ENVIRONMENTAL IMPACT ASSESSMENT

SIFAKA GEOHAZARD SEISMIC SURVEY

ENVIRONMENTAL BASELINE STUDY

COASTAL BATHYMETRIC SURVEY

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NON-TECHNICAL SUMMARY

This EIA is submitted by ExxonMobil Exploration and Production (Northern Madagascar) Limited (EMEP(NM)L), for the Sifaka Prospect Offshore Geohazard Seismic Survey and Environmental Baseline Study and the Bathymetric Study along the upper slope of the Ampasindava Block in Madagascar to the Office National pour l'Environnement (ONE)de Madagascar, relevant authorities and the public. This EIA includes a project description and related impact assessment, the mitigation measures and the Project Environmental Management Plan.

This EIA has been developed in accordance with the Madagascar MECIE Decree. All exploration activities and associated operations will be in full compliance with Malagasy regulations, applicable international treaties and in accordance with the Operation Integrity Management System (OIMS) developed by ExxonMobil.

Project description

ExxonMobil Exploration and Production (Northern Madagascar) Limited (EMEP(NM)L), plans to carry out a high resolution 2D seismic survey over prospective drilling locations of the Sifaka Prospect, take sea floor and water samples in the prospect area for an Environmental Baseline Study, conduct a multi-beam bathymetry study and survey the upper slope to identify shallow water features in the Ampasindava Block, offshore Madagascar. The work will be conducted in May to June, 2008 for a period of approximately 30 days.

This survey will (1) enable EMEP(NM)L to evaluate alternative well locations, (2) maximize the safety of subsequent drilling operations by identifying and avoiding potential shallow hazards in the prospect area, and (3) help establish the pre-drill environmental conditions around the drilling location.

The 2-D High Resolution seismic survey area, as shown in Figure 1.1, is located in the southwest part of the Ampasindava block, 35 km off the coast of the Madagascar mainland and approximately 35 km northwest of Nosy Lava.. The proposed survey lines, up to 12 km x 12 km, that will be acquired on a 200 m x 500 m grid, are located mainly in deep waters away from the continental shelf.

A seismic survey vessel, utilizing an air gun source will be contracted to acquire the data. It will include a multi-beam echo sounder bathymetry survey as well as the collection of water and sea floor sediment samples. A side-scan sonar survey will also be conducted in a limited near-shore area. The purpose of the survey is to obtain additional information on sea bed features and sediments and in particular to identify shallow underwater features, such as submerged coral reefs, so that they can be avoided during future exploration operations.

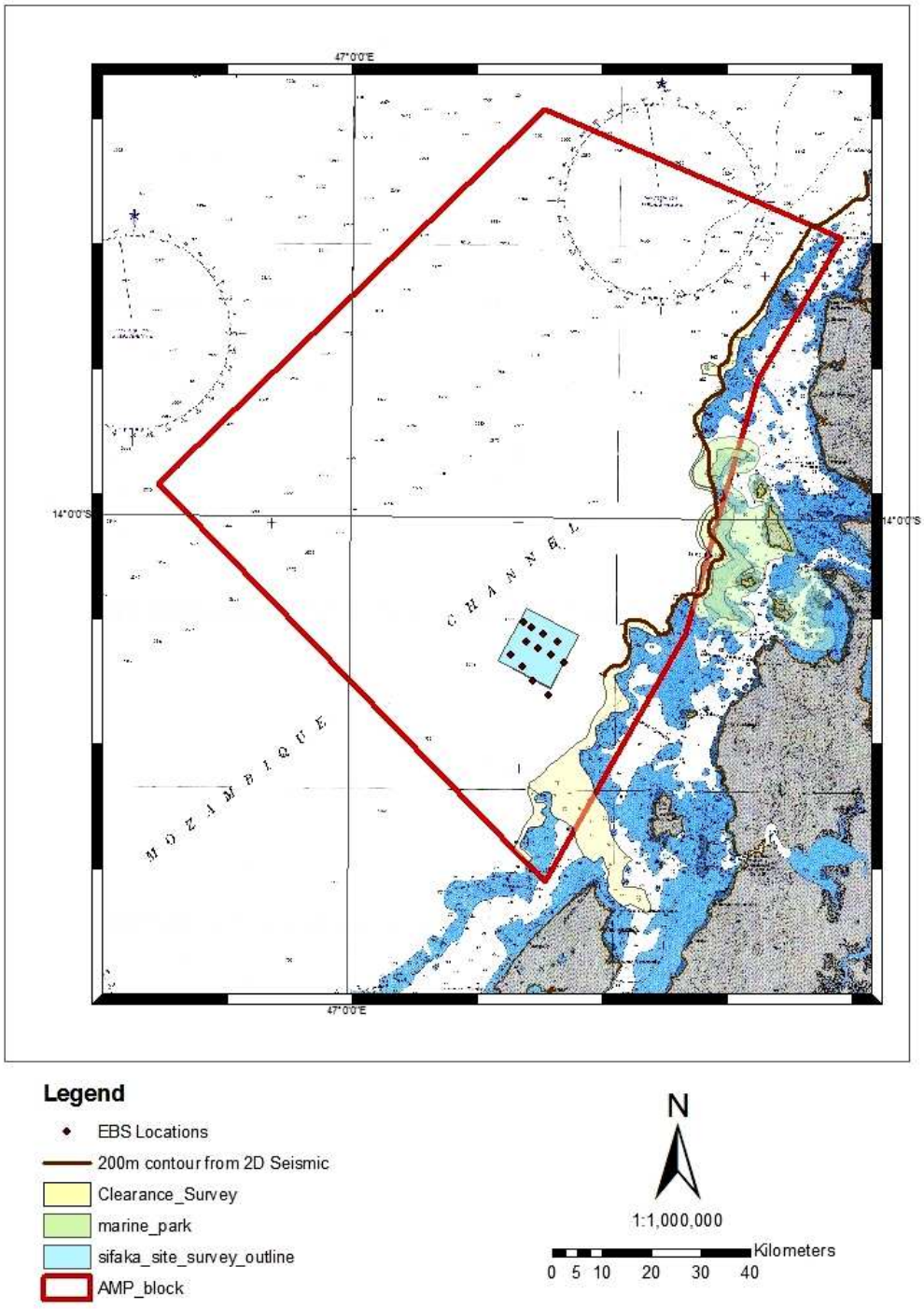

Figure 1.1: Survey area for Geohazard Seismic and Bathymetry and Environmental Baseline Study

The survey vessel will move at a constant speed of around 5 knots and must hold a fixed course along each survey line. The vessel will be towing an underwater sound source and a 3000 m long thin plastic tube ('streamer') containing very sensitive receivers (hydrophones). Both the streamer and the sound source will be towed approximately 5 meters underwater and so will not be visible from the surface. The streamer's end is marked by a towed buoy. Survey operations will be conducted during both day and night. During the survey program, it is anticipated the vessel will not come closer than 15 km to the Madagascar coast, remaining in water depths exceeding 200 meters. The side scan sonar survey will be conducted along the upper edge of the slope measuring the water depths as shallow as 30 meters. It will for the most part remain more than 10 kilometers from the Madagascar mainland. The multibeam echo sounder will be mounted to the hull of the vessel and will be operated simultaneously to supplement the seismic and side scan sonar bathymetry data.

Description of the Environment

A comprehensive and thorough description of the marine environment of the Block and the adjacent coastal ecosystem is provided.

This study area is characterized by a slow, semi-closed anti-cyclonic current circulation (Comoros gyre) fed by warm waters of the East Madagascar Current coming from the north. Currents in the study area are weak and variable with the dominant influence coming from tidal variation. Horizontal and vertical water mixing is limited with relatively long dispersion and residence times, which may be an important aspect to consider for the dispersion of discharges to the sea.

Biological features

The study area offshore deep waters are relatively unstudied. However, certain characteristics can be expected based on extrapolation from similar regions. The deep water area is located along cetacean migration routes. Continental shelf areas of mid-depth are an important zone for demersal fishes which are diverse and abundant in the zone. Sensitive seabed areas are present including coral reefs.

The Coastal zone is notable as an area of significant development of intertidal ecosystems. The zone is the most productive coastal fishing area of Madagascar (shrimp, crabs, sharks and fish). Several important shrimp farms are located in the area. The survey area does not include any portion of the Coastal zone.

The offshore pelagic surface zone is of considerable importance in the life cycle of commercial tuna (skipjack and yellowfin). The zone of NW Madagascar represents the second most important in the Western Indian Ocean in terms of commercial capture. The zone is rendered sensitive by its use by tuna for spawning.

Species of conservation importance

The presence of coelacanths cannot be reliably predicted. However, their habitat, consisting of sub-marine caves and overhangs, has not been identified with existing bathymetric data.

Regarding cetaceans, the study area is known for the presence of certain whales and dolphins, some of which are rare and all of which are fully protected under national law. The study area is on the migration route of humpback whales.

Five species of turtles are known to be present in or near the survey area and all are fully protected species under national and international law. A small number of known nesting sites are near, but outside of the survey area. .

Certain vulnerable species of deep sea sharks & rays are known to exist in the study area, distributed mainly on the continental slope. The Dugong, a highly endangered marine mammal may be present in the area covered by the side scan sonar survey. They are a fully protected species under national law.

Sea birds use the area for feeding, while breeding mainly on small islands to the south or north of the study area. Their presence in the survey area is linked to the presence of skipjack and yellowfin tuna.

The National Park of Sahamalaza and Radama Islands is located 35 km north of the seismic survey area and the slope area just west and adjacent to the park will be included in the side scan sonar survey.

Socio-economic aspects

The main impacts of this survey will be on commercial deep sea fishing and coastal cargo vessels in the deeper water depths during the seismic program and traditional fishing in the shallower water depths of the side scan sonar survey. Fishing boats will need to stay away from the survey vessel to minimize the possibility of entanglement with the survey equipment, especially the streamer. Any nets or other fishing equipment will also need to be moved from the path of the vessel. Cargo ships moving through the survey area may be delayed by having to go around the survey vessel and the equipment it is towing. Other vessels will need to be made aware that the survey vessel tows a considerable length of underwater equipment, most of which cannot be seen at the surface. Where possible, vessel captains will need to be briefed on safe clearance distances: this may require liaison through ship agents, coast guard services or fishing organizations.

Since the vessel will come to Madagascar fully equipped and the project is of a very short and limited duration, the socio-economic impacts will focus primarily on fishing and other marine activity.

EMEP(NM)L recognizes that the near shore part of the survey area is an important prawn fishing area and will take steps to ensure local communities are notified of the scope and timing of the operations. Relevant Government Ministries, the Port Authority at Mahajanga, and Government Authorities in the Region of Sofia will be fully informed of the survey. Other measures to minimize unnecessary disturbance to wildlife and

human activities in the survey area will also be implemented.

Impacts and Mitigation Measures

The environmental impact assessment of the proposed seismic survey has determined that effects on the environment will likely be for the most part localized and temporary and therefore of minor to no significance.

The survey area is located offshore in an area that is frequented by other similar vessels. It is therefore concluded that the survey will have no impact on local or regional air quality.

With respect to noise disturbances, the seismic acquisition will be "soft starting" the airguns and other acoustic equipment, a practise which allows mobile species close to the vessel to move away before the survey commences. This practice will mitigate the possibility of damaging mobile marine species which happen to be close to the vessel at the start of the survey.

Impacts of the survey operations from airguns and multi-beam and side scan sonar acoustic equipment on marine fauna are anticipated to be negative but insignificant,

During the seismic survey the survey vessel will remain in offshore waters and come no closer than 15 km to the shoreline. During the side scan sonar upper slope bathymetry survey the vessel will work primarily in locations >10 km from the Madagascar mainland. Therefore it will have minimal effects on the local populations along the coast during the survey operations.

The impacts on Wildlife and Humans due to Noise and vibrations are minimized by the used of a smaller 750cc air gun array for the seismic survey. The effects are summarised in the following table.

Impact	Impact Assessment	Mitigation
Disturbance to turtles	Possible behavioural effects including avoidance of immediate vicinity of source. Localized and temporary effect. Insignificant impact.	Soft start minimizes risk of injury. Smaller air gun array utilized.
Disturbance to cetaceans (whales and dolphins).	Behavioural effects including avoidance behaviour. Temporary and localised effect as vessel moves on. Insignificant impact.	Soft start minimizes risk of injury. Smaller air gun array utilized. Observers used to ensure no presence of cetaceans within 500 meters of seismic vessel
Disturbance to dugong	Habitats where dugongs occur do not overlap with the survey or study area and acoustic impacts are negligible in their habitat. . No impact.	Smaller air gun array limits noise beyond the immediate survey area. Observers used to ensure no presence of dugongs within 500 meters of seismic vessel

Impact	Impact Assessment	Mitigation
Disturbance to fish	Localised behavioural effects including avoidance behaviour. Effect is localized and temporary due to survey vessel moving on. Insignificant impact.	Soft start minimizes risk of physical damage. Smaller air gun array utilized.
Damage and mortality to eggs, larvae and other effectively immobile pelagic organisms.	Damage and some mortality likely within a few meters of the airguns each time they discharge. Temporary and very localized effect with rapid repopulation Insignificant impact	Wide spacing of survey lines minimizes this impact.
Damage and mortality to benthic organisms directly under survey lines.	Est. Maximum noise level 150 dB. Insignificant impact	Seismic survey predominantly in very deep water. Smaller air gun array utilized.
Disturbance on marine birds	Food sources may be temporarily relocated for some species Insignificant impact	
Direct disturbance to people	Temporary exclusion of fishing activities in the immediate area of the vessel. Insignificant impact	Sound does not transmit well across air/water interface. Diving does not occur in the survey area.
Indirect effects on fishing	Fishing within or close to the survey area may experience temporary changes in catch rate as fish are repelled from the immediate vicinity of the source. Effect is temporary due to survey vessel moving on. Beneficial or adverse depending on fishing location relative to survey and individual species behaviour Insignificant impact	Fishing boats will be advised to move away from the survey line

The mitigation measures reflect the special sensitivities of the western Madagascar offshore environment. Adopted for the geohazard seismic program and bathymetry surveys, they have been developed based on particular reference to international industry practice, technical requirements, equipment design constraints and current understanding of the Western Madagascar offshore environments that may be encountered during the planned survey program.

The Ampasindava survey program will be conducted in a manner that aims to minimize the adverse impacts on the natural and social environment. This will be achieved largely through survey planning, controlled acquisition techniques, proper handling and disposal of material wastes, discharges and emissions.

The residual impacts identifies have been brought to insignificant or acceptable risk levels with the implementation of mitigation measures. The mitigation significance of the non routine discharge impact is evaluated as insignificant.

The Environmental Management Plan (EMP) will ensure that all mitigation measures identified in the EIA will be implemented to the fullest and within the required time frame. The EMP chapter summarizes impacts and mitigations, and develops specific action plans for the implementation of mitigation measures and monitoring.

The high resolution 2D seismic, multi-beam bathymetry, environmental baseline survey and side scan sonar survey over a portion of the Ampasindava Block offshore Madagascar implements ExxonMobil's Operations Integrity Management System (OIMS) at a project level. It ensures all environmental, health and safety risks are adequately managed within the project.

The objectives are to provide a flawless operation thorough a partnership between management and staff and providing the tools and training to facilitate this goal. OIMS is ExxonMobil's management system designed to create and implement operational policies, procedures, project monitoring, evaluation, training and continuous improvement. Compliance with these policies is mandatory for both employees and contractors.

EMEP(NM)L will develop and ensure implementation of specific management plans that are presented in the EMP.

