

# Fish Monitoring Program

## Maxima 3D Marine Seismic Survey, Scott Reef

Woodside Energy Ltd.

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# 1 Introduction

## 1.1 Project Description

Woodside Energy Ltd. (Woodside) proposes to undertake a three-dimensional (3D) marine seismic survey (Maxima 3D Marine Seismic Survey or Maxima 3D MSS) over an area of approximately 362 square kilometres covering both State and Commonwealth waters of Scott Reef. South and North Scott Reefs (collectively known as Scott Reef) are situated in the Browse Basin approximately 430 kilometres north of Broome in Western Australia (**Figure 1**).

The survey is planned to commence in September 2007, depending on vessel availability, and will last for approximately 50-60 days. The precise duration of the seismic acquisition is heavily dependent on weather and sea state conditions encountered during the survey.

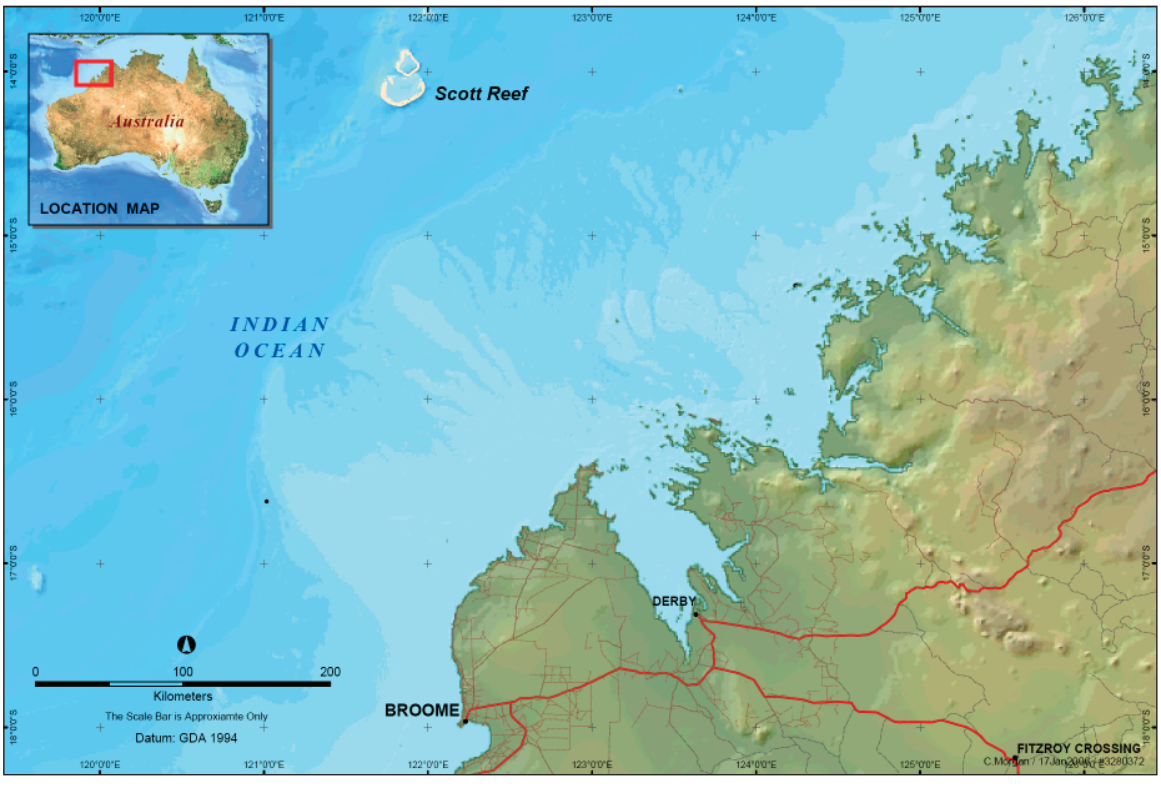
## 1.2 Environmental Management and Monitoring Programs

As part of the environmental management and monitoring for Maxima 3D MSS, Woodside have prepared an Environment Plan (EP). The EP is the overarching management document and describes the proposed activity, the existing environment, potential environmental risks and impacts and strategies to minimise those risks. The strategies are presented within the EP as either specific 'stand-alone' operational procedures or detailed in activity-specific Management or Monitoring Plans. The activity-specific Plans underpin the EP and have been developed by Woodside, in accordance with the Government of Western Australia's 'Ministerial Conditions', to limit the potential impacts this survey may have on the environment (Government of Western Australia, 2007). The five management plans that have been developed under the EP are:

- Adaptive Management Program;
- Cetacean Monitoring Plan;
- Non-Indigenous Marine Species Management Plan;
- Fish Monitoring Program; and
- Oil Spill Contingency Plan.

This document presents the Fish Monitoring Program.

Figure 1 Location Map, Scott Reef



## 1.3 Purpose of the Fish Monitoring Program

As part of the environmental management commitments to limit the potential impacts the survey may have on the marine environment, Woodside has committed to the development and implementation of a Fish Monitoring Program (FMP). This has also been set as a requirement of the environmental approval under the WA Environmental Protection Act, as set out in Condition 9 of the Ministerial Conditions (Government of Western Australia, 2007).

Specifically, those conditions relating to the FMP are as follows:

**9 Fish Monitoring**

9-1 Prior to the commencement of phase I of the Maxima 3D Marine Seismic Survey, the proponent shall design and prepare a Fish Monitoring Program.

The objective of this Program is to acquire information about the impacts of seismic surveys on fish.

