tim Reddel, Andries Olivier, Captain Francois Bouman and the crew of FV Zeearend for unstinting assistance. Thanks also to the Namibian Ministry (MFMR) in particular, the NatMIRC Scientists Paul Kiange, John Kathema and Dr Chris Batholomae for their exceptional cooperation and acknowledged efforts in making this project possible. Special thanks to James Gaylard, Dr Hilkka Ndjaula and Dr Kevern Cochrane for their outstanding contributions.

SUPPORTING DOCUMENTATION


Fairweather T and Leslie R (2008). *Merluccius capensis* and *M. paradoxus* length at 50% maturity based on research survey biological data. *MCM/2008/AUG/SWG-DEM/42*


Heymans J (2004). The effects of internal and external control on the Northern Benguela ecosystem. (upbub).


Assessment Report


Staby A and Krakstad JO (2008). Review of the state of knowledge, research (past and present) of the distribution, biology, ecology, and abundance of non-exploited mesopelagic fish (Order Anguilliformes, Argentiniformes, Stomiiformes, Myctophiformes, Aulopiformes) and the bearded goby (*Sufflogobius bibarbatus*) in the Benguela Ecosystem. *BCLME project LMR/CF/03/08.*


Annexure 1. Coordinates for the original and actual trawl stations.

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Annexure 2. Fish (monk and hake) length at 50% maturity and their length-weight relationship.

**Fish length at 50% maturity**

All monk and hake with inactive gonads were considered to be immature (except for those gonads which were inactive and spent), whereas all stages from active to spent were considered as representing mature fish. Mature and immature fish were sorted into 4 cm size classes and the percentage of mature fish was calculated for each length class. The resultant curves are shown in Figures 35 – 40. Females of both species matured at greater lengths than males. The percentage of fish below the length of 50% maturity was calculated for monk females (80%), monk males (45%), hake females (6%) and hake males (8%).
Figure 35: Percentage of mature female monk per length class. Length at 50% maturity is also shown.

Figure 36: Percentage of mature male monk per length class. Length at 50% maturity is also shown.
Fish length – weight

Biological testing, consisting of individual weight and length measurements, sex, maturity stage and stomach contents were carried out for monk and hake for each station. Length-weight relationships are presented for monk and hake in Figure 47 and 48, respectively.
Figure 39: Length-weight relationship for monk.

Figure 40: Length-weight relationship for hake.