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CHAPTER 1 – INTRODUCTION

1.1 Objective of the EIA report

ExxonMobil Exploration and Production Northern Madagascar Limited (EMEPNML) is planning to carry out a high resolution 2D seismic survey over prospective drilling locations of the Sifaka Prospect, take sea floor and water samples in the prospect area for an Environmental Baseline Study, conduct a multi-beam bathymetry study and survey the upper slope to identiy shallow water features in the Ampasindava block, offshore Madagascar.

This survey is an essential stage in the task of prospecting for oil. It will enable EMEPNML to evaluate alternative well locations, to maximize the safety of subsequent drilling operations by identifying and avoiding potential shallow hazard in the prospect area, help establish the pre-drill environmental conditions around the drilling location and to identify shallow water features that will need to be avoided in future exploration and drilling operations.

Figures 1.1. shows the study area and survey line plan while Figure 1.2. shows a picture of the seismic survey vessel contracted to acquire the data. The survey vessel will move at a constant speed of around 5 knots and must hold a fixed course along each survey line. The vessel will be towing an underwater air gun sound source and a 3000 m long thin plastic tube ('streamer') containing very sensitive receivers (hydrophones). Both the streamer and the sound source will be towed approximately 5 meters or more underwater and so will not be visible from the surface. The streamer's end is marked by a towed buoy. Survey operations will be conducted during both day and night.

This Environmental Impact Assessment (EIA) was written to be presented to the Office National pour l' Environnement (ONE, the National Department of the Environment of Madagascar), as well as to other government agencies and the general public, in order to provide a detailed study of the environmental issues and the measures to be taken to protect the environment during the survey operations.

This document was made in accordance with the requirements for environmental assessments imposed by the Decree on the Compatibility of Industrial Investments with the Environment (MECIE). It is presented in support of an application for an environmental license for the survey operations planned to start in May 2008, which are described and analyzed in detail in this EIA report.

If further seismic, sampling or exploration drilling operations are planned, additional environmental assessments will be developed detailing the potential impacts

1.2. The Promoter / Operator "ExxonMobil"

ExxonMobil (EM) affiliates are present in many countries in all regions of the world. EM has an industry leading inventory of discovered oil and gas resources. The company is the largest non-governmental refiner and marketer of petroleum products in the world.

1.2.1. Exploration and Production

ExxonMobil holds exploration rights to 109 million undeveloped acres in 37 countries, including leading positions in some of the world's most promising areas. The resource base consists of 73 billion oil equivalent barrels of discovered oil and gas resources, complemented by industry's strongest portfolio of proprietary technology. EM is active in more than 100 major new development projects and global gas and power marketing activities. Including joint venture projects, these include deepwater projects in West Africa and the Gulf of Mexico and a liquefied natural gas project in Qatar. ExxonMobil produces more than 4 million oil equivalent barrels of oil and gas per day in fields extending from West Texas to West Africa and from Australia to Alaska. EM works in some of the world's most remote regions and under extreme conditions – in deep seas, arctic ice, deserts and tropical rain forests. ExxonMobil is also the world's largest non government marketer of equity natural gas. The company has access to 58 trillion cubic feet of proved reserves and more than 182 trillion cubic feet of discovered gas resources. In addition, backed by proprietary technologies, EM is a leader in commercializing large, remote gas resources.

Exxon Mobil Corporation, the parent company of EMEPNML, has numerous affiliates, many with names that include ExxonMobil, Exxon, Esso and Mobil. For convenience and simplicity in this document, those terms and terms like EM, corporation, company, our, we, and its may sometimes be used as abbreviated references to specific affiliates or affiliate groups.

1.2.2. Petroleum Products

By itself, ExxonMobil's downstream business would be one of the world's largest companies. EM has interests in 45 refineries in 25 countries, 25,000 miles of pipelines, 32 crude oil and petroleum product tankers and more than 37,000 retail sites in more than 100 countries. In addition, fuels products and services are provided to aviation customers at more than 600 airports and to marine customers at 300 marine ports around the world.

1.2.3. Chemicals

ExxonMobil's chemical business is a premier supplier of olefins, polyolefins and aromatics, the basic petrochemical building blocks. The company also has a leading position in a number of specialty businesses. Chemical products manufactured by ExxonMobil are used to make everything from plastic packaging and surgical gowns to auto bumpers and flooring.

1.3. Development context

Four sedimentary basins exist offshore west Madagascar. They are Ambilobe, Majunga, Morondava and Cap Sainte Marie Basins. The small Ile Sainte Marie basin lies in the eastern coast. Past Exploration drilling has been concentrated mainly in the Morondava basin and to a lesser extent in the Majunga basin. The remaining basins are virtually unexplored.

Interest in hydrocarbon exploration in Madagascar started in the early 1900's, with the discovery of large accumulations of tar and heavy oil at Bemolanga and Tsimiroro, in the Morondava Basin. Modern exploration did not begin until the early 1950s, after which seismic data were acquired and 73 exploration and appraisal wells have since been drilled. No commercial oilfield has been put under production.

Beginning in 2000, the Madagascar government proactively sought partnerships to explore and develop the oil reserves in Madagascar. Under the responsibility of OMNIS (the National Office of Mines and Strategic Industries), Madagascar sedimentary basins were divided up into oil exploration areas, referred to as "blocks". In July 2007, there were 19 blocks under lease on land, and 6 blocks under lease offshore. The rights to explore and produce in the assigned 'blocks' are gained through Production Sharing Contracts (PSC). The terms and conditions for exploration as well as the share in production profits if the exploration is successful and commercialized, are established in a Production Sharing Contract (PSC).

On 29 November 2004, Sterling Energy (UK) Ltd signed a Production Sharing Contract (PSC) with the government of Madagascar for the 'Ampasindava Block', located off the northwest coast of Madagascar in the Majunga Basin. This contract gave Sterling the right to explore for and exploit oil and gas in the Block and provided a legal and commercial framework for such activities. On October 1, 2006 EMEP(NM)L became operator of the block.

The Ampasindava block area is situated in the Mozambique Channel, off the north-west coast of Madagascar. The concession area is located in water depths ranging from 0m to approximately 3000m and covers an area of about 15991.km². The EIA boundaries, for which an Environmental Permit is requested, corresponds to two areas in the block 1) the 20km x 20km area to be included in the Sifaka seismic survey and 2) the zone parallel to the coast along the slope corresponding aproximately to the 200m to the 30m water depths. The permit does not include any portion of the Sahamalaza National Park.

1.4. Scope and approach of the EIA process

This Environmental Impact Assessment (EIA) was has been prepared by EMEP(NM)L from December, 2007 by the ExxonMobil with assistance from Dr. Lalanirina Rasoanandrianina, a consultant in Madagascar environmental studies, environmental specialists from EMEP(NM)L affiliate companies, and with contribution of ExxonMobil team of experts, combining specialists in different areas, such as applied geophysics, offshore seismic, geology, marine & coastal biodiversity, oceanography, bathymetry, socio-economics, EIAs for the upstream oil industry and public consultations. This document was prepared in order to meet the requirement for an environmental impact assessment of seismic surveying activities in Madagascar (MECIE Decree 99-954 and its modifications Decree n°2004-167).

This report builds on the findings of earlier environmental assessments including the Vanco 2001 2-D, Vanco 2004 3-D and most recently the 2006 TGS Nopec 2-D seismic programs conducted in the same general area. The contents of the EIA and the methods used to assess the environmental impact were defined in the Terms of Reference included as Annexe 1.

EMEP(NM)L intends to facilitate public involvement in the project development throughout its duration. The Terms of Reference were compiled after a series of public meetings in Antananarivo and in the area concerned, signifying the first stage of the public consultation process. This EIA report incorporates the feedback from the public consultation process.

1.5 Report Overview

This document describes the surveying activity, the physical and human environment of the survey area and presents an assessment of the potential environmental impact which may arise from the survey.

Chapter 2 summarizes the legal framework for the survey activity and this report. Chapter 3 provides a

description of the proposed project and Chapter 4 gives more information on the seismic method and the characteristics of underwater noise. The description of the environment is contained in Chapter 5 and potential impacts are assessed in Chapter 6. Mitigation measures and an environmental management plan are proposed in Chapter 6 and 7. These are designed to facilitate the planning and execution of the survey and to help ensure that operations are carried out in an environmentally acceptable manner.

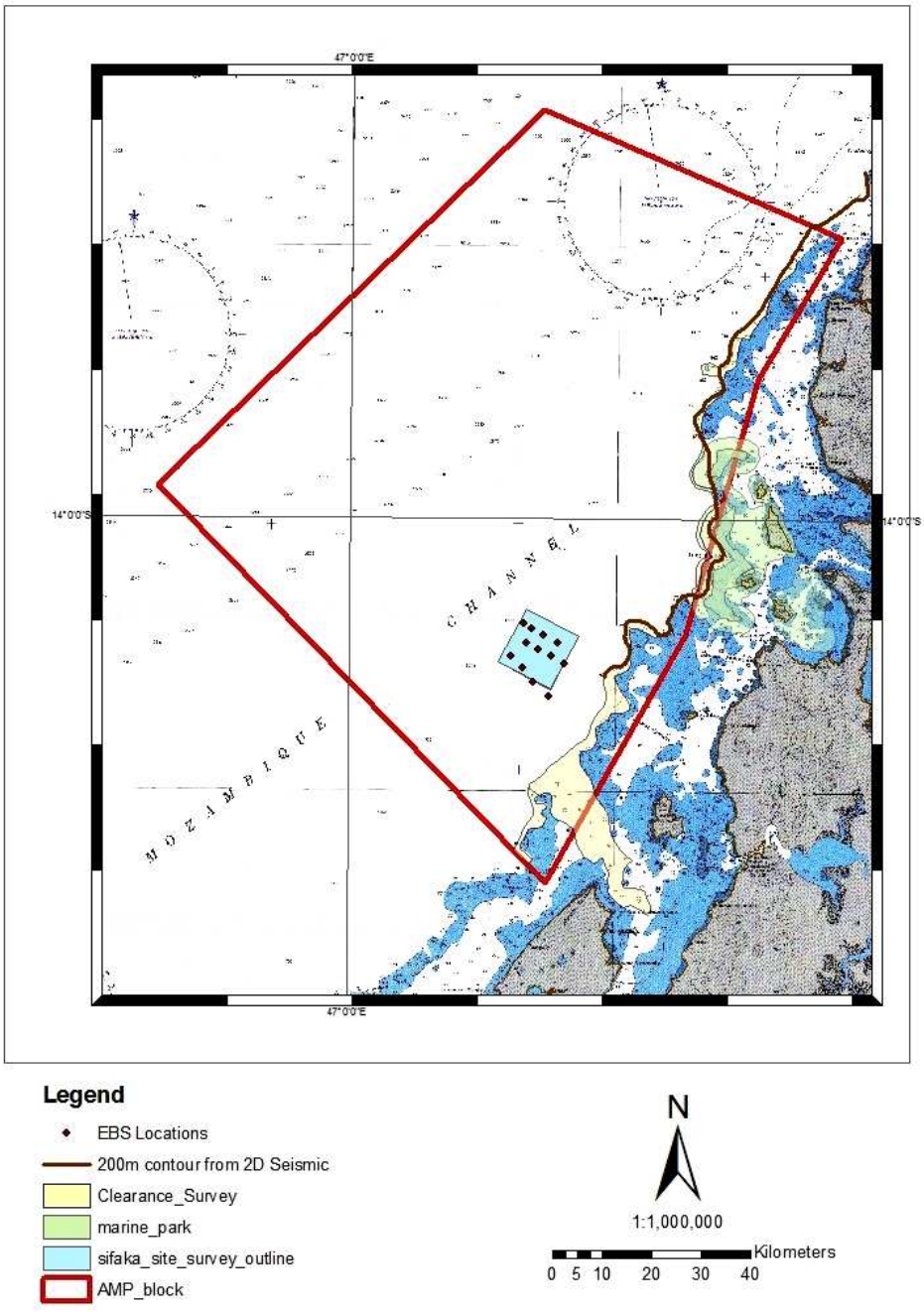


Figure 1.1. Sifaka site investigation study area and Bathymetry Survey

Figure 1.2. Teknik Perdana seismic survey vessel.

CHAPTER 2 - LEGAL AND INSTITUTIONAL FRAMEWORK

The site investigation survey described in this report is covered by the Malagasy MECIE decree in 1999.

The environmental and social restrictions of the existing legal texts target first and foremost the continent's terrestrial and offshore environments. Since land-based activities are better known and easier to control, the standards for waste discharged into the natural environment have, for example, been developed since 2003 for surface and ground water.

Legal measures have been initiated to improve the Malagasy government regulatory system for the environmental management of oil-related activities, and in particular for offshore exploration & production. Parallel to this process, the Ampasindava exploration project will enable the various stakeholders, one of which is the government's Environmental Agency, to gain a better understanding of what actually occurs in exploration operations. In particular, the environmental and social standards imposed internally by Exxon Mobil Corporation can serve as a reference for similar operations in the future in the absence of local laws and regulations.

The objective of this Chapter is two-fold: first, to present the regulatory texts and national institutions which will provide a framework for the environmental management of EMEP(NM)L's offshore exploration activities, and secondly to describe the Exxon Mobil Corporation's internal environmental management system (OIMS).

2.1 National Legislation

Three categories of regulations cover the environmental management of the Project. The first relates to the requirements of environmental monitoring and evaluation throughout the life cycle of the industry's activity, from the planning of a production installation to its dismantling, and including control of the activity during its operation. The second category of regulations relates to the transposition into national law, of international conventions concerning the marine environment. The third category relates to the maritime mining and oil sector, with the most significant being the Petroleum Code, as well as the Production Sharing Contract signed specifically for the exploration and production activities of block 2001c, Ampasindava Offshore Block.

Environmental assessment & management legal framework

The environmental assessment and management of oil exploration activities are covered by four main regulations:

- Madagascar Environment Charter (1990, revised in 1997).
- The decree on the compatibility of investments with the environment - MECIE, 1999, revised in 2004, 2004-167.
- Order n° 6830/2001 on public participation in environmental assessment.
- The law on the management and control of industrial pollution (June 1999).

2.1.1 Charter for the Environment

The law upon which modern Malagasy environmental laws are based is the Malagasy Charter on the Environment (CEM) adopted in 1990 (CEM - Law n° 2004-015 dated 19 August 2004 modifying and supplementing certain provisions of the appendix to the law n°90-033 dated 21 December 1990 containing the Malagasy Charter on the Environment and the law n° 97-012 dated June 1997). The Charter acknowledges the environment as a priority concern for the general interests of the State, the duty of all to protect it, and the right of each individual to be informed of those decisions liable to have any impact upon the environment and to participate in these decisions.

The CEM sets forth the general principles and the main lines of the National Environmental Policy (NEP). NEP defines the operational implementation of this policy by laying down the Environmental Action Plan (PAE), which is based on the setting up of priority projects known as "Environment Programmes" (PE1,2 & 3). It also establishes the creation of an institutional framework linked to the constitutional and administrative organization of the country. It is therefore a strategic and planning document, but is of a general application in terms of its obligations. The CEM did, however, introduced EIA for investment projects (Art.10), as applied by the subsequent MECIE decree. The Code also makes operators subject to compensation obligations or to the payment of financial penalties in the event of activities which are damaging to the environment.

2.1.2 MECIE Decree

Decree n°99-954 (December 1999) establishes the rules and procedures to be followed in light of the compatibility of investments with the environment (MECIE) and specifies the nature, the respective responsibilities and the degree of authority of the institutions or agencies authorized for this purpose (Article 1). Decree n°2004-167 dated 03 February 2004 modifies some of the provisions of decree n°99-954: the aim of these modifications is to simplify the tasks relating to environmental impact assessments (EIA), and to confirm the role of the delegate Contracting Authority and the ONE (National Office for the Environment) as a single point of contact in MECIE matters.