This Program shall include methodologies for:

1. Characterisation of the behaviours of tropical marine fish species representing members of those groups predicted to flee from seismic shots and members of those groups predicted not to flee from seismic shots, prior to, during and after exposure to a range of seismic shot sequences;
2. Investigation of the types and magnitudes of psychological impacts on the auditory and non-auditory tissues of tropical marine fish as a result of exposure to a range of seismic shot sequences;
3. Investigation of the time-related sequence of damage to, and repair of, auditory hair cells of tropical marine fish following exposure to a range of seismic shot sequences;
4. Investigation of the hearing sensitivity of tropical marine fish species prior to and after exposure to a range of seismic shot sequences; and
5. Characterisation of any changes to the levels of fish diversity and abundance resulting from the Maxima 3D Marine Seismic Survey, and if changes are detected, characterisation of the recovery of fish diversity and abundance levels until there are no significant differences from the levels of diversity and abundance prior to the Maxima 3D Marine Seismic Survey, or until three years has elapsed since completion of the Maxima 3D Marine Seismic Survey.

9-2 The proponent shall ensure that the Fish Monitoring Program required by condition 9-1 has been peer-reviewed and shall submit the Program to the Department of Fisheries and the CEO together with peer-reviewer reports and the proponent's responses to the peer-reviewer reports not less than ten business days prior to the scheduled commencement of Phase I of the Maxima 3D Marine Seismic Survey.

9-3 The proponent shall implement the Fish Monitoring Program required by condition 9-1.

9-4 The proponent shall make the Fish Monitoring Program required by condition 9-1 publicly available in a manner approved by the CEO.

9-5 Within two years following the commencement of the Maxima 3D Marine Seismic Survey, the proponent shall have prepared peer-reviewed reports or publications addressing the first four components of the Fish Monitoring Program listed above (condition 9-1, points 1 to 4).

Copies of each report / publication shall be provided to the Department of Fisheries and to the CEO as soon as possible after they are completed.

9-6 Within twelve months of finding no significant difference between the pre-survey and post-survey levels of fish diversity and abundance or within one year after monitoring ceases in accordance with condition 9-1(5), the proponent shall complete peer-reviewed reports or publications addressing the fifth component of the Fish Monitoring Program listed above (condition 9-1, point 5).

Copies of each report / publication shall be provided to the Department of Fisheries and to the CEO as soon as possible after they are completed.

## 1.4 Objectives of the FMP

The objectives of the FMP are based on the requirements of the Ministerial Conditions (Section 1.3). These are described below:

1) To monitor and report on the **Behaviour of Tropical Marine Fish** exposed to airgun emissions from the Maxima 3D MSS;

2) To monitor and report on any **Physiological Impacts** to the auditory and non-auditory tissues of tropical marine fish exposed to airgun emissions from the Maxima 3D MSS;

3) To monitor and report on any **Damage to and Recovery of Auditory Hair Cells** of tropical marine fish exposed to airgun emissions from the Maxima 3D MSS;

4) To monitoring and report on the **Hearing Sensitivity** of tropical marine fish exposed to airgun emissions from the Maxima 3D MSS; and

5) To monitor and report on any changes to **Fish Diversity and Abundance** as a result of the Maxima 3D MSS.

## 1.5 Structure of the Program

The remainder of the FMP is set out as follows:

- *Section 2* presents the FMP design, including background, objectives, sampling procedures, methodologies and parameters to be monitored as part of the FMP; and
- *Section 3* details the reporting requirements of the FMP.

# 2 Fish Monitoring Program

## 2.1 Introduction

This section presents the FMP design, background, objectives, sampling procedures, methodologies and parameters to be monitored as part of the FMP. For clarity and consistency, this section is arranged in line with the objectives described in Section 1.

## 2.2 Objective 1 – Behaviour of Tropical Marine Fish

This section presents the elements of the programme designed for monitoring the behaviour of tropical marine fish when exposed to airgun emissions during the Maxima 3D MSS.

### 2.2.1 Background

The response of marine fauna to seismic airgun noise has been predicted to range from no effect to various behavioural changes (Woodside, 2007). Immediate physical effects are likely only to occur at very short ranges and high sound intensities and will largely be unlikely to occur for the majority of species, as most free-swimming animals will practice avoidance manoeuvres well before they get within the ranges at which physical effects may occur. Animals that do not move away from the path of a seismic vessel because of behavioural or physical constraints, or which are caught unaware within a few hundred metres of an array when it suddenly starts up, will be most at risk of physiological and pathological effects.

As part of the Environmental Protection Statement (EPS) (Woodside 2007), Woodside completed a detailed literature review and risk assessment to examine the potential for high-level behavioural and physiological effects in both site-attached and non-site attached teleost fishes.

The results of the risk assessment predicted that a range of behavioural reactions to airgun emissions would be expected to occur within both site-attached and non-site attached fish, depending on the sound exposure levels upon which they would be exposed to. For the Maxima 3D MSS, these levels were summarised into three impact categories, within which a range of Sound Exposure Levels are predicted to occur (see **Table 1**).

In general, however, the risk assessment predicted that behavioural impacts would be of a temporary or transient nature. No long term impacts at a significant population-level were therefore predicted to occur (Woodside, 2007).

Table 1 Impact Categories[1]

| Impact category | Range of Cumulative Sound Energy Levels *(over single seismic line sequence)* predicted to cause each level of impact (dB re 1 μPa$^2$.s) | Impacts associated with each category as a result of exposure to airgun emissions from a single seismic line or from adjacent planned and infill seismic lines |
|---|---|---|
| 1 | 180 to <187 | • Temporary threshold shift from which at least 98 per cent of fish recover within six hours or the time interval greater than six hours, determined in accordance with conditions 5-7.<br>• No non-auditory tissue damage.<br>• No direct mortality. |
| 2 | 187 to <200 | • Temporary threshold shift from which fish may not recover within six hours or the time interval greater than six hours, determined in accordance with conditions 5-7.<br>• Permanent threshold shift.<br>• Non-auditory tissue damage unlikely, (less than five per cent of any fish population exhibiting non-auditory tissue damage.<br>• No direct mortality. |
| 3 | Equal to or greater than 200 | • Temporary threshold shift.<br>• Permanent threshold shift.<br>• Possible injury to non-auditory tissues.<br>• No direct mortality. |

(1) Please note that the predicted impacts in Table 1 are related to adult fish, as per Appendix C of the EPS (Woodside, 2007).