The MECIE decree is central to the issue of this impact assessment. The text devotes much space to the obligations of investors for the implementation of a new development/project via the completion of an EIA process. The following points of the MECIE decree are particularly noteworthy:

- According to article 6 of decree n°2004-167, seismic operations cannot begin until an environmental permit drawn up by the ONE has been issued. This should be after a positive evaluation of the impact assessment, on the basis of the technical opinions of the Technical Evaluation Committee in charge of evaluation.
- Article 4 specifies that an Environmental Management Plan for the Project (EMP) shall comprise the environmental specification documents of the project. These consist of a programme for setting up and monitoring the measures contemplated by the EIA to remove, reduce and possibly compensate for any damaging consequences caused to the environment by the project.

- The ONE, in collaboration with the Ministries for the sectors concerned, is responsible for proposing boundary values and benchmark environmental standards. The ONE is also responsible for drafting or contributing to the drafting, of technical environmental directives, for each type of activity in question. It provides the monitoring and evaluation of the application of the standards and sector-related procedures concerned as established by the compatibility of investments with the environment.
- For the permitted emissions thresholds in the host environment, the standards recommended by international agencies affiliated to the United Nations may serve as a benchmark standard in the event that national standards are inexistent or lacking (see Article 9). The MECIE decree therefore establishes a link between the shortcomings of the national system and the existing international standards. This benchmark is essential as it offers the option of turning to the guideline values of institutions such as the World Bank or the World Health Organization, until such time as texts targeting the same activities become available on a national level.

The MECIE decree, in appendix I relating to oil and fossil fuels, provides that the following projects must be subject to an environmental impact assessment:

- any oil or natural gas exploration project using the seismic method and/or drilling;
- any oil or natural gas extraction and/or pipeline transport project;
- any project for the extraction and industrial exploitation of hard or coke oven coal;
- any project for the installation of a crude oil refinery, gasification or liquefaction plant of a capacity of more than 20,000 equivalent barrels of oil/day;
- any project for the extraction of bituminous mineral substances exceeding 500 m3/day;
- any project for storage of oil products and derivatives or natural gas of a combined capacity of more than 25,000 m^3 or 25 million liters.

The Project's seismic and drilling operations are therefore subject to environmental impact assessment, as they fall into the category of developments, contracts and works which, due to their technical nature, their size and the sensitivity of the host environment, are liable to have damaging consequences on the environment.

2.1.3 Public Consultation

Order n° 6830/2001 defines the methods and procedures for public participation in environmental evaluation, in application of the provisions of order n° 99-954 (MECIE), and in particular articles 15 to 21, 24, 25 and 27. The fundamental points of this text, which must be emphasized by this EIA, are described in the following paragraphs.

The participation of the public in environmental evaluation [...] is intended to inform those members of the public affected by the project of its existence, and to obtain their opinion on the matter. This can be done [...] either through onsite consultation of the documents, or by public inquest, or by public hearing, and includes a phase for giving information about the project and a consultation phase, during which the opinions of the members of the public affected by the project are gathered.

The ONE will notify the developer of the decision regarding the form that the public participation in the environmental evaluation is to take [...] at least a fortnight before the public evaluation. For the purpose of information, the decision criteria are as follows:

- An onsite consultation of the documents may be required if the investment of the project in question is of less than 10 billion FMG [Malagasy Francs], or if the population at the site development location is less than 10,000 people;
- A public inquest may be required if the investment of the project in question is of more than 10 billion FMG, or if the geographical area covered by the project affects at least two municipalities, or if the population at the project site location exceeds 10,000 people;
- A public hearing may be required for projects which could give rise to a specific agreement in accordance with the provisions of article 49 of this order, or if the completion of the project requires expropriations for reasons of public use, or population displacements affecting more than 500 people.

2.1.4 Management and control of industrial pollution

2.1.4.1 Law

The law 99-021, dated July 1999, defines the general framework of a policy for rational management and control of industrial pollution. It covers the management of liquid effluents, solid waste, atmospheric pollution and nuisances to the community. The law sets forth inspection procedures for industrial installations. The following articles in particular should be emphasized in the context of this assessment:

- **Art. 26**: Any flow of industrial origin, sewage waters or liquid effluents, which do not comply with the boundary values for waste discharge, can only be released into the host environment [...] after having undergone treatment to bring it into compliance with these boundary values.
- **Art. 28**: Solid industrial waste must be subject to appropriate measures serving to minimize and reduce at source the quantity and toxicity of such waste, to recycle or optimize the manufacturing by-products and to provide waste disposal site storage or removal of the solid waste according to the rules of proper management.
- **Art.42:** All operators must adopt the practice of self-supervision, [which is] managed by the operator itself, under the control of the public authorities. Art.43: Self-supervision notably entails [...] any measure intended to preserve the environment, as well as the conditions of environmental management of the company, particularly the measures and the implementation plan which are expressly referred to in the operational authorization application dossier which serves as a specifications sheet; A constant supervision and accompanying improvement to the waste discharge control systems, technical methods for treatment; [...] A rational waste management system and steps intended to reduce or even eliminate pollution.
- **Art.54**: Until such time as national benchmark environmental standards have been published, the standards recommended by the international agencies affiliated to the United Nations can serve as a benchmark standard.

2.1.4.2 Standards on waste discharge

Liquid effluents

The Water Code was put into effect as law n°98-029 in January 1999. It describes the general framework within which any exploitation of water as a resource must be carried out. However, it covers the continent's surface and ground water, and does not apply to sea water. Its applicable decrees, and in particular Decree 2003-943 on waste discharge into surface waters, and Decree n°2003-464 defining a classification of surface waters which sets the standards for aqueous effluent discharges, only concern polluting activities affecting water on land.

Soil

Madagascar does not, as such, have a law on polluted sites and soils. The search for an individual responsible for the clean-up of a polluted site finds its legal grounds in the regulations relating to installations classified for environmental protection in Law 99-021 on the management and control of industrial pollution. This means that under the terms of article 99 (chapter II – Repair of damage to the environment), and article 101 (Chapter III - Prevention and suppression of any act or any failure to act liable to cause a hazard), any operator of an installation of an industrial nature "creating, even without the intention to cause harm, a risk or a hazardous situation threatening health, safety, public health, community facilities or liable to be a cause of deterioration to the environment and natural resources, is bound to remedy this, using all the measures appropriate to this situation".

Air

In 2007, there was no national legislation defining threshold values for atmospheric emissions.

2.1.4.3 Solid waste

There is currently no national legislation applicable in Madagascar regarding solid and semi-solid waste. However, certain texts refer to the management of this waste: i) The Penal Code (Art. 472), which applies penalties for the dumping in public places of items, products, or materials liable to be a hazard or to obstruct public highways; ii) the order dated 24/05/1943 covering hygiene applicable to the Malagasy urban road system and ancillaries, defines the provisions against health hazards on public highways. It prohibits the discharge of refuse into bodies of water; iii) Articles 169 and 170 of the Urbanization Code (decree 63-192 dated March 1963) specify the conditions for disposal of household waste in the case of apartment blocks; iv) Articles 15 to 18 of the Water Code stipulate that the elimination of industrial and mining waste is covered by the generator initiative; v) Law n° 99-021 on the policy for management and control of industrial pollution gives general guidelines on the management of solid industrial waste, without specifying the details. It nevertheless specifies that the management of industrial waste is under the responsibility of the generator.

2.2 International Conventions

The Republic of Madagascar is signatory to a certain number of multilateral agreements in the environmental domain, a large proportion of which concern the protection of biodiversity and the marine environment.

2.2.1 Biodiversity

The conventions relevant to the environmental analysis of the exploration activities covered by this EIA are:

- **RAMSAR 1971** - RAMSAR Convention on Wetlands of International Importance, particularly as water-bird habitats. Ratified by the law 98-003 in February 1998.
- **Rio CBD 1992** - Convention on Biological Diversity. Ratified by the Law 95-013 in August 1995.
- **NAIROBI 1985** - Convention for the Protection, Management and Development of the Marine and Coastal Environment of the East African Region. Ratified by the law 98-004 in February 1998.
- **Bonn CMS 1979** - Convention on the Conservation of Migratory Species of Wild Animals. Signed but not yet ratified.
- **Montego Bay UNCLOS, 1982** – United Nations Convention on the Laws of the Sea. Ratified by the law 2000-20 in November 2000.

2.2.2 Marine pollution

The Inter-Governmental Conference on the Convention on the Dumping of Wastes at Sea, which met in London in November 1972 at the invitation of the United Kingdom, adopted this instrument, generally known as the London Convention. When the Convention came into force on 30 August 1975, IMO (International Marine Organization) was made responsible for the Secretariat duties related to it. The Convention has a global character, and contributes to the international control and prevention of marine pollution. It prohibits the dumping of certain hazardous materials, requires a prior special permit for the dumping of a number of other identified materials and a prior general permit for other wastes or matter. "Dumping" has been defined as the deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures, as well as the deliberate disposal of these vessels or platforms themselves. Wastes derived from the exploration and exploitation of sea-bed mineral resources are, however, excluded from the definition.

Madagascar has not signed the 1972 London Convention on the Prevention of Marine Pollution by Dumping of Wastes. However, in the domain of the prevention of marine pollution linked to oil, the country has ratified the two most restrictive conventions:

- The MARPOL Convention 73/78, covering the Prevention of Pollution of the Marine Environment by Ships. Ratified in November 2004 by law 2004-37.
- The 1990 International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC convention 90) ratified in November 2001 by the law 2001-011.

Additionally, the following conventions have been ratified:

- The Safety and Security of Ports and Ships (SOLAS convention – ISPS code),
- CLC 1992 - International Convention on Civil Liability for Oil Pollution Damage. Ratified in September 2001 by the law 2001-012. The convention applies to the damage caused by pollution resulting from spills of persistent oils from laden tankers occurring on the territory and within the Exclusive Economic Zone of a Signatory State of the convention. It is important to stress the restrictive nature of the definition of pollution damage according to the convention. Damage caused by non-persistent oil does not fall under its field of application, which means that spills of petrol and kerosene oil are not under the jurisdiction of this convention. Furthermore, it does not apply to all ships. It covers only ships which actually transport oil in bulk as cargo (laden tankers).
- IOPCF 92 – International Convention for the Creation of an International Oil Pollution Compensation Fund (IOPCF). Ratified in September 2001 by the law 2001-013.

OPRC 90, CLC 92, and IOPCF 92 are covered by a law n°2004-019 dated August 2004, containing the implementation of the International Conventions on the Protection of the Marine and Coastal Environment against Pollution from Oil Spills. This text itself specifies in Article 10. that "ship captains, operators of offshore units, operators of maritime ports and oil handling installations must each have their own control action plan in the event of pollution, [...], in order to be allowed to be operational [...]".

2.2.3 What are the obligations arising from these agreements?

The MARPOL convention is aimed at preserving the marine environment by ensuring the prevention of accidental pollution with oil and other harmful substances and minimizing accidental spillages of these substances. It is designed to avoid all forms of pollution caused through the operation of ships, in other words not only pollution with oil but also pollution with sewage water, chemical products and other harmful substances. It also regulates the discharge of waste by ships, in particular prohibiting the discharge of plastic in all its forms. With regard to oil pollution, it strictly regulates any discharge, prohibited in some areas and subject to very strict conditions elsewhere. In addition, it issues technical instructions regarding the construction and operation of oil tankers, for example requiring the presence of technical equipment intended to prevent pollution. The signatories to the Convention must inspect ships in port or at sea, supervise and penalize polluting ships and ensure that the country's ports are equipped with suitable installations for handling sewage and waste from the ships[1].

The OPRC Convention refers in its introduction to the "polluter pays" principle. It sets forth that the States must set up a response system for oil accidents, that they must adopt texts requiring vessels flying their flag to draw up an emergency plan, and requiring captains to report any event on the boat involving an oil spill or a risk of oil spill to the nearest coastal State without delay. The coastal State called upon must inform the States which are affected or liable to be affected of the measures taken to deal with the situation. As far as its means allow, each State has an obligation to assist in the event of a particularly dangerous accident. The signatories to the OPRC Convention must inspect ships and set up a response system for oil accidents.

[1] Source: Dealing with pollution from ships. Report by the comptroller and auditor general. June 2002.

Offshore ports, ships and installations must have their own action plan against spills and must document any incident. They must install suitable equipment to combat any incident, carry out training and simulation exercises, and possess communication instruments allowing them to respond without delay to any spill.

The NAIROBI convention is one of a series of Regional Seas conventions promoted by UNEP, which has three main aims: i) to protect and manage the marine environment and coastal areas of the East African region, ii) to ensure the protection of threatened and endangered fauna and flora and their important natural habitats in East Africa and iii) develop a framework for a coordinated response in the event of large-scale spillages of oil and other hazardous substances in the area of application of the convention.

2.3 Regulations within the sector

2.3.1 Petroleum Act

The articles relevant to this EIA, from the law 96-018 containing the Petroleum Act, are as follows:

Art. 6 - [...] "national mining domain" should be taken to mean all areas where oil prospecting, research, exploration, exploitation, transformation and transport activities are performed;

Art. 9 - Any "upstream" activity in the national mining domain must be subject to a mining permit issued by decree [...]. As soon as the mining permit has been issued, the technical agency must inform the relevant decentralized territorial authorities.

Art. 12 - No "upstream" activity in the national mining domain can be undertaken unless an oil contract has been concluded with the national company.

Art. 13 - [...] the National Company [...] may conclude a production sharing contract with oil companies.

Art. 15 – A contract relating to the national mining domain must contain the following stipulations [...]: 7. The risks, dangers and constraints linked to the safety of the environment and to the financial and social obligations are borne solely by companies which have finalized a contract with the National Company during the exploration phase [...].

Art. 28 – The contracting companies, holders of a mining permit, are bound for the entire duration of their operations [...] to take all the environmental protection and safety measures in accordance with the legislative and regulatory texts currently in force.

Art. 32. - [...] Malagasy legislation and regulations apply to upstream activities in Malagasy maritime areas [...].

Art. 33 - These installations [used for upstream activities being performed out at sea] are subject to the international conventions and regulatory texts regarding maritime navigation and

safety of the environment, in particular the 1990 international convention on oil pollution prevention, response and cooperation.

Art. 35 – A safety area shall be established around the installations and systems to ensure their protection.

Art. 36 - [...] In order to provide verification that the aforementioned obligations are complied with, the competent authorities shall have access to the installations, systems and signaling devices.

Art. 92 – Notwithstanding the legal provisions currently in force, holders of a mining permit for the exploration and exploitation of oil may occupy properties belonging to private individuals or properties which are the domain of the State and the decentralized territorial authorities subject to an agreement between the licensee and the owner and/or the occupier.

2.3.2 Maritime Code

The Law n°99-028 dated 3 February 2000 revising the Maritime Code governs the administration, trade and disputes relating to Malagasy territorial waters. Chapter 10 of book I of the first part of the maritime code details the measures regarding the protection and preservation of the marine environment.

Article 1.10.04. On the dumping of waste in the sea is particularly relevant for this EIA: the Malagasy State adopted the laws and regulations in order to prevent, reduce and manage pollution of the marine environment by the dumping of waste in the sea. The dumping of waste in territorial waters and the exclusive economic zone or on the continental plate cannot take place without prior express agreement from the Malagasy State [...].

2.3.3 Protected Areas Code

The main tool for the conservation of biodiversity is based upon the network of protected areas managed by the ANGAP (the National Association for Protected Areas Management). The reference text is the Protected Areas Code (Law 2001-05) which regulates the creation and management of both new and existing protected areas. Their main vocation is the conservation of biodiversity, but it also includes the social and economic development of local populations, the development of ecotourism and research.

A protected area is a defined territory, whether land, coastal or marine, offshore and continental saline and aquatic waters, the components of which present a particular value, and notably a biological, natural, aesthetic, morphological, historical, archaeological and cultural value, and which therefore, in the interests of all, requires preservation against any effect of natural destruction and against any artificial intervention liable to alter its appearance, composition and evolution.

The Protected Area Code was written primarily with terrestrial protected areas in mind. Towards the end of Environmental Program II, procedures were developed for the establishment of marine and coastal protected areas. New decrees are also under preparation

to define new categories of protected area, including new categories more suitable for marine and coastal protected areas.

Within its boundaries, the territory of a protected marine and coastal area notably comprises: i) sea water, ii) the bottom of the sea and the seabed, iii) littoral fringe land, including wetlands; iv) islands or islets surrounded by sea; v) parts of the public natural domain, including sea forming gulfs, bays or straits which carve out inland enclaves, the seashore up to the limit of the highest seasonal or normal tides; and vi) the area of geometric pitch, along the whole seashore, of a length of 80 meters measured from the highest tides.

Several laws have been enacted to protect marine wildlife and coastal habitats in Madagascar. Those relevant to this survey area include:

Decree No. 61-096 (Anon., 1991) is to protect Dugong in Madagascar

Resolution of 23 May 1923 (Journal Officiel 9/6/23) which provides for 'areas reserved for turtles';

Resolution of 24 October 1923 (Journal Officiel 17/11/23 p 856) which bans the capture of sea turtles while nesting, and those of less than 50 cm across the plastron;

Ordonnance No. 75-014, via which Madagascar ratified (and therefore formally acceded to) the Washington Convention on International Trade in Endangered Species (CITES). Although the convention does not specifically address protection of sea turtles against exploitation in Madagascar, it currently prohibits import and export of all sea turtle products.

Arrêté n°169-EP/FOR of 29.5.58 classifies Betsiboka protected area of mangroves, with a surface area of 24,000 ha;

Decree n°97-1452 of 18.12.97 defines the Baly Bay National Park as classified forests on the islands of the Betsiboka estuary with an area of 6,265 ha (Arrêté du 7.9.44.)

Decree N° 2007-247 creates " Sahamalaza / Iles Radama " National Park within the Districts of and Ambanja (DIANA Region) and Analalava (SOFIA Region) located in the northwest coast of Madagascar. This Park of Biological and Ecological interest site including terrestrial, coastal and marine protected area as central area of Biosphere Reserve [2] (labelled by l'UNESCO) extends over approximately 26 035 ha.

[2] Biosphere reserves are designated by the UNESCO at the request of the State concerned. Each of which remains under the sole soveregnity of the State where it is situated and thereby submitted to State legislation only. The Statutory Framework for the World network of Biosphere Reserves (endorsed by UNESCO) includes the biosphere should include to contribute to the conservation of landscapes, ecosystems, species and genetic variation; foster economic and human development which is socio-culturally and ecologically sustainable;provide support for demonstration projects, environmental education and training, research and monitoring related to local, regional, national and global issues of conservation and sustainable. (http://www.unesco.org/mab/doc/statframe.pdf)

Sahamalaza / Iles Radama National park is part of the protected areas national network of Madagascar. It is managed by the Association Nationale pour la Gestion des Aires Protégées (ANGAP) according to the Management Plan established and approved as per article 33 of the Protected Areas Code.

Environmental protection related to the Mining Activities:

Arreté interministeriel n° 12032/2000 dated 06/11/00 related to the Mining sector legislation with respect to environmental protection specifies:

Art. 1er. Provisions on the mining sector legislation with respect to environmental protection to implement articles of Decree No 2000-170 dated 15 March 2000 which define implementation conditions of Mining Code No 99-022 dated 19 August 1999 related to Mining Code, as well as articles of Decree No 99-954 dated 15 December 1999 related to MECIE "mise en compatibilite des investissements avec l'environnement", both in order to put in force article 10 of the Law No 90-033 dated 21 December 1990 related to Malagasy Chart for the Environment.

Art. 2. Any mining license owner can perform neither exploration nor production operations as per their license or authorization without preliminary environmental authorization / permit delivered by competent Authority according to this Arrêté; moreover, they are authorized to execute only operations previewed and related to the EIA document or the environmental commitment plan for which the authorization or permit has been granted.

2.4 Corporate Environmental Policy and Management System

It is Exxon Mobil Corporation's policy to conduct its business in a manner that is compatible with the balanced environmental and economic needs of the communities in which it operates. The Corporation is committed to continuous efforts to improve environmental performance throughout its operations.

Accordingly, the Corporation's policy is to:

- comply with all applicable environmental laws and regulations and apply responsible standards where laws and regulations do not exist;
- encourage concern and respect for the environment, emphasize every employee's responsibility in environmental performance, and ensure appropriate operating practices and training;
- work with government and industry groups to foster timely development of effective environmental laws and regulations based on sound science and considering risks, costs and benefits, including effects on energy and product supply;
- manage its business with the goal of preventing incidents and of controlling emissions and wastes to below harmful levels and design, operate, and maintain facilities to this end;
- respond quickly and effectively to incidents resulting from its operations, cooperating with industry organizations and authorized government agencies;

- conduct and support research to improve understanding of the impact of its business on the environment, to improve methods of environmental protection, and to enhance its capability to make operations and products compatible with the environment;
- communicate with the public on environmental matters and share its experience with others to facilitate improvements in industry performance,
- undertake appropriate reviews and evaluations of its operations to measure progress and to ensure compliance with this environmental policy.

To address this commitment, Exxon Mobil Corporation developed and implemented an Operation Integrity Management System (OIMS), which EMEP(NM)L has adopted.

2.4.1 Operations Integrity Management Systems - OIMS

The independent assessors Lloyd's Register Quality Assurance has recognized OIMS as meeting all requirements of the International Organization for Standardization's standard for environmental management systems - ISO 14001. The OIMS process requires continuous evaluation and improvement of management systems and standards as well as the involvement of every employee. It has established a common language for discussion and sharing of successful systems and practices among different parts of ExxonMobil's business. The OIMS framework has 11 elements, each with clearly defined expectations that every operation must fulfill, as follows.

Table [2.1] - The 11 elements of EXXONMOBIL OIMS

1.	Management, leadership, commitment and accountability. Employees at all levels are held accountable for safety, health and environmental performance.
2.	Risk assessment and management. Systematic reviews evaluate risks to help prevent accidents from happening.
3.	Facilities design and construction. All construction projects from small improvements to major new expansions are evaluated early in their design for safety, health and environmental impact.
4.	Information and documentation. Information that is accurate, complete and accessible is essential to safe and reliable operations.
5.	Personnel and training. Meeting high standards of performance requires that employees are well trained.
6.	Operations and maintenance. Operations and maintenance procedures are frequently assessed and modified to improve safety and environmental performance.
7.	Management of change. Any change in procedure is tested for safety, health and environmental impact.
8.	Third-party services. Contractors are important to safe operations.
9.	Incident investigation and analysis. Any incident, including a "near miss," is investigated.
10.	Community awareness and emergency preparedness. Good preparation can significantly reduce the impact of an accident.
11.	Operations integrity assessment and improvement. A process that measures performance relative to expectations is essential to improved operations integrity

The environmental work program that EMEP(NM)L will implement in Madagascar under the Ampasindava Exploration program, will comply with all eleven OIMS elements.

2.4.2 Health Policy

It is the Company's policy to:

- seek to identify and evaluate health risks related to its operations that potentially affect its employees, contractors or the public;
- implement programs and appropriate protective measures to control such risks, including appropriate monitoring of its potentially affected employees;
- communicate in a reasonable manner to potentially affected individuals or organizations and the scientific community, knowledge about health risks gained from its health programs and related studies;
- determine at the time of employment and thereafter, as appropriate, the medical fitness of employees to do their work without undue risk to themselves or others;
- as appropriate provide or arrange for medical services necessary for the treatment of employee occupational illnesses or injuries and for the handling of medical emergencies;
- comply with all applicable laws and regulations, and apply responsible standards where laws and regulations do not exist;
- work with government agencies and others to develop responsible laws, regulations, and standards based on sound science and consideration of risk;
- conduct and support research to extend knowledge about the health effects of its operations;
- undertake appropriate reviews and evaluations of its operations to measure progress and to foster compliance with this policy;
- provide voluntary health promotion programs designed to enhance employees' well being, productivity, and personal safety. These programs should supplement, but not interfere with, the responsibility of employees for their own health care and their relationships with personal physicians.
- Information about employees obtained through the implementation of these programmes should be considered confidential and should not be revealed to non-medical personnel except: at the request of the employee concerned, when required by law, when dictated by overriding public health considerations, or when necessary to implement the Alcohol and Drug Use Policy.

2.4.3 Safety Policy

It is the Company's policy to conduct its business in a manner that protects the safety of employees, others involved in its operations, customers, and the public. The Company will strive to prevent all accidents, injuries, and occupational illnesses through the active participation of every employee. The Company is committed to continuous efforts to identify and eliminate or manage safety risks associated with its activities.

Accordingly, the Company's policy is to:

- design and maintain facilities, establish management systems, provide training and conduct operations in a manner that safeguards people and property;
- respond quickly, effectively and with care to emergencies or accidents resulting from its operations, in co-operation with industry organizations and authorized government agencies;
- comply with all applicable laws and regulations, and apply responsible standards where laws and regulations do not exist;
- work with government agencies and others to develop responsible laws, regulations, and standards based on sound science and consideration of risk;
- conduct and support research to extend knowledge about the safety effects of its operations, and promptly apply significant findings and, as appropriate, share them with employees, contractors, government agencies, and others who might be affected;
- stress to all employees, contractors, and others working on its behalf their responsibility and accountability for safe performance whilst at work and encourage safe behavior outside of work;
- undertake appropriate reviews and evaluations of its operations to measure progress and to foster compliance with this policy.

2.5 Role of the PSC within the legislative framework

A Production Sharing Contract (PSC) is a contract established to define the terms and conditions under which an Oil and Gas company shall perform exploration and production activities over a delimited area, named Contract Area. Currently, the Contractor group consists of ExxonMobil (70%), Sterling Energy (UK) Ltd (30%).

The PSC, including the Petroleum Operations and all related disputes, is subject to Madagascar law and the international principles of law generally accepted in the field of hydrocarbons. The Madagascar laws relating to the environmental framework relevant to the Project operations are detailed in the sections thereafter.

In addition to the national and international system, the production sharing contract established between the OMNIS and the Contractor in Article 35 specifies the environmental obligations of the Contractor).

Art. 35.1: During the performance of the Petroleum Operations, the Contractor shall undertake the measures necessary […] to protect the environment and prevent pollution in accordance with the environmental regulations in effect in Madagascar and according to generally accepted practices in the international petroleum industry […].

Art. 35.2: Before each relinquishment of all or part of the Contract Area, the Contractor shall be required to take the necessary measures to clean up and restore the environment in order to return it to the extent possible to its initial condition before the Petroleum Operations, in accordance with the generally accepted practices in use in the international petroleum industry […]. These measures shall include, among others, removal of the facilities, materials and

equipment that OMNIS declares it does not need, as well as reasonable and necessary provisions to preserve flora, fauna and the ecosystem.

Art. 35.3: The Contractor shall take the necessary precautions and make the necessary provisions to prevent pollution, protect the environment (flora and fauna), springs and all other natural resources in accordance with generally accepted practices in the international petroleum industry […].

Art. 35.4: The Contractor shall observe the preservation of property and agricultural, fishing and navigation zones.

Art. 35.5: Before commencing the Exploration Operations in the Contract Area, the Contractor shall produce and submit an environmental impact study in accordance with the provisions of Decree nº 99-954 of December 15, 1999.

Art. 5.6: If a portion of the Contract Area is located inside a natural reserve area officially designated by the Government, the Contractor shall do everything possible to minimize any negative impact on these nature reserves […].

Art. 35.7: […] If, after the Effective Date a part of the Contract Area is designated as a national park or natural reserve area, OMNIS and Contractor shall meet and mutually agree to adjust the boundaries of the Contract Area or restore the economic balance in accordance with Article 28.5.

Key institutions governing technical & environmental aspects of oil exploration in Madagascar

The technical and environmental framework of oil exploration activities in Madagascar is provided by three governmental agencies: OMNIS, ONE and OLEP.

2.5.1 OMNIS

The Malagasy National Mines and Strategic Industries Office (OMNIS) is a government agency whose role is to promote and regulate the development of the country‘s oil resources. In this capacity, according to Decree 96-133, modified by Law n°99-033 and Decree n°99-697, OMNIS is responsible, in the mining domain, for the optimization of geological data and also functions as an office for the promotion of mining. Within the oil sector, the Office ensures the implementation of national policy on oil exploration and exploitation.

2.5.2 ONE

The National Office for the Environment (ONE) is one of the institutions created just after the Charter on the Environment in 1990 came into effect. The ONE was created by the decree n°90-066 dated 20 September 1990. It is a Public Administrative Institution (EPA) under the aegis of the Ministry for the Environment, Water and Forests. The decree which created it specifies that it is the agency responsible for enforcement of the environmental management

policy, and during the two first environmental programmes I and II, the ONE was mainly called upon as a coordination body. In Environmental Programme III, ongoing in 2007, two areas of activity have been assigned to the ONE:

- The development and management of the MECIE system (see National Legislation above), the management and prevention of pollution; and
- The management, production and distribution of environmental information, of Environmental Road Maps and of educational and advertising tools.

The ONE provides a framework for leading the environmental evaluation process, playing the following roles: i) coordination and participation in the creation of Terms of Reference for the EIA; ii) receipt of EIA dossier submissions and the examination and issue of permission rulings; iii) the proposition of the Technical Evaluation Committee, as well as participating in and serving as the secretariat to this Committee by providing the Secretariat; iv) issue of environmental permit rulings; and v) coordination and participation in the control and monitoring of the EMP (Environmental Management Plan), as well as the examination of the audit report as part of an environmental audit.

2.5.3 OLEP

The task of the Agency for Prevention of Marine Pollution with Oil (OLEP in French - Organe de Lutte contre l'Evènement de Pollution marine) is the preparation and coordination of operations for the prevention of pollution in marine and coastal environments. OLEP was created by the decree n°2004-994 dated 26 October 2004, and placed under the technical authority of the Ministry of Environment, Water, and Forests.