### 2.2.2 Objective

The objective is to monitor the behaviour of both site attached and non-site attached tropical marine fish exposed to airgun emissions as a result of the Maxima 3D MSS.

### 2.2.3 Sampling Design

The Maxima 3D MSS at Scott Reef will be divided into two phases, the Phase one survey and the Phase two survey.

The Phase one survey will be a preliminary survey at Scott Reef to trial the proposed seismic survey vessel and airgun array to be used for the Phase two survey and ensure compliance with requirements of the Ministerial Conditions (Government of Western Australia, 2007). The survey will be undertaken at Scott Reef using the seismic survey vessel and airgun array proposed to be used for the Phase two survey. The survey will consist of a series of scientific investigations designed to satisfy the requirements for the Adaptive Management Program (AMP) (WEL, 2007).

The results of the Phase one survey will be evaluated for conformance with the Ministerial Conditions for the Maxima 3D MSS. The Phase two survey will commence upon acceptance of the results of the Phase one survey.

In addition to the Preliminary Field Survey required as part of the AMP, a number of scientific investigations will also be undertaken for the FMP during Phase one. Monitoring the behaviour of tropical marine fish will be one of those.

The design for monitoring the behaviour of tropical marine fish representing members of those groups predicted to flee from seismic shots and members of those groups predicted not to flee from seismic shots, prior to, during and after exposure, takes into account the following factors:

- Predictions on fish behaviour; and
- Expected use of the data.

In order to collect data on behaviour of both fleeing and non-fleeing fish, a series of observations will be undertaken on tropical marine fish representing both groups. This will consist of observations of both caged fish exposed to underwater sound exposure levels from the airgun emissions, as well as free swimming wild fish populations. Observations of caged fish will be taken from the scientific investigations being undertaken as part of the AMP for the Phase one survey, however, footage collected under this monitoring will also be used for the FMP behaviour monitoring.

Baseline data will be collected no earlier than two (2) weeks prior to the Phase one survey, whereas, exposure monitoring will be undertaken during the pass of the operating seismic survey vessel and post-exposure monitoring immediately after, as part of the Preliminary Field Survey.

### 2.2.4 Sampling Methodology

#### 2.2.4.1 Observations of Caged Tropical Marine Fish

As stated above, observations of caged tropical marine fish will be collected as part of the design of the scientific investigations for the AMP. Footage collected as part of these surveys will be used to acquire information about the impacts of seismic surveys for the FMP. A description of this investigation is described below.

Purpose built fish cages will be placed at locations within areas predicted to experience each of the three impact categories, i.e. Category 1, Category 2 and Category 3, to monitor for any changes in behaviour patterns (see Government of Western Australia, 2007 for reference). Cages in the potential Category 3 area will be placed as close as practicable to the seismic survey array such that the cages allow safe passage of the seismic vessel and its source array overhead, and the cages are clear of propeller wash. Nevertheless, cages will be placed as shallow as possible to reduce the potential confounding effects of barotraumas in the fish.

Due care will be taken to ensure that live corals experience as little impact as possible through cage deployment (and removal). Cages will be secured to the bottom to avoid being lost and potentially dragging on the seabed.

Where possible, individuals of three different representative species of reef fish will be collected from Scott Reef for each test cage (see AMP for further details). Fish will also be selected to allow both fleeing and non-fleeing fish, and both hearing specialist and non-hearing specialist fish species to be represented (see Government of Western Australia, 2007 for further details).

As fish will be collected on-site, species and numbers will be selected depending on availability. However, it is envisaged that the following species will be targeted:

- *Lutjanus gibbus* (Paddletail) – Fleeing / Non-Hearing Specialist;
- *Dascyllus aruanus* (Humbug Damselfish) and/or *Chromis viridis* (Green Puller) – Non-Fleeing / Non-Hearing Specialists; and
- *Sargocentron spiniferum* (Spiny Squirrelfish) – Non-Fleeing / Hearing Specialist.

Each of the above species are considered to be common at Scott Reef and are thus representative of the types of fish species that may potentially be exposed to airgun emissions. Should sufficient numbers of the above species be unavailable during the Phase one survey, alternative species will be selected to best represent tropical marine fish present at Scott Reef.

Once collected, fish will be kept either in floating holding pens at a site remote to the survey area or onboard the support vessels in appropriate conditions. All holding pens will be at a distance sufficiently far from seismic operations so as not to confound the results.

To minimise additional stress on the organisms through sensory identification of potential predatory species each species will be placed in separate cages.

Prior to the seismic survey, selected fish will be placed within the already deployed fish cages. Underwater video will be set up to record the behaviour of the fish at various times before, during and after exposure to shots fired from the airgun. Video cameras will be attached to fish cages that ensure a view of the fish within the cage. Cages will be securely fastened to the seabed to ensure it is not knocked over or moved during the airgun overpass.

Airgun shots will be fired from a moving vessel that will pass over each cage in the Category 3 area. Shots will be fired directly above the cages. Video footage of each cage will be recorded throughout the run of the seismic vessel.

Runs will not start until at least 30 minutes after divers who set up the cameras have left the site. Firing of airguns will commence when the vessel is at a nominal distance of six kilometres from the first cage and will continue to at least six kilometres past the final cage in the Category 3 area.

Acoustic measurements will also be collected during the pass of the seismic vessel by attaching fixed sea noise loggers to the fish cage. This will therefore allow sound exposure levels (SEL, dB re 1 $\mu Pa^2.s$) received at the fish cage to be logged to identify actual SELs to which caged fish are exposed.

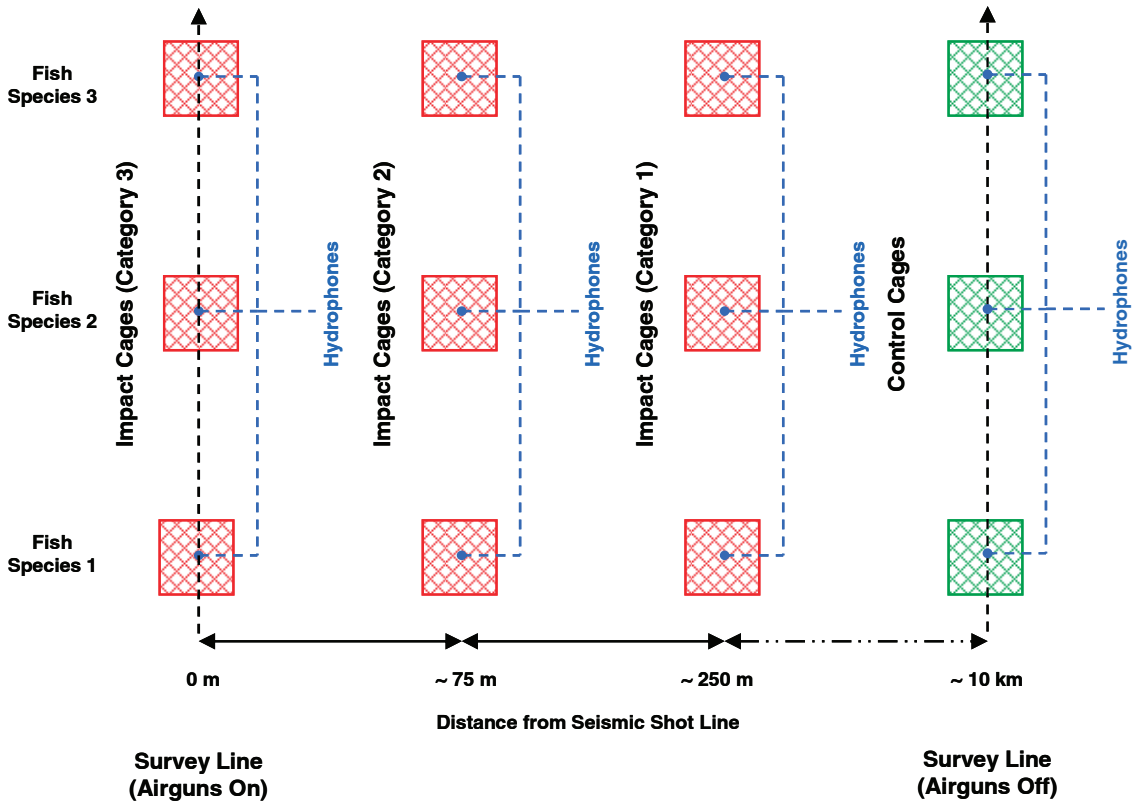
Video cameras will be retrieved once the vessel has departed the area to allow for any behavioural changes or direct mortality to be observed.

Control cages will be situated at a site of similar characteristics to the test site, but a sufficient distance away not to be affected by sound exposure levels. Control cages will be set up according to the same design as the impact cages, i.e. three cages each holding a separate species of fish. Following the airgun trial on the impact cages the boat will then pass over the control cages without any shots being fired to observe the reactions of the fish to propeller noise. These will be videoed in the same manner as the exposed cages.

An indicative example of the proposed seismic vessel run is presented in **Figure 2**.

Following the completion of the survey, video footage will be collected for analysis of the behaviour of the caged fish prior to, during and after exposure to seismic shots.

Figure 2 Schematic of Fish Cage Layout



### 2.2.5 Observations of Free Swimming Tropical Marine Fish

In addition to the observations of caged tropical marine fish, the FMP will collect data on the behaviour of free swimming tropical marine fish prior to, during and after exposure to seismic shots. As above, these observations will be collected as part of the Phase one survey.

In order to satisfy the objective, static underwater video cameras will be set up at set locations within each of the three impact categories, i.e. Category 1, Category 2 and Category 3, to monitor for any changes in behaviour patterns. Locations will be selected to collect video footage of free swimming tropical marine fish species representing members of those groups predicted to flee from seismic shots as well as members of those groups predicted not to flee from seismic shots. If necessary, separate cameras will be used to collect footage of these different groups.

Long-play video cameras will be used where possible to provide a practical maximum amount of footage to be collected, however, at a minimum, one and a half hours of video footage would be taken after the camera is set up prior to the arrival of the operating seismic vessel. The camera will then be retrieved no sooner than one and a half hours after exposure. For all footage, the first half an hour will be discarded as diver disturbance may affect normal behaviour of the marine fish.

In addition to the above impact sites, cameras will be set up at a control site located at sufficient distance to the impact site which will have been predicted not to be exposed to SELs. This control site will be used to collect footage on behaviour on both fleeing and non-fleeing free swimming tropical marine fish. The control site will allow the investigation of the effect of the seismic vessel approaching without the airgun firing on fish behaviour and assist in differentiating between behavioural impacts associated with the airgun emissions and those simply as a result of the presence of the survey vessel.