OLEP's primary role is to prepare and to coordinate all operations to manage oil spill contingency in Madagascar marine and coastal waters. In this capacity, OLEP is i) to draft, set up and update action plans; ii) to coordinate the prevention operations, iii) to organize simulation exercises, and iv) to organize training (internal or external) for participants in the prevention plans

3. CHAPTER 3 - PROJECT DESCRIPTION

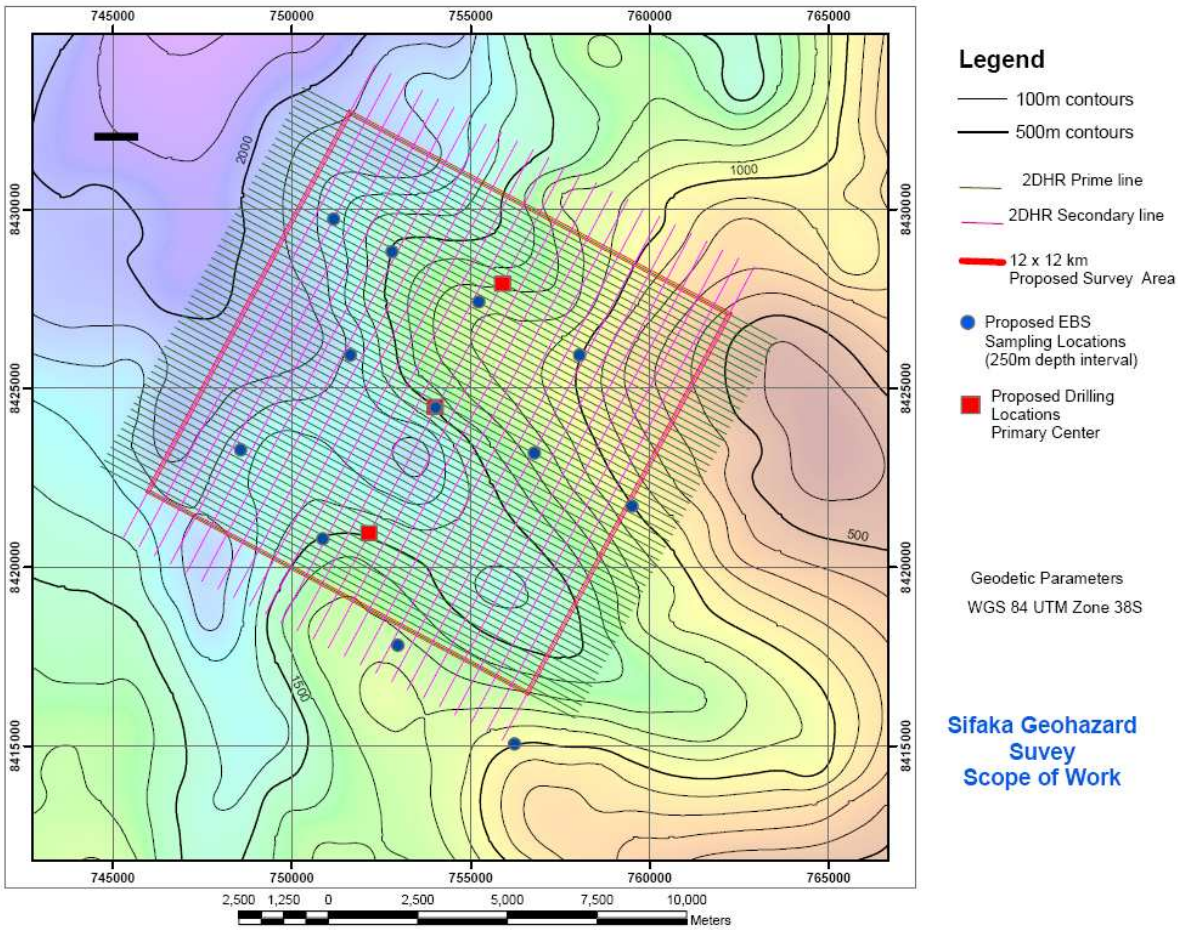
3.1 Survey Programme

3.1.1 Objective

As previously mentioned, the site investigation survey described in this report will (1) enable EMEP(NM)L to evaluate alternative well locations, (2) maximize the safety of subsequent drilling operations by identifying and avoiding potential shallow hazards in the prospect area, (3) help establish the pre-drill environmental conditions around the drilling location and (4) identify and delineate shallow water environments, such as submerged coral reefs, so that they can be avoided during future exploration operations. Surveys of this type are routinely conducted in offshore exploration operations worldwide. They are currently the only feasible means to accomplish the objectives listed above.

3.1.2 Overview

EMEP(NM)L proposes to acquire approximately 1032 line kilometers of seismic data in the Ampasindava Block. The lines will be arranged in a 200 m x 500 m grid across an area up to 12 km x 12 km. Lines will be oriented NW-SE, and parallel to the coast (SW-NE) as shown in the **Figure 3.1** below:



Surveying is estimated to commence in May, 2008. A multi-beam echo sounder bathymetry survey will be taken coincident with the seismic survey. These data will be supplemented with a side scan sonar survey to be conducted along the shelf – slope break. In addition, 5 – 10 piston cores, 12 – 15 box cores, and 2 – 3 vertical sets of water samples will be collected. Survey operations normally continue 24 hours a day. The entire survey is expected to take up to 30 days to acquire, including time for delays.

TL Geohydrographics, headquartered in Kuala Lumpur, Malaysia, is the seismic contractor proposed to carry out the survey using the vessel 'Teknik Perdana' (see Figure 1.2).

3.1.3 Survey Vessel

Seismic survey vessels are equipped with state-of-the-art navigation, communications and safety equipment. A very sophisticated Global Positioning System must be used in order to accurately navigate along the predetermined seismic lines and determine the location of each component of the survey equipment at any point in time during the survey. Communications equipment includes radio (JRC VHF) and inmarsat phone, fax and email to enable the vessel to stay in daily contact with the client company and government regulators.

The main characteristics of the proposed survey vessel **'Teknik Perdana'** are as follows:

Year built: 1973
Flag: Panama
Classification: NK*, NMS*, Ice class C
Length: 86.95 meters
Width: 13.40 meters
Draft: 5.26 meters
Gross/net tonnage: 1,830/681 tons
Cruising range/speed: 15,000 nautical miles/15 knots
Fuel capacity/endurance: 620 tons/60 days
Fresh water capacity: 260 tons

Teknik Perdana will be self-sufficient in fuel, food and water for the duration of the survey. The vessel can accommodate up to 55 personnel, though the crew normally consists of 33. The seismic crew looks after the geophysical surveying operation and the maritime crew takes care of the vessel and tasks such as food preparation and cleaning. The ship's Captain has overall responsibility for the vessel and the health and safety of all those on board.

3.1.4 Seismic Survey Equipment

3.1.4.1 Air Guns

The marine seismic source consists of an airgun array towed behind the seismic vessel at a fixed depth estimated to be 4.0 ± 0.5 meters. The array is a small capacity "high resolution" source which comprises eight individual guns arranged in pairs in one sub-arrays or 'string' with a total length of around 7 m. The airguns are discharged approximately every 8 seconds, at 18.75m intervals along each survey line. A controlled volume of air is expelled rapidly under pressure (2,000 psi) into the water. The resultant rapid

expansion and oscillation of the produced air bubble generates seismic energy. Arrays are designed to focus sound energy downwards and therefore lateral sound levels are lower than levels directly below the array. The required size and power of the airgun array is determined by geophysicists by consideration of geological conditions and the depth below the sea floor to which the seismic energy must penetrate.

Teknik Perdana's array specifications and operating parameters are as follows:

Energy Source: Airguns (Sodera G gun and IO Sleeve gun)
Output: 36.5 bar-m peak to peak
Array volume: 760 cubic inches
Configuration: 4 x 40ci, 4 x 150ci
Operating Pressure: 2,000 psi (138 bar)
Airgun Tow Depth: approx. 4 meters
Shot Point Interval: 18.75 meters
Time Between Shots: around 8 seconds

The depth of the gun array is achieved by attaching large floats to the guns. Gun depths cannot be adjusted dynamically and to vary the tow depth the guns have to be recovered and the floats adjusted.

3.1.4.2 Streamer

One 3000 m long streamer will be deployed behind the survey vessel to record the returning seismic signal. The length of the streamer is predetermined by geophysicists by consideration of the target depth below the sea floor which must be imaged by the seismic data. The streamer is subdivided into sections (64mm by 75m) that contain the hydrophones and other electrical components within a polyurethane skin. The end of the streamer is marked by a 'tailbuoy' which is a raft-like structure fitted with radar reflector and flashing light.

The streamer contains kerosene which helps to keep it neutrally buoyant in the water column. Each 75m section contains approximately 200 litres of kerosene. Variations from optimum streamer depth affect seismic data quality and therefore the depth of the streamer is monitored closely from the vessel by telemetry. Streamer depth is controlled from the survey vessel using wing-like attachments on the streamer known as 'birds'. The vessel must maintain forward motion (above 3.5 knots) in order to keep control over the position and depth of the streamer and other towed equipment.

3.1.5 Seabed Survey

Seabed Survey Objectives

A Multi-beam Echo Sounder, mounted to the hull of the vessel, will be used to measure water depths during the seismic program. The Multi-beam Echo Sounder will produce a higher quality bathymetry measurement than currently exists in the Sifaka prospect area. These data will assist in the optimal positioning of the sea floor well head in a flatter, more stable area of the sea floor. This aspect of the program is conducted at the same time as the seismic survey and does not call for any addtional vessel operations.

Side Scan Sonar will be used outside the seismic survey area to image seafloor features, textures and sediments along the shelf – slope break. A Side Scan Sonar survey will be conducted along the shelf –

slope break in a limited area across the block. This survey will produce a detailed image of the seafloor which will be used to identify and delineate shallow water environments such as submerged coral reefs. These data will be used in future exploration operations to ensure the safety of future operations and the protection of these sensitive environments.

Field Method

3.1.5.1 Multibeam Echo Sounder

- The Multi-beam echo sounder can be thought of as series of discrete single beam echo sounders mounted in such a way as to collect a swath of depth measurements at each sample. These data must be corrected for ship motion and slant range using a water velocity function to allow a complete 3-dimensional digital terrain model of the seabed to be built up with successive passes. In general around 20% of the sample area is overlapped onto the adjacent line to ensure data integrity, the need to overlap beams dictates line spacing and is related to water depth because as the beam pattern is fixed, the swath width varies with depth. Multi-beam transducers can be permanently mounted to the ships hull (preferred) or installed on a temporary over side mount (TL Perdana has two permanently installed systems, one medium frequency unit for shallow water and one low frequency unit for deep water). Both return time and returned signal strength are recorded for later interpretation. Post acquisition processing is an integral part of the methodology. Return time once corrected gives a depth below datum for each discrete beam, which is integrated into the digital terrain model during processing. Reflectivity can be used to interpret relative sediment density at the sea bed.

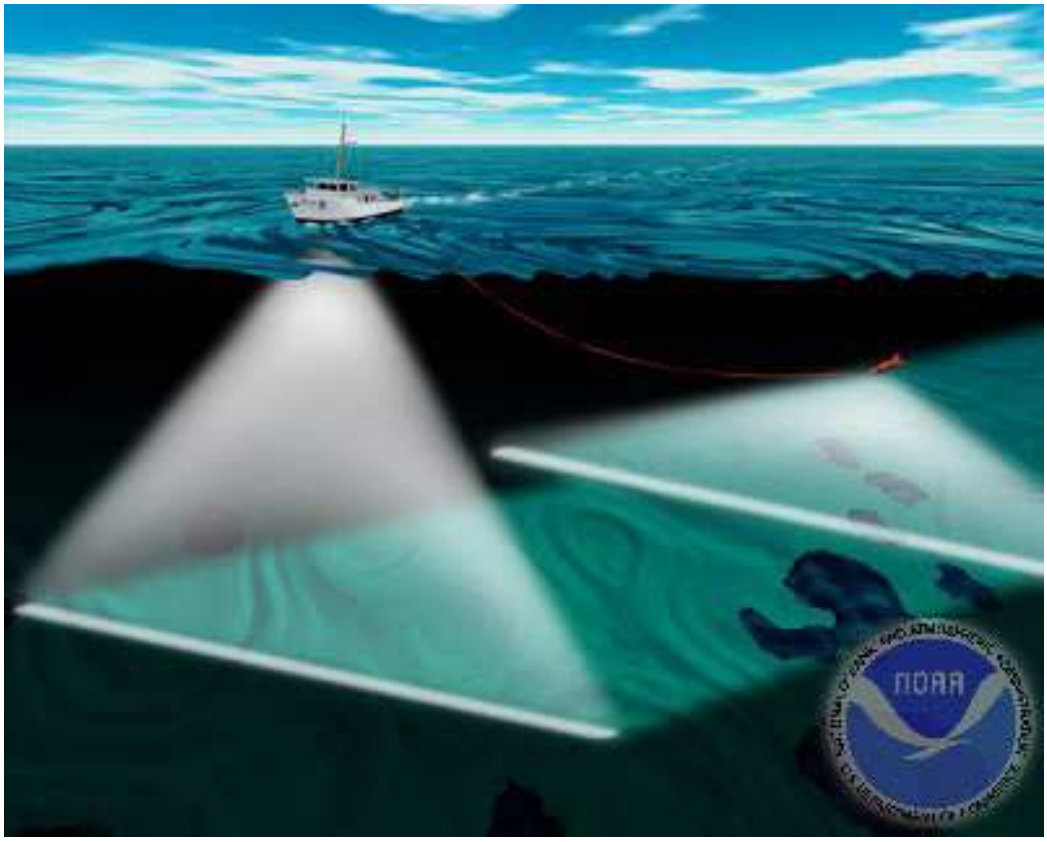


Figure 3.15: Schematic of Multi-beam bathymetry (left) and Sidescan Sonar (right)

3.1.5.2 Side-Scan Sonar

- Side scan sonar can be thought of as two sideways looking high frequency sonar sources with ~ 10 degree vertical beam width mounted on a fish towed behind the vessel close to the seabed. It is primarily an amplitude and range measuring device which "illuminates" the seabed with pulses of sound. The sidescan sonar image of reflected acoustic energy is much like an image produced by radar. Darker returns represent areas where more acoustic energy is returned, such as hard debris, rock or sand ridges; light returns are representative of low reflectivity zones, such as very soft, fine grained sediments. Returning signal level is measured as a function of both amplitude and time. This produces a seabed reflectivity image each side of the fish and is especially good for the detection of objects projecting upwards (such as wrecks and coral pinnacles, whose height can be estimated from the length of the induced shadow) and for the comparision of different sediment types. The fish is generally towed at a height of above the seabed of some 10-20% of the pre-set range per channel. This may be increased in highly irregular or unknown areas to avoid collision of the fish with the seabed. Height above the seabed determines the geometry of the resultant data; too low or too high produces a poor image. The pre-set range (cross line distance imaged) may be increased, up to the limits that a signal can be detected. However as the range increases, resolution decreases. Height above the seabed is controlled by the amount of tow wire spooled out and ships speed through the water. Typically a cable length of around 3 to 4 times the water depth is required to tow the fish at the required depth. This ratio increases as depth increases. As a result of this function, it becomes impractical to try to operate a conventional side scan sonar in

depths greater than around 1000 – 1500 meters. A small strip of seabed is missed beneath the fish at each pass, but for the purposes of the reconnaissance survey, this is insignificant. Line separations are generally calculated to ensure this is covered on an adjacent pass. The tow fish is sometimes tracked using a USBL acoustic system as the laybacks can be significant in deep water and cross line currents cause positioning errors if the fish is assumed to be directly behind the boat

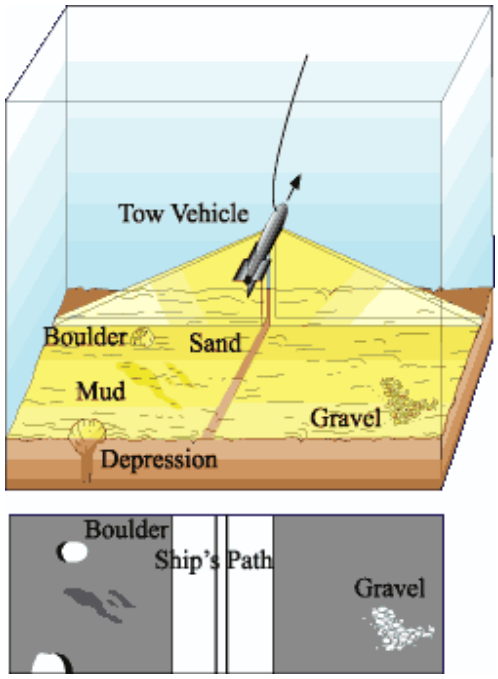


Figure 3.2: Map showing the location of the side scan sonar lines relative to survey area.