### 2.2.6 Use of Data

The results of the observations of behaviour of tropical marine fish will be analysed to compare the findings of behaviour prior to, during and after exposure to airgun emissions from the Phase one survey. Observations will also be compared against those collected at the control site to evaluate whether any changes on behaviour observed are attributable to airgun emissions, or potentially as a result of the presence of the seismic survey vessel.

The findings of the monitoring will be used to provide information about the impacts of seismic surveys on fish and presented in the *Fish Monitoring Program Report* (see Section 3).

## 2.3 Objective 2 – Physiological Impacts

This section presents the elements of the programme designed for monitoring any physiological impacts to tropical marine fish as a result of airgun emissions during the Maxima 3D MSS.

### 2.3.1 Background

Vulnerability to impacts from the impulsive, broad spectrum, low frequency (10 – 1000Hz), acoustic emissions from airguns is primarily related to the presence of gas filled chambers within animal structures. Most invertebrates (except cuttlefish) do not have gas filled chambers and therefore are not vulnerable. The ear chambers, swim bladders and lungs of vertebrates however, make them more vulnerable to impacts from seismic surveys. Whilst no areas within or adjacent to the survey area have been predicted to be exposed to received sound exposure levels that are expected to cause direct lethal effects in adult fish, there is, however, a possibility impacts may occur to both auditory (e.g. hair cells) and non-auditory tissues (e.g. swim bladder) in some site-attached fish species.

### 2.3.2 Objective

The objective is to monitor physiological damage to fish auditory and non-auditory tissues via sampling and analysis of target fish species exposed to airgun emissions during the Phase one survey.

### 2.3.3 Sampling Design

The design for the investigation into the types and magnitudes of physiological impacts on the auditory and non-auditory tissues of tropical marine fish takes into account the following factors:

- Predictions of impact; and
- Expected use of the data.

The investigation will consist of sampling exposed and control groups of target fish species for analysis post-survey as well as a baseline group that has not been set out in cages. Representative control samples will be taken for comparison with fish that have been exposed to seismic airgun emissions.

### 2.3.4 Sampling Methodology

As discussed above, tropical marine fish collected at Scott Reef will be exposed to seismic airgun emissions through controlled scientific investigations being undertaken as part of the AMP for the Phase one survey. It is proposed that a selection of these fish will be used for the investigation into any potential physiological impacts following exposure.

Fish will be collected from areas within each of the three impact categories, i.e. Category 1, Category 2 and Category 3, to monitor for any differences in physiological impacts. In addition to these impact fish, free swimming fish that have not been exposed to seismic airgun emissions will also be selected for sampling and analysis.

Three species of fish will be selected for analysis, representing tropical marine fish species predicted to flee from seismic shots as well as members of those groups predicted not to flee from seismic shots.

Samples of selected fish from each species will undergo gross and histopathological examination to determine whether impacts to non-auditory tissue have occurred through exposure to airgun emissions. Examinations will be undertaken by a qualified Fish Pathologist. Examinations of exposed fish will also be undertaken within a minimum of six hours following exposure to identify any acute impacts,

As part of the examination, tissues including gills, lateral line, kidney, liver / pancreas, spleen, eye, gonad, intestine, stomach, swim bladder and brain will be inspected. Hearing structures will also be removed for analysis.

In order to be able to identify whether observations of any present tissue damage are as a result of exposure to airguns, control fish will also be examined that have not been exposed to airgun emissions but have been placed in cages and passed over by the seismic survey vessel. Similarly, in order to provide further comparison, a baseline sample of representative fish will be examined prior to the impact testing. Baseline fish will have had minimal handling and will not have been put out on the reef in cages.

Impact fish that are dead or demonstrate any behavioural effects, such as impaired buoyancy, following exposure will be prioritised for examination.

In order to identify any sub-acute impacts, a further selection of fish will undergo examination at a period of 48 hours following exposure. The examination will follow the same procedure as that described above.

### 2.3.5 Use of Data

The results of the investigation into the types and magnitudes of physiological impacts on auditory and non-auditory tissues of tropical marine fish will be analysed to compare the findings of fish exposed to airgun emissions from the Phase one survey and those not exposed.

The findings of the monitoring will be used to provide information about the impacts of seismic surveys on fish and presented in the *Fish Monitoring Program Report* (see Section 3).

## 2.4 Objective 3 – Damage to and Recovery of Auditory Hair Cells

This section presents the elements of the programme designed to investigate any damage to and recovery of auditory hair cells in tropical marine fish exposed to airgun emissions during the Maxima 3D MSS.

### 2.4.1 Background

As discussed in Section 2.3.1, exposure of airgun emissions to tropical marine fish may result in impacts to both auditory (e.g. hair cells) and non-auditory tissues (e.g. swim bladder) in some site-attached fish species. It is noted, however, that auditory tissues can demonstrate recovery over certain periods, depending on the extent of the initial damage.

### 2.4.2 Objective

The objective is, to investigate the time-related sequence of damage to, and repair of, auditory hair cells of tropical marine fish exposed to airgun emissions during the Phase one survey.

### 2.4.3 Sampling Design

The design for the investigation into the time-related sequence of damage to, and repair of, auditory hair cells of tropical marine fish takes into account the following factors:

- Predictions of impact; and
- Expected use of the data.

The investigation will consist of sampling exposed and control samples of target fish species for analysis post-survey. Representative control samples will be taken for comparison with fish that have been exposed to seismic airgun emissions.

### 2.4.4 Sampling Methodology

As discussed above, tropical marine fish collected at Scott Reef will be exposed to seismic airgun emissions through controlled scientific investigations being undertaken as part of the AMP for the Phase one survey.