3.1.6 Support Facilities

Seismic vessels are recognised as having a restricted ability to maneuver and in this respect, under marine sailing directions, they must have priority over vessels which are not similarly restricted. A seismic vessel towing a cable will display internationally recognised symbols (by day) or lights (by night) indicating restricted manoeuvrability. In areas where poor charting or the presence of other vessels may pose a potential problem to the survey operation, the seismic vessel is often accompanied by a smaller escort vessel known as a chase boat or guard boat. The primary function of the chase boat is to ensure that other vessels do not cross over or otherwise interfere with the towed equipment. The chase boat may also check that the way ahead of the survey vessel is clear of obstructions such as uncharted shallow water, and fishing equipment, which may need to be removed from the path of the vessel. Technical details of the chase boat will be provided to the Malagasy government in advance of the survey should such a vessel be necessary.

3.1.7 Environmental baseline survey

An environmental baseline survey (EBS) will be conducted following the seismic site investigation survey in the block. The survey will cover part of the Sifaka prospect, located 25 to 45 km offshore NW Madagascar. The physical and chemical conditions of water, sediment, and biota will be evaluated to document baseline conditions prior to planned petroleum exploration activiites.

Objectives

The objectives of the EBS are to define the range of sediment habitat conditions for an area within the Ampasindava block targeted for oil and gas exploration drilling and to evaluate chemical and biological patterns of variability in relation to sediment physical characteristics and water depth.

To meet these objectives, sediments would be collected from stations, including two potential well sites, located within a 400 km^2 area of the block, following the geohazard seismic survey. Sampling locations would be arranged in three offshore transects with four stations each, and ranged in depth from 1941 to 2889 meters. Sediments would be sampled for grain size, organic carbon, hydrocarbons, metals, and benthic community parameters. General information on water quality and physical structure would be collected to compare results to previous findings. Water quality and chemical data would be collected from three water depths at each of the two candidate well sites. Total suspended solids, dissolved oxygen, hydrocarbons, and metals would be measured at the surface and at water depths of approximately 400 and 1000 m. High resolution salinity, temperature and density water column profiles would be collected at the same two stations.

Field Method

3.1.7.1 Vessel Operations and Navigation

Field operations will be conducted from the *Teknik Perdana* outfitted with a hydraulic winch operating through a stern-mounted A-frame. The vessel is equipped with wet and dry laboratories, and storage rooms containing sample freezers and dry storage areas. A C-Nav mobile Differential Global Positioning System (DGPS) using a Winfrog navigation package will be used to position and navigate the vessel during all fieldwork. Accuracy of the navigation system will be approximately ± 2 m. Targeted station positions along with the tentative cruise track will be provided to the ship's captain prior to sampling. The sample station will be allocated a range target specified by the scientific crew, typically +/- 25 meters. Geographical locations of sampling stations will be recorded in latitude/ longitudes (WGS 84 datum) as well as the UTM 38S planar system in northings / eastings. Positions will be printed out at the time of sample collection, recorded electronically and stored on an onboard computer until subsequent transfer to the field database. Water depth will be recorded for each station using the ship's fathometer.

Standard operating procedures governing all field operations will be reviewed by the scientific team members and included establishing shift assignments, maintaining effective communications, preparing for sampling activities while in transit, recording field data, storing and tracking of samples, and packing and shipping of samples upon cruise completion.

3.1.7.2 Pre-sampling Preparation

Transit time to and between stations would be used to prepare for the next sampling event by setting up field sampling equipment for immediate deployment (grab sampler, water column sampler) and preparing sample preservatives and storage containers. The following decontamination procedures would be used to minimize ship-borne contamination:

1. Chemical sampling equipment would be decontaminated by scrubbing with non-phosphate cleanser (i.e., Alconox™) and rinsing with deionized water after use at each station.
2. Access doors to the box-core sampler would be kept closed when it is not in use.
3. U.S. Environmental Protection Agency (EPA) certified clean jars would be used for allocation of sediment and water chemistry samples.

3.1.7.3 Water Column Sampling

Discrete water samples would be collected from three depths at each of two stations located within ± 20 m of corresponding sediment station locations. Samples would be collected from the water surface (approximately 1-m depth), at 350-400 m, and at 1000 m depth. All samples would be analyzed for dissolved oxygen in the field using an ion-specific electrode. Sample aliquots would be collected for laboratory analysis of TSS, eight metals, SHC, and PAH.

Water samples would be collected using a 5-liter (L) bottle attached to the winch cable and deployed from the A-frame to the targeted depth. The sample bottle would be deployed open at both ends, and closed at the targeted depth with a brass messenger.

The bottle would be thoroughly decontaminated prior to use with a dilute acid and would be followed by a reagent-grade hexane rinse. The bottle would then be washed with a non-phosphate detergent, then rinsed with deionized water and filtered seawater between stations. For hydrocarbon analysis, subsamples would be transferred from the Niskin bottle into two pre-cleaned 1-L amber glass bottles.

For metals (except mercury), subsamples would be collected from the Niskin bottle directly into a pre-cleaned 1-L polyethylene bottle, containing 0.5 mL of 50% nitric acid preservative to obtain a pH less than 2. Mercury samples would be collected in 250-mL ultra-clean glass bottles, and preserved with nitric acid. All chemistry water samples would be refrigerated at 4^{o}C while on board ship.

For TSS samples, 1250 mL of water would be passed through a 0.45 µm filter on-board ship. The filter would be then wrapped in foil and stored in the ship's refrigerator.

The water column would be continuously profiled at each of two water stations using conductivity/temperature/depth (CTD) meter (Figure 2-1). Water column data would be collected between the near-surface (ca. 1 m depth) to near-bottom water depth (ca. within 20 m of the seafloor based on ship's fathometer).

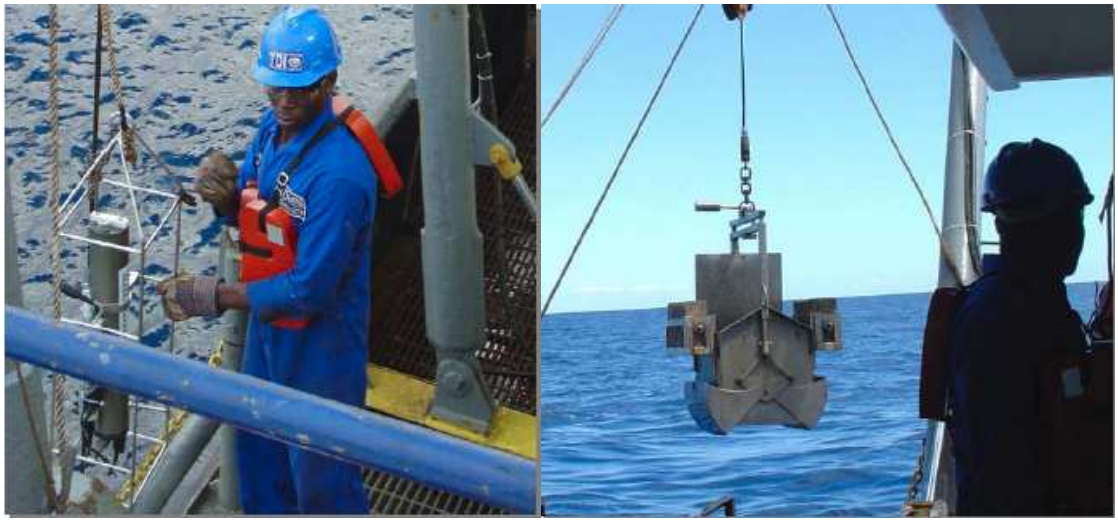
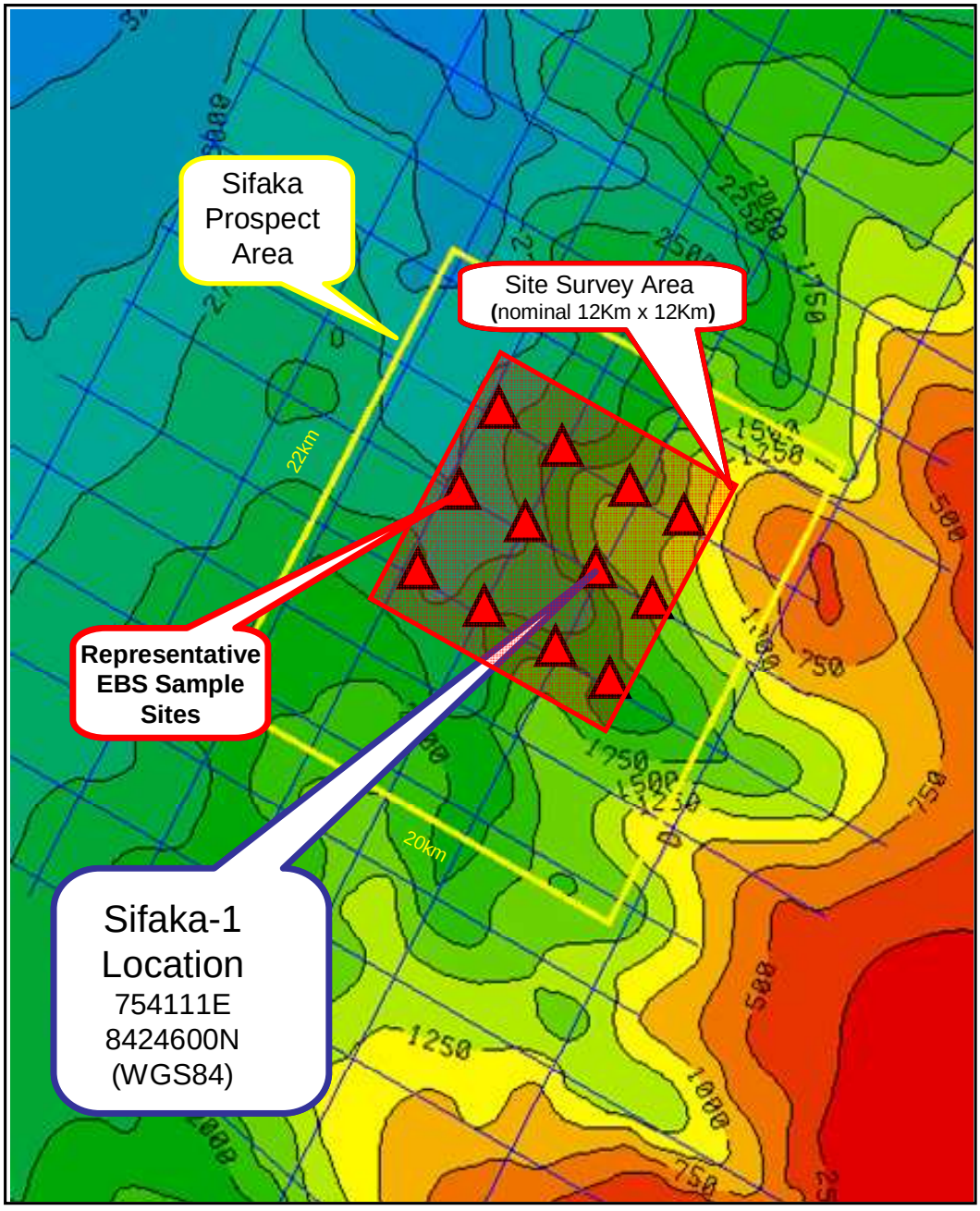


Figure [3.3]. Deploying the CTD (left) and sediment box core (right).

3.1.7.4 Sediment Sample Collection

Up to twelve (12) stations would be sampled within the Ampasindava Block (see following Figure 3.4 : Sifaka-1 site Survey and EBS).

Fig.[3.4] EBS sampling Site coverage



Sifaka-1 Site Survey and EBS

Sediments would be sampled with a 50-cm x 50-cm stainless steel box corer, providing a sampled surface area of 0.25 m2. Photographs of the sediment surface would be taken for all acceptable box core samples and a brief description of each core would be recorded in the field log book.

Physical and Chemical Measurements. A 0.1 m^2 sleeve would be placed in the box core and over-lying water would be removed with a siphon from outside the sleeve. Aliquots would be collected outside the sleeve for physical and chemical analyses from the top 10 cm of sediment. Once all samples would be collected, ORP measurements would be made by inserting a 3-inch plastic core tube with a series of holes drilled 1 cm apart into a corner of the box core. The core tube would be sealed and carefully withdrawn from the box core and ORP measurements would be taken immediately at 3-, 6-, and 9-cm depths of the core tube using a platinum probe with a standard hydrogen reference electrode. Sediment for metal analyses would be sampled using a plastic "spoon" and placed into a quart plastic bag. Sediment for PAH and SHC analyses would be sampled using a stainless steel "spoon" and placed into pre-cleaned glass jars. Sediment for the determination of grain size would be sampled with a stainless steel "spoon" and placed into a quart plastic bag. All chemistry samples would be stored frozen and grain size samples would be refrigerated. Samples for grain size would be stored at 4 ºC.

Benthic Infauna. The top 15 cm (including overlying water) of sediment would be sampled from the entire area of a 0.1 m2 sleeve (placed in the corner of the box core) (see Figure 2-2) and sieved through a 0.3-mm diameter screen. After sieving, infauna samples would be preserved with approximately 50% volume of 10% buffered formalin and Rose Bengal. The preservative would be sufficient to cover the entire sample, and exceed the retained material volume by at least 10%. Rose Bengal, which is a vital stain, stained all biological material red, facilitating the efficient removal of biological material from the sample during laboratory sample sorting.

A solvent-resistant label would be placed inside the sample container. When necessary, high-volume samples would be stored in more than one sample container, which would be labeled accordingly. Samples would be inverted several times to thoroughly expose the organisms to the preservative. Samples would be stored in buffered formalin and shipped in ice chests at ambient temperature to the benthic laboratory at Barry Vittor and Associates in Mobile, Alabama, U.S.A.

3.1.7.5 Sample Tracking, Storage and Shipping

All collected samples would be placed in appropriate storage containers immediately after collection and affixed with a unique pre-printed label containing the following information: sample identification number, date and time of collection, technician's initials, type of analysis, designated laboratory, and preservative. This information would be recorded in the field notebook immediately after collection and subsequently transcribed into an electronic field database. Sediment chemistry samples would be then transferred to freezers, sediment grain size samples would be stored in the dark at 4^{o}C; water column samples would be refrigerated, and preserved benthic samples would be stored at room temperature, each in designated areas. A complete sample inventory would be generated from field logbooks and checked for completeness. This information would be used to generate sample chain-of-custody forms and shipping manifests for sample transfer and shipment to the analytical laboratories.

Water and TSS filter samples would be hand-carried to the U.S. and transported directly to the laboratories from the airport after clearing customs. Sediment samples would be packed in coolers with blue ice and benthic samples would be packed without ice for international air-freight, and custom manifests would be

completed. Each shipping container/cooler would include a chain-of-custody form and copy of the shipping manifest. The shipper, sample custodian, chain-of-custody and manifest numbers would be entered into the field database. International shipment of samples would be coordinated between sample custodians associated with each analytical laboratory and the survey field leader.

3.2 Identification of Key Environmental Aspects of Survey Operations

The key environmental aspects of the survey operation which may potentially result in impacts to the natural or human environment of the survey area are:

- Underwater noise
- Physical presence of the survey vessel and equipment
- Discharges to water
- Air emissions
- Management of solid waste

The potential impacts due to these aspects of the operation are assessed in Chapter 4 & 6.

3.3 Overview of Survey Methods and underwater noise

3.3.1 Seismic Data Acquisition

A typical seismic survey programme follows the following sequence of tasks:

- mobilisation to the survey area
- deployment and calibration of surveying equipment
- data acquisition
- demobilisation.

Mobilisation includes obtaining supplies (food, fuel, water), travelling to the survey area and completing any customs or other formalities in the destination country. Once the vessel is on location the survey equipment is checked, deployed, calibrated and tuned to optimise acquisition parameters according to the client's requirements.

Survey lines are usually arranged in a grid pattern over the area of interest. To acquire seismic data, the seismic survey vessel travels along each pre-determined survey or sail line at a fixed speed not exceeding 5 knots. The vessel must proceed at a fixed speed in order to keep control over the location and tow depths of the survey equipment. At regular points (known as 'shot points') along each line, the seismic source (compressed air 'guns' arranged in an array) is used to produce a short burst of sound energy (known as a 'shot') which transmits downwards into the sub-surface geology. The sound energy reflected back from sub-surface interfaces is detected by hydrophones inside the streamer towed behind the survey vessel. The reflections arrive in the form of pressure waves which are converted to an electrical signal and then sent down the streamer to the survey vessel for electronic collation and storage. The time between generation of the sound wave and the reception of the reflected wave is known as the 'travel time'. The amount of data collected at each shot is determined by the recording period or 'record length'. In this case, the record length will be 6.0 seconds, ie data arriving at the hydrophones with a travel time greater than 6.0

seconds will not be recorded. A different record, or 'trace', will be recorded for each channel (240) of the streamer. Multi-channel seismic processing will subsequently 'stack' the different traces and ultimately produce the seismic reflection profiles. At the end of each survey line the vessel makes a turn and continues to the start of the next line. The order of lines can be varied depending on factors such as tide, current and traffic in the area.

After acquisition of all lines is completed, the airgun array, streamer and tail buoy are retrieved from the water and the vessel proceeds to the subsequent phases of the project (EBS and Side Scan Sonar Survey). The seismic data are processed (usually ashore) through various stages of signal processing and computer summing to produce seismic reflection profiles (horizontal distance versus seismic travel time plots) of the sub-surface. It is these seismic profiles and amplitude characteristics that will be used by the EMEP(NM)L site investigation team to assess any shallow hazards in the prospect area. Their interpretation will then be used by other members of the prospect team, including geoscientists and engineers, to optimize the well location while still avoiding any potential shallow hazards, such as shallow gas zones, and to find an optimal location on the sea floor to place the well.

Listed below is the planned sequence of events for each phase of the project:

- Complete Sifaka site survey analogue and 2D HR as mapped
- On Completion of Sifaka Site Survey, recover 2D HR equipment and conduct EBS sampling in Sifaka area
- Steam to southern end of marine park exclusion area at intersection with 200m contour, launch sidescan fish and survey south following 200m contour, until the southern end of the block is reached. Turn and map all features on the landward side to the 30m contour, working shorewards, using sidescan sonar and multibeam. Ship to remain in surveyed and interpreted area at all times.
- Run a single swath line with sidescan sonar along the seaward edge of the marine park exclusion area until the 200m contour is reached.
- Survey north following the 200m contour to the northern end of the block. Turn and map all features on the landward side to the 30m contour, working shorewards, using sidescan sonar and multibeam. Ship to remain in surveyed and interpreted area at all times.
- Estimated time to complete hazard clearance survey 3-5 days, depending on water depths discovered.

After completion of all phases of the survey, including sampling for the Environmental Baseline Study and the Side-Scan Sonar survey, the vessel may return to port to disembark passengers, re-fuel and prepare to sail to the next job.

3.3.2 Sound Level and Propagation

The unit used to measure sound level is the decibel (dB). Sound measurements are expressed using the dB scale as if the listener were 1m away from the source. The decibel scale is logarithmic, such that an increase of 6 dB represents an approximate doubling of sound pressure level. Sound measurements underwater use a reference point of 1 micro Pascal (1µPa) which is a different reference from that used in air. To convert underwater sound measurements to their equivalents in air, it is necessary to subtract approximately 62 dB from each measurement given.

Sound level output from the air gun array described in this report is expected to be between 190-200 dB, equivalent to about 128-138 dB in air. As a comparison, the approximate sound intensities of other events can be summarised as follows:

Normal conversation: 60 dB in air, equivalent to 122 dB underwater;
Jet engine: 120 dB in air, equivalent to 182 dB underwater;
Maximum intensity of whale song: 200 dB underwater;
Richter Scale 4 earthquake: 270 dB underwater.

The table at the end of this Section details sound source frequencies and levels from various maritime activities (Evans and Nice, 1996).

In open, deep water, sound spreads spherically from the source and its decay with distance (known as transmission loss) is described by the inverse square law. Mathematically, this is described by the expression:

Sound pressure level (SPL) = SL - 20 log R (R is range from source, in meters)

In water, this transmission loss due to spherical spreading results in a reduction in sound level of 60 dB in the first kilometer. Therefore, an underwater sound whose underwater source level is 200 dB would register at around 140 dB at a distance of 1 km from the source. Typical air gun arrays have source levels of approximately 250 dB; however a smaller, higher frequency source is being utilized due to the shallow objectives and the need for higher resolution data for the seismic geohazards survey.

Simple spherical propagation of sound is generally assumed in deep water but does not hold true in shallow waters (less than 50m deep) for several reasons. The sea surface and the seabed act to constrain the propagation sphere so that sound spreading in shallow water effectively takes place within a vertical cylinder around the sound source. Reflection of sound from the sea surface and the sea floor leads to interference, in which sound waves travelling in different directions cancel each other out. There is also increased scattering of sound energy from plankton suspended in the water column. As a result, sound waves attenuate much faster in shallow water. Richardson *et al*. (1995) cite a horizontal linear absorption rate of –0.97 $dB.km^{-1}$ measured in waters of <20m depth, compared to 0.06 $dB.km^{-1}$ in deep water.

3.3.3 Sound Frequency

Environmental issues relating to seismic surveys are focused on the potential effects of sonic disturbance to marine fauna from the sound waves associated with the seismic energy source. The pulses ("shots") produced by airgun arrays focus most of their energy in the frequency range of 10 to 300 Hz. The compressed air shots associated with seismic surveys produce a steep-fronted detonation wave which is transformed into a high-intensity pressure wave (shock wave and an outward flow of energy in the form of water movement). There is an instantaneous rise in maximum pressure followed by an exponential pressure decrease and drop in energy.

Most emitted energy (for deep water surveys) is low frequency, between 10-120 Hz, but pulses also contain some higher frequency energy up to 500-1,000 Hz. The latter components are weak when compared to the

low frequency energy (but strong when compared to ambient noise levels) (Richardson *et al*, 1995). Baleen whales and seals are thought to hear well at these low frequencies. Baleen whales themselves sometimes use very low-frequency sound (less than 1 Hz) for communication, although they also use the range 10 - 1,000 Hz. Most toothed whales, dolphins and porpoises are thought not to hear well at frequencies below 1,000 Hz, and use higher-frequency sounds (10,000-150,000 Hz) for echolocation and the detection of prey. The main range of human hearing is about 500 - 10,000 Hz (Evans & Nice, 1996).

3.3.4 Background Sound Levels

The propagation of low frequency signals in the sea is efficient, with little loss due to attenuation (i.e. due to absorption and scattering). Close to an airgun array, spherical spreading loss (the reduction in intensity caused by the spreading of waves into an ever increasing space) results in signal intensity dropping quickly. This loss is around 6 dB per doubling of distance. However, attenuation depends on the propagation conditions. In good propagation conditions, the signal may be above the background level for more than 100 km; in poor propagation conditions, it may reach background level within a few tens of kilometers (Mc Cauley, 1994).

The sound waves that travel sideways will continue until they meet an object or they are dissipated by normal decay of the signal. Despite these factors, in-water sound travels a long distance and some low frequency sound waves from the seismic survey may be detectable at tens of kilometers from the source. Nevertheless, the intensity of the sound waves does decay exponentially and although low level signals travel for long distances the higher amplitude waves lose much of their energy very close to the airgun source.

Once the noise associated with a seismic survey has decreased to the background noise level of the sea, it may be assumed to be of no further consequence. Background noise in the sea comes from many different sources. In deep water (off the continental shelf) typical marine noise sources include shipping traffic, surface wave action, natural seismic disturbances, oceanic turbulence, and thermal noise. At sound frequencies in the range of airgun emissions (0.02 – 0.12 KHz), shipping noise is an important factor. Urick (1983) gives values for oceanic waters equivalent to peak-to-peak noise levels of 75 to 95 dB re 1µPa, depending upon proximity to shipping lanes. Ambient noise in shallow, continental shelf waters (less than 200m) comes from a wider variety of sources including shipping and industrial noise, wind noise and biological noise. The latter is generated chiefly by cetaceanes, certain families of teleost fish (such as parrot fish) and marine mammals (Urick, 1983). Typical peak levels of ambient noise in shallow-waters range from 110 to 120 dB re 1 µPa, depending on wind speed and shipping and other human activity. Table 3.1 details sound levels from various maritime sources.

Due to the moderate level of shipping traffic going along the coast, it is likely that ambient sound levels in the survey area may vary from 85 dB re 1µPa in deep waters to 115 dB re 1µPa in waters less than 200m deep

3.3.5 Bathymetric Multibeam Echosounder

Multibeam surveys have a footprint on the seabed of up to 7.4 times the water depth and to a width of 1.5º. Such a system, mapping in 1000m of water, would ensonify a moving area 7.4 km by 50m. Multibeam surveys typically work in parallel tracks with some overlap between swaths and move at speeds of up to 12

knots. At this speed, a point 1000m away from the ship would experience sound levels >50% beam strength for <10 seconds.

Source : Multi beam
Sound pressure level: 235 dB re 1µPa
Ping Energy: 218 dB re 1µPa
Ping duration 20 ms
Duty cycle: 0.4%
Peak freq. :12 kHz
Band Width: narrow
Directionality: Vertical
(information from SIMRAD EM1002 Multi beam echosounder hull mounted)

Multibeam systems generally operate with frequencies above 12kHz with deep water systems below 20kHz. Source levels for the deep water systems are quoted as maximums of 236-238 db re 1 dB re 1 micro Pa. Systems for shallower water are both higher frequency and lower power, down to small systems deployed on launches.

3.3.6 Side Scan Sonar

The sidescan sonar system offered by TLGH is the EG&G Model 260TH. The system produces images that are corrected for slant range, ship speed, and signal amplitude. The basic system configuration consists of the Model 260TH Recorder, Model 272-T Tow fish, remote controlled winch and tow cable. Two frequencies, 100kHz and 500kHz (nominal), can be selected.

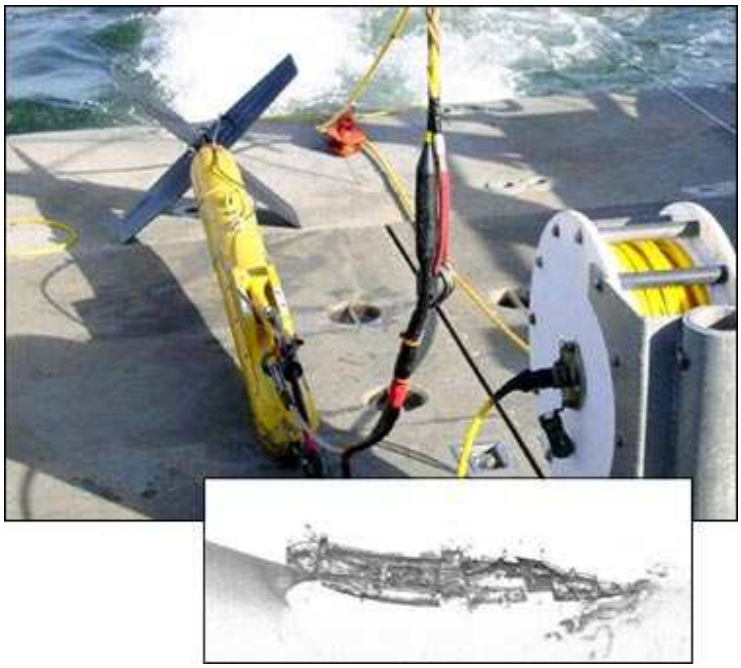
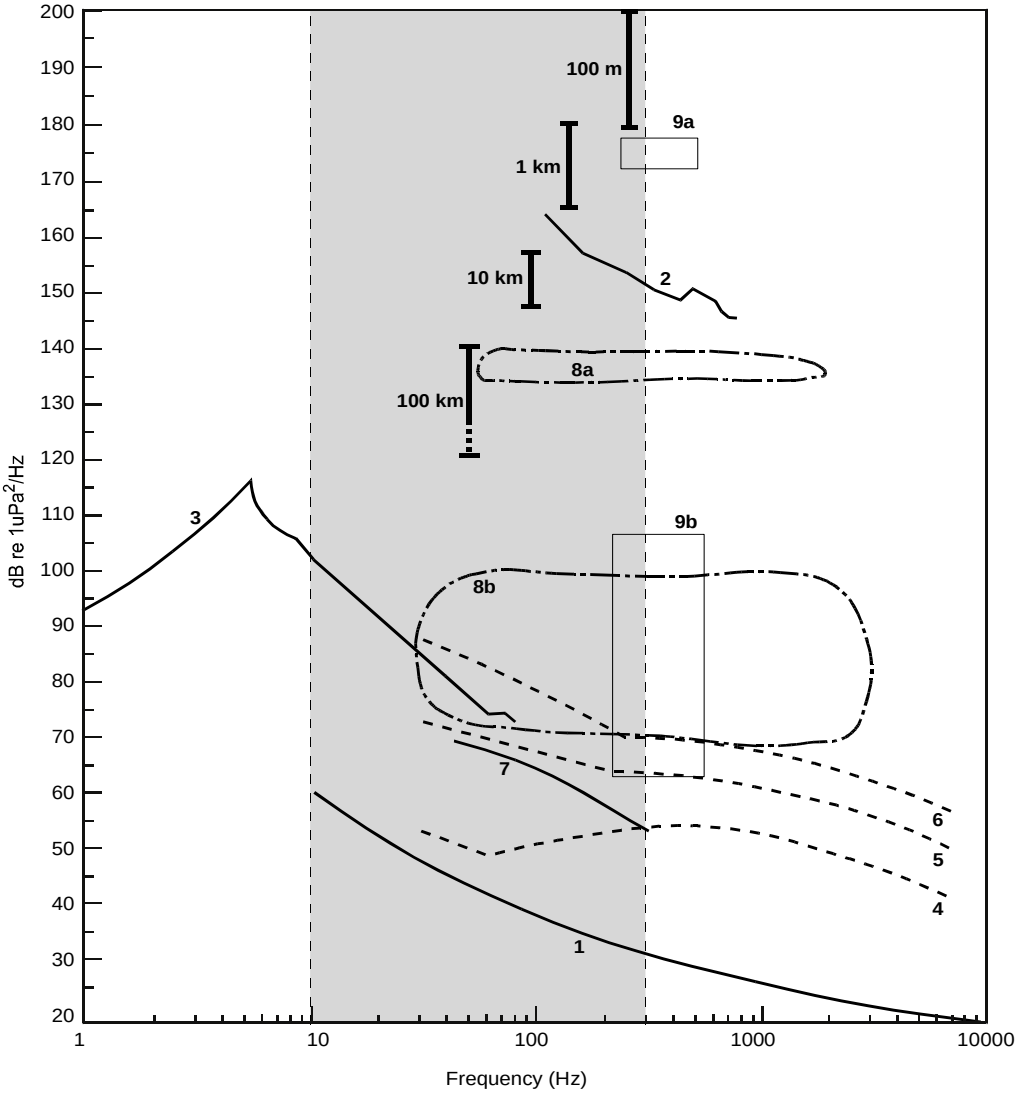


Figure 3.5: Side Scan Sonar Tool or "fish"

Short duration acoustic pulses are transmitted from two transducers mounted in a compact towfish. The pulses are emitted in a thin fan-shaped pattern that spreads downward to either side of the fish in a plane perpendicular to its path. As the fish follows the tow vessels track, this beam scans a bottom segment ranging from a point (almost) directly beneath the fish outward as near as 25metres or as far as 600 metres per side, dependant on the operator-selected range setting. The optimal sonar image is obtained when the towfish is flown at a height above the seafloor of 10 - 20% of the selected sonar range. In irregular sea bottom condition the operator must be constantly aware of the towfish height and be prepared to make corrections by means of the remote control winch. Acoustic energy reflected from the seafloor is received by the same set of transducers, amplified and transmitted as an electrical signal back to the towing vessel. The signals are processed, amplified and converted to hard copy and/or digital files by the sidescan recorder. The acoustics, signal processing, data recording, and graphic recording are consistent with a pixel size of 1/800 of the range per channel (ie. to each side) and amplitude dynamic range of 64db.