It is proposed that a selection of these fish will be used for the investigation into the time-related sequence of damage to, and repair of, auditory hair cells. In addition to these impact fish, both fish that have not been exposed to seismic airgun emissions, but placed in cages on the reef and passed over by the seismic airgun vessel, and wild fish that have not been placed in cages on the reef will also be selected for sampling and analysis.

Following the completion of the Phase one survey, the inner ears of a sample of caged fish that have been exposed to airgun emissions will be collected immediately and at periods of 24 and 72 hours after exposure. These tissues will be preserved and taken onshore at the conclusion of Phase one for examination of the hair cells using Scanning Electron Microscopy (SEM). Tissues will also be collected from caged fish over which the seismic survey vessel passed but did not fire the airgun array immediately and at periods of 24 and 72 hours after passing of the seismic survey vessel for SEM examination of hair cells following Phase one. In addition tissues will be collected from a sample of fish that were not put out in cages on the reef for SEM examination of hair cells. These samples will serve as a control for handling.

In order to examine potential long-term recovery of any damage to auditory hair cells of tropical marine fish, a selection of experimental fish that have been exposed to airgun emissions will be taken back to an onshore laboratory to continue the experiment. Such fish, if any, will be those that have been identified during the Auditory Brainstem Response (ABR) investigation (see Objective 4) to have not recovered within 48 hours (or more) after exposure.

As best possible, fish will be kept alive in controlled conditions in the onshore laboratory maintaining good fish husbandry. Fish will undergo a simple hearing test, at set intervals of every five (5) days, to determine whether they demonstrate any recovery. Fish hearing structures will be removed at a set interval of every twenty (20) days to further investigate the extent of recovery of the hair cells through comparison with the hearing structures of the control and baseline fish. These experiments will be continued to a period of ninety (90) days following the initial exposure to airgun emissions.

In order to minimise the use of fish unnecessarily, representatives from only one species will be selected for this analysis from the experimental fish in the field. Depending on availability, this species will be selected in the field, however, where possible this species will be from groups representing tropical marine fish species predicted not to flee from seismic shots.

### 2.4.5 Use of Data

The results of the investigation into the damage to, and repair of, auditory hair cells of tropical marine fish will be analysed to compare the time-related sequence of experiments on fish exposed to airgun emissions from the Phase one survey and those not exposed.

The findings of the monitoring will be used to provide information about the impacts of seismic surveys on fish and presented in the *Fish Monitoring Program Report* (see Section 3).

## 2.5 Objective 4 – Hearing Sensitivity

This section presents the elements of the programme designed to investigate hearing sensitivity of tropical marine fish before and after exposure to airgun emissions during the Maxima 3D MSS.

### 2.5.1 Background

Modelling of predicted sound exposure levels has indicated that no areas within or adjacent to the Maxima 3D MSS area would be expected to be exposed to received levels that are expected to cause direct lethal effects in adult fish. There is, however, a likelihood that the survey will result in low level short term reversible loss in hearing sensitivity (Temporary Threshold Shift (TTS)) effects in some site-attached fish species. Similarly, there is a possibility that the survey could result in long term loss in hearing sensitivity (Permanent Threshold Shift (PTS)) effects in some site-attached fish species (Woodside, 2007).

### 2.5.2 Objective

The objective is to investigate the hearing sensitivity of tropical marine fish species prior to and after exposure of airgun emissions from the Phase one survey.

### 2.5.3 Sampling Design

The design for the investigation into hearing sensitivity of tropical marine fish takes into account the following factors:

- Predictions of impact; and
- Expected use of the data.

The investigation will consist of sampling exposed and control samples of target fish species as well as a baseline group. Representative control samples that have been in cages and passed over by the seismic survey vessel, but not exposed to airgun emissions, and baseline samples that have not been put in cages out on the reef will be taken for comparison with fish that have been exposed to seismic airgun emissions.

### 2.5.4 Sampling Methodology

As discussed above, tropical marine fish collected at Scott Reef will be exposed to seismic airgun emissions through controlled scientific investigations being undertaken as part of the AMP for the Phase one survey. It is proposed that a selection of these fish will be used for the investigation of hearing sensitivity of tropical marine fish following exposure to airgun emissions.

As best possible, fish will be collected from areas within each of the three impact categories, i.e. Category 1, Category 2 and Category 3, to monitor for any differences in hearing sensitivity. In addition to these impact fish, fish that have not been exposed to seismic airgun emissions will also be selected for sampling and analysis.

Three species of fish will be selected for analysis, representing tropical marine fish species predicted to flee from seismic shots as well as members of those groups predicted not to flee from seismic shots.

Fish that have been selected for hearing sensitivity analysis will be brought onboard for testing. For each test subject, measurement of the Auditory Brainstem Response (ABR) will be used to determine the change in hearing threshold at frequencies within its hearing range (Kenyon et al. 1998) before and after exposure to airgun sound emissions.

Fish test subjects will be retrieved from cages, weighed and measured, and then anesthetized using a solution of a soluble anaesthetic in seawater. The exact amount of anaesthetic will be adjusted based on the size of the specimen. Larger fish will also be given a muscle relaxant if needed to reduce the stress of being handled.

Sedated fish will be placed in mesh sling and suspended into a cylindrical test chamber filled with seawater. Sub-dermal electrodes will be carefully inserted just underneath the scales to record the ABR. The test chamber will be constructed to minimise interference from air-borne noise, structural vibrations, and electrical sources.

Acoustic stimuli will then be generated at increasing sound pressures through an underwater speaker attached to the bottom of the test chamber. Sound pressure levels received by the fish will be measured with a small hydrophone placed adjacent to its head. The auditory threshold will be recorded as the minimum sound pressure level at which an ABR is evoked by the fish. Where possible, fish will be tested two at a time unless space limitation due to individual body size encountered.

ABR measurements will be collected over set time intervals to measure the auditory recovery of TTS in fish exposed to Category 1, 2, and 3 SELs. ABR measurements will cease once fish show auditory thresholds equivalent to those recorded for baseline fish.

In order to investigate the potential cumulative effects on hearing sensitivity, a selection of fish that have demonstrated auditory recovery, as well as a selection of those that appear to have not recovered from TTS within 48 hours after exposure, will be re-exposed to airgun emissions through a second pass of the seismic vessel. The fish will again be removed and ABR measurements repeated to examine potential cumulative effects.

### 2.5.5 Use of Data

The results of the investigation into hearing sensitivity of tropical marine fish will be analysed to compare hearing sensitivity both prior to and after exposure to airgun emissions from the Phase one survey.

The findings of the monitoring will be used to provide information about the impacts of seismic surveys on fish and presented in the *Fish Monitoring Program Report* (see Section 3).

## 2.6 Objective 5 – Fish Diversity and Abundance

This section presents the elements of the programme designed to characterise any changes to the levels of fish diversity and abundance resulting from the Maxima 3D MSS.

### 2.6.1 Background

The assessment of impacts presented in the Environmental Protection Statement (Woodside, 2007) relating to disturbance to fish diversity and abundance, based on the literature review and the risk assessment, concludes that the Project is not expected to have any long term, biologically significant impacts on the fish communities at Scott Reef, and the risks presented by acoustic emissions from this survey are acceptable.

It is noted, however, that the received energy levels on the reef surface could cause some high level behavioural effects and possible physiological effects to a small proportion of the site-attached (non-fleeing) fish species resident in these habitats. These effects could expose some fish to increased mortality via increased predation, impaired foraging ability or reduced reproductive fitness, however, it is considered highly unlikely that these temporary/transient impacts will result in significant population-level effects for any species of site-attached fish.

Although the above impacts will be examined as part of Objectives 1 – 4 of the FMP, it is necessary to verify there is no long-term change in the characteristics of fish diversity and abundance at Scott Reef through the Maxima 3D MSS.

### 2.6.2 Objective

The main objective is, therefore, to characterise any changes to the levels of fish diversity and abundance from the Maxima 3D MSS.

### 2.6.3 Sampling Design

The design for the investigation into characterisation of fish diversity and abundance takes into account the following factors:

- Spatial variability in data;
- Temporal variability in data;
- Predictions of impacts; and
- Expected use of the data.

The investigation will consist of using the Long Term Monitoring Program (LTMP) underwater visual fish census method and the Baited Remote Underwater Video (BRUV) method. The data will be used to determine whether there have been any changes in fish diversity and abundance that can be attributable to the Maxima 3D MSS.

### 2.6.4 Sampling Methodology

#### 2.6.4.1 Long Term Monitoring Program Method

In order to provide a robust and defensible assessment of any long term changes to the levels of fish diversity and abundance, it is proposed that historical monitoring sites be surveyed using the Long Term Monitoring Program (LTMP) method (Halford and Thompson, 1996).

The use of historical sites will provide increased statistical power in the analysis of data and assist in the prevention of committing a Type I statistical error. Such an error is defined as likelihood, or probability, of determining that a factor is not significant, i.e. change in fish diversity, when it potentially is. In contrast, a Type II error is defined as failing to detect environmental change when there actually is one, i.e. the statistical power of the tests is too weak.

Seven long term monitoring sites on Scott and Seringapatam Reefs will be surveyed. These transects run parallel to the reef crest along the depth contours at six to nine metres with 10 - 40 metres separation between them for independence. As Seringapatam Reef will not be exposed to airgun emissions as a result of the Maxima 3D MSS, the data collected at these sites will act as a control reference for this component of the monitoring.

Historical baseline data taken from the historical dataset will be used to supplement the comparison of change between impact and control sites, if any.

In order to collect data on fish diversity and abundance, two separate teams of SCUBA divers will count all fish (other than young of the year) visible in belt transects of standardised width. The standard procedure is for the lead diver of the first team to count large, mobile fish in a swathe up to five metres on both sides with the buddy diver rolling out a tape to measure the distance. Five replicate transects will be swum at each of the seven sites.

Once the first team has left the water at the end of the 5 x 50 metre transects, the second team of SCUBA divers will commence the survey. Working from the opposite end as the first team, the second team returns to the origin with the lead diver counting small, sedentary fishes in a swathe of one metre on both sides of the tape. Where possible, details on any damaged or dead invertebrates will also be recorded. The second diver reels up the transect tape.

These censuses will be repeated at least twice more after the seismic program to determine whether there has been any change in the abundance of all species with average densities greater than 0.2 fish $m^{-2}$.

In order to characterise any changes in levels of fish diversity and abundance prior to and after the Maxima 3D MSS, a baseline survey will be undertaken no more than six (6) weeks prior to the commencement of seismic operations. A post-seismic will be completed no more than six (6) weeks following the cessation of seismic operations. It is currently envisaged that a second post-seismic fish diversity and abundance survey will also be conducted in early to mid-2008.

Further post-seismic surveys will be conducted as necessary should a significant reduction in fish diversity and / or abundance be recorded in the post-seismic surveys when tested against the baseline surveys. Surveys will be repeated until there are no significant differences from the levels of diversity and abundance prior to the Maxima 3D MSS or until three years has elapsed since completion of the Maxima 3D MSS.

#### 2.6.4.2 Baited Underwater Remote Video Method

In order to characterise any change in levels of fish abundance and diversity in habitats that cannot be surveyed by conventional SCUBA apparatus, i.e. deep water habitats, the Baited Underwater Remote Video (BRUV) technique will be employed. The BRUV survey will allow the collection of data on deep water fish diversity and abundance, typically representative of those fleeing fish that may be in the surrounding area during the survey period.

The BRUV design consists of a galvanized roll-bar frame enclosing a simple camera housing made from PVC pipe with acrylic front and rear ports. The bait arm holds a plastic mesh bait canister containing crushed fish, e.g. pilchards (*Sardinops neopilchardus*). The BRUV is deployed using a combination of ropes and surface floats bearing a flag and is retrieved with a hydraulic winch.

BRUVS provide a standardized measure of species richness by recording the total number of species seen over a fixed period of observation. They also provide measures of relative abundance in two ways. For uncommon fish, the unambiguous signal is the maximum number seen in a single video frame. For more common species, the times of first arrival and subsequent accumulation curves provide useful estimates of relative abundance.

At least eight sites in each of three ecoregions will be surveyed on two occasions, four to six days apart[2]. The sites will be located in parts of the ecoregions directly under the paths of Maxima and will be relatively uniformly distributed across the ecoregions. The precise location of each site will be determined at a later stage. All BRUVS will be deployed and retrieved during daylight hours and, where possible, sites will be surveyed at the same relative time of the day at each site during each survey period event.

(2) Examination of geophysical survey data of Scott Reef by the Australian Institute of Marine Science (AIMS, 2007) lead to a regionalisation of the reef into three large "Ecoregions". These three regions are likely to be relatively homogeneous in terms of presence and abundance of deep water fishes, and thus be suitable as large scale spatial units

At each site, 4 BRUVS will be deployed (i.e. 4 BRUV stations within a site) and they will sample for a minimum period of 45 minutes. The video tapes will be read and data extracted for each species observed as the maximum number of individuals observed in a frame (maxN) and the time of occurrence will be recorded. The richness (number of species) and total abundance of all species will be calculated for each BRUV station.

As with the LTMP shallow water surveys, in order to characterise any changes in levels of fish diversity and abundance prior to and after the Maxima 3D MSS, a baseline BRUV survey will be undertaken no more than six (6) weeks prior to the commencement of seismic operations. A post-seismic will be completed no more than six (6) weeks following the cessation of seismic operations. Again, a second post-seismic BRUV survey is expected to be conducted in early to mid-2008.

Further post-seismic surveys will be conducted as necessary should a significant reduction in fish diversity and / or abundance be recorded in the post-seismic surveys when tested against the baseline surveys.

Surveys will be repeated until there are no significant differences from the levels of diversity and abundance prior to the Maxima 3D MSS or until three years has elapsed since completion of the Maxima 3D MSS.

### 2.6.5 Use of Data

The results of the fish diversity and abundance will be tested to determine whether levels recorded during the post-seismic monitoring present a significant reduction than those recorded during baseline monitoring.

It is important to note that the reference of significant reduction is not intended to refer to statistical significance, as the prevention of the identification of such differences in fish abundance and diversity would be practically impossible. As such, significant difference has been taken to be the identification of ecological significance, which, for the purposes of this assessment has been taken to be 25 per cent decline in abundance and/or diversity of fish communities (AIMS, 2007).

The findings of the monitoring will be used to provide information about the impacts of seismic surveys on fish and presented in the *Fish Monitoring Program - Fish Diversity and Abundance Monitoring Report* (see Section 3).

# 3 Reporting

## 3.1 Introduction

The following section presents the reporting requirements of the FMP for the Maxima 3D MSS.

## 3.2 Reporting Format and Schedule

The results of the monitoring for Objectives 1 to 4 of the FMP will be presented in the *Fish Monitoring Program Report* within no more than two (2) years of the completion of the Maxima 3D MSS. Where possible, however, reports will be submitted as soon as they are completed.

Copies of the report will be provided to the WA Department of Fisheries (DoF) and the WA Department of Environment and Conservation (DEC) as soon as they are completed. The report will be peer-reviewed prior to submission.

The *Fish Monitoring Program Report* will include at least the following:

- Up to half a page executive summary;
- Introduction;
- Background information;
- Drawings showing locations of the monitoring stations and seismic survey lines;
- Monitoring results (in both hard and diskette copies) together with the following information:
  - *monitoring methodology;*
  - *name of equipment used and calibration details;*
  - *parameters monitored;*
  - *monitoring locations (and depth);*
  - *monitoring date, time, frequency and duration; and*
  - *QA/QC results.*
- Details on influencing factors, including:
  - *major activities, if any, being carried out on the site during the period;*
  - *weather conditions during the period; and*
  - *other factors which might affect the results.*
- Results for each monitoring parameter, including any statistical analysis of the data; and
- Comments and conclusions.

The *Fish Monitoring Program Report* will be in paper form and/or electronic upon request.

In addition to the *Fish Monitoring Program Report*, the findings of Objective 5 – Fish Diversity and Abundance monitoring will be presented in a separate *Fish Monitoring Program - Fish Diversity and Abundance Monitoring Report*.

This *Fish Monitoring Program - Fish Diversity and Abundance Monitoring Report* will be submitted no later than 12 months of findings no significant difference between the pre-survey and post-survey levels of fish diversity and abundance or within one year after monitoring should no significant differences be recorded. Where possible, however, reports will be submitted as soon as they are completed.

Copies of the report will be provided to the DoF and the DEC as soon as they are completed. The report will be peer-reviewed prior to submission.

# 4 References

Australian Institute of Marine Science, 2007. Scott Reef Seismic Surveys (Maxima): Design of a Program to Estimate Changes in Biodiversity, Abundance and Community Structure of Deep-Water Fish Species, 7th July 2007.

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