Curve	Description
1	Lowest level of prevailing sea noise
2	Mean source level curve for 50 merchant ships over frequency range 100-700 Hz. Note that levels increase below 100 Hz, and may reach >190 dB re. 1uPa²m/Hz at 5-50 Hz for supertankers and large container ships.
3	Earthquake spectra measured at ~313 km from epicentre, Richter magnitude <4, frequency peak at 5 Hz
4	Wind noise (Australian waters), at Beaufort 1, (1 ms^{-1})
5	Wind noise (Australian waters), at Beaufort 3, (5 ms^{-1})
6	Wind noise (Australian waters), at Beaufort 5, (15 ms^{-1})
7	Predicted traffic noise, Indian Ocean
8	a) Source level for fish b) Ambient noise level for fish
9	a) Source leave for whales b) Ambient noise level for whales

Range of frequiencies generated by airguns

Airgun sources at different distances

Figure 3.6: Noise and Frequency Range for Underwater Noises Sources

Table. [3.1] Sound Sources from Various Maritime Activities

Activity	Frequency Range	AV Source Level	km	km	km	km
Geophysical seismic surveys	**(khz)**	**(dB/1µPa/1m)**	**.1**	**1.0**	**10.0**	**100**
a) High resolution						
- pingers, side-scanner, fathometer	10-200	<230	190	170	149	128
air guns (type to be used)		190 – 200	160	140	120	100
b) Low resolution						
- airguns[1]	<0.5	230-250	190-210	170-190	149-169	128-148
- airguns[2]	0.008-0.2	248	210*	144*	118*	102†
- sleeve exploder	0.005-0.5	225-270	185-230	165-210	144-189	123-168
- vibroseis	0.02-0.07	260	220	200	179	158
- explosives (TNT)	-	270	230	210	189	168
c)Drilling exploration						
- jack-up	0.005-1.2	85-127	45-87	25-67	4-46	<25
- semi-submersible	0.016-0.2	167-171	127-131	107-111	86-90	65-69
Drilling production	0.25	163	123	103	82	61
d) Dredging						
- gravel island	-	130	90	70	49	28
- suction dredge	0.38	160	120	100	79	58
Vessels						
- 650 cc jet ski	0.8-20.00	75-125	35-85	15-45	<25	<25
-6 hp outboard inflatable	0.8-20.0	105-130	65-90	45-70	24-49	<25
- 90 hp outboard speedboat	0.8-20.0	110-130	70-90	50-70	29-49	<25
- 240 hp inboard fishing boat	0.1-20.0	110-135	70-95	50-75	29-54	<25
- large merchant vessel	0.05-0.9	160-190	120-150	100-130	79-109	58-88
- supertanker	0.02-0.1	187-232	147-192	127-172	106-151	85-130
-oceanographic vessel	<0.1	170-230	130-190	110-170	89-149	68-128
- icebreaker	0.01-1.0	183-191	143-151	123-131	102-110	81-89

Source: Evans & Nice 1996

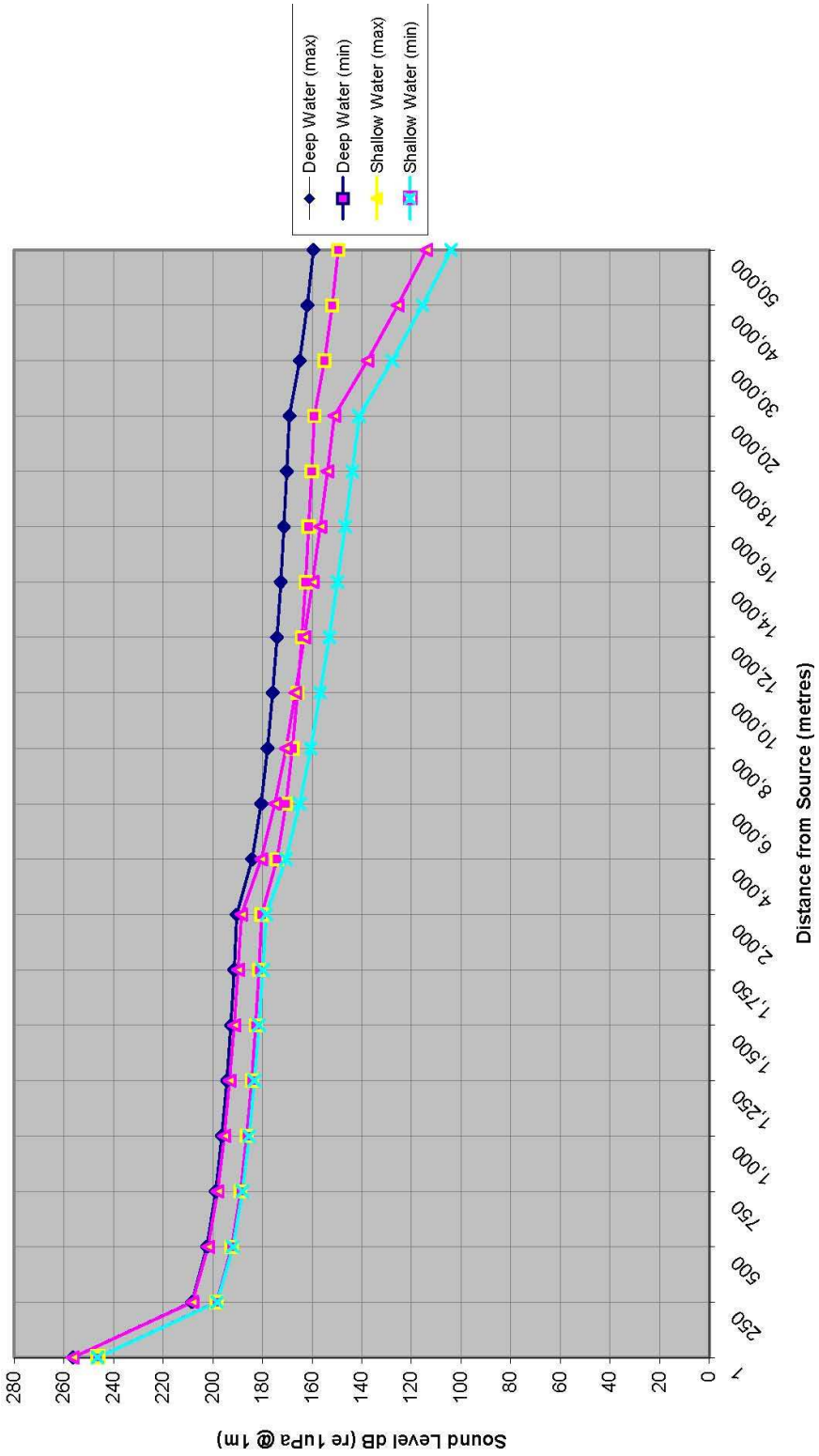


Figure [3.7]. Underwater Sound Levels

CHAPTER 4 RISK ASSESSMENT

Despite the precautions taken during the survey, the possibility of an accident cannot be totally ruled out. The impact assessment intends to distinguish between normal routine operations and abnormal operations in the event of an accident. The acceptability of accidental events and impacts is evaluated by considering the risk.

The key environmental risks two fold: 1) loss of streamer fluid during the seismic program or 2) accidnetal grounding of the vessel during the Side Scan Sonar survey.

Accidental streamer rupture, which would result in the loss of streamer fluid, could originate from:

1. Vessel collision with the streamer: The streamer will be at a depth of 4 – 5 meters. Small vessels, such as those used by local fisherman will not harm the streamer. However, larger fishing vessels, such as those used by the tuna fiisheries, could cut the streamer. This could be due to poor visibility or the inability of the tuna vessel to see the streamer, which extends approximately 3000 meters behind the vessel.

2. Damage to the streamer from marine life, the most likely risk being from shark bites.

3. Damage to the streamer from shallow water features such as submerged coral reefs.

Rupture of the streamer would most likely affect only one segment, which contains up to 200 liters of fluid (kerosene). The risk of streamer damage caused by another large vessel is considered unlikely due to the slow speed of the seismic vessel and the very predictable course it will follow. In additon, communications will be utilized and notification will be given to the local tuna industry informing them of the timing and the nature of the operation. Notifications will also be given to the local fishing organizations in Analalava and the Region of Sofia. Damage of the streamer due to shallow underwater features is also very unlikely due to the location of the survey in water depth >500 meters. The multi-beam echo sounder will also be measuring the water depth in front of the vessel should a completely unexpected under water feature be encountered. The seismic stereamer will not be deployed during the shallow water Side Scan Sonar bathymetry survey. Streamer damage due to shark bites has historically been the cause of streamer damage, although it too is rare.

Accidental grounding of the vessel in the course of the bathymetry survey along the shelf – slope break is considered unlikely. Side Scan Sonar measues the water depth several hundred meters to the side of the vessel. Thus it is possible to measure the next track of the vessel. This allows the vessel to sail only in waters that have already been suveyed and avoid any areas that may be too shallow. The Side Scan Sonar survey will survey to water depths of 30 meters, thus avoiding shallow waters.

4.1 Potential impacts

A kerosene spill from streamer failure during the seismic phase of the project is the most likely source of hydrocarbon spill. The quantities of oil spilled into the marine environment would be relatively low because the streamer is segmented, with each segment containing 200 liters of fluid.

Any seabirds on the water surface would be potentially at risk from any slicks that form although the extent of such a slick would be limited. Marine mammals are considered to be less vulnerable to fouling than seabirds, as they would be expected to move away from any oil pollution. However, marine mammals are believed to be more at risk from inhaling volatile elements in the oil, although these would generally evaporate rapidly from the slick.

The relatively low volumes of oil involved in most streamer accidents and light nature of the oil in the streamers as well as the open area of the survey zone means that it would quickly evaporate and disperse. The impact is then negligible.

4.2 Mitigation measures

The mitigation measures here relate to existing control measures and best practice.

Selection of survey contractor with demonstrable planned preventive maintenance procedures will lead to fewer emissions, equipment failures and accidental events. In addition, training of staff at all levels in environmental awareness will encourage best practice. Procedural controls, stemming from industry-standard guidelines and best practice procedures, will limit the possibility of accidental events. Quality procedures, incorporating the tenet of continuous improvement, apply and should be considered at the contractor selection stage.

A full risk assessment against accidental events will be performed as part of survey design: scheduling the survey during a period of no extreme meteorological event (May), notification of local (Region and District) fishing authorities and communications with the tuna fishieries will ensure other users will be aware of our operations. The Ministry of Agriculture, Livestock and Fish (Ministere de l'Agriculture, de l'Elevage et de la Peche), who track all commercial fishing operations in Madagascar and APMF (Agence Portuaire Maritime et Fluviale) will also be notified of the survey operations.

The risk of a major accident, such as collision with another vessel, is considered to be very low. The environmental impacts are considered acceptable when the probability of the event is very remote.

Historical data suggest that streamer oil spills of < 200 liters will represent the most likely oil spill scenario for a seismic survey. Impacts from these spills are likely to be very minor.

EMEP(NM)L Operations Integrity Management System (OIMS) provides a systematic foundation and approach to the management of operations, technical standards and all aspects of health, safety and environment for all its activities. EMEP(NM)L conducts its seismic survey operations in accordance with the requirements of its OIMS Guidelines for exploration seismic activities. This document complements and interprets the Corporate OIMS Framework for its use in the management of seismic survey operations. The OIMS implements the health, safety and environmental (HSE) policies and objectives set by ExxonMobil to ensure that high operational standards and practices are established and maintained.

CHAPTER 5 - DESCRIPTION OF THE ENVIRONMENT

5.1 General

This chapter presents the baseline information on the physical, biological and human environments of the project area in the Ampasindava Block.

The Sifaka study area encompasses the 12 km x 12 km area of the Sifaka Project, which includes the area of the proposed seismic program, with an additional 8 km perimeter for over-shoot, equipment start-up and testing. The vessel will go beyond this area for the purposes of turning around but no seismic activity will be conducted during this operation. During the seismic and Environmental Baseline Studies it is anticipated the vessel will not come closer than 15 km to the Madagascar coast, remaining in water depths exceeding 200 meters. During the Side Scan Sonar survey, which does not require the streamer, the vessel will come closer to shore. It will measure the water depths as shallow as 30 meters, although it will still (for the most part) remain more than 10 km from the Madagascar mainland. The Multi-beam Echo Sounder is run simutaneously with the seismic and side scan sonar equipment and does not require additional vessel operations.

The environmental study focuses primarily on the pelagic (water column) environment as the coastal environment will not be affected and the benthic (sea bed) environment will not be affected beyond the immediate area of the core acquisition. Since the vessel will come to Madagascar fully equipped and the project is of a very short and limited duration, the socio-economic impacts will focus primarily on fishing and other marine activity.

Numerous fishing villages and the village of Analalava are found along the coastline adjacent to the study area. Fishing activities are the principal direct or indirect forms of revenue for most of the working coastal population in this area. Prawn fishing by a variety of means is a major economic activity, which is undertaken by commercial and artisanal fishing companies/groups, as well as traditional fishing communities. In addition, there are commercial and subsistence captures of a wide range of finfish and shellfish. In addition, the commercial farming of prawns has been developed in several locations along the nearby coast. Tourist resorts are located near the study area, just south of the village of Analalava, in the Resort of the Hotel Anjajavy. Mahajanga is the principal port for both cargo and fishing vessels and is also well known as a tourist destination for foreigners and Malagasy people, although marine recreational activities are limited.

Data and information were gathered from a number of different sources: publication in the public and scientific domain as well as studies performed on behalf of EMEP(NM)L

5.2 Delineation of the study area

The Ampasindava Block is located off the northwest coast of Madagascar in water depths ranging from 0 to 3000m and covers an area of 15,991 km^2. The block is located between 20 km and 110 km offshore the mainland Madagascar coastline, between Narinda Bay to the southwest and Pointe d'Angadoka to the northeast.

The Sifaka seismic project area consists of a relatively small 12 km x 12 km block in the southwest part of the block, 35 km off the coast of the Madagascar mainland and approximately 35 km northwest of Nosy Lava. Since emissions and discharges will be limited to the immediate area of the vessel and acoustic noise will decrease by 30% within one kilometer of the source, the study area is primarily constrained to the project area.

The environmental study focuses primarily on the pelagic (water column) and shallow marine environments. The benthic (sea bed) environment will be minimally affected acoustically by the seismic and side scan sonar surveys and locally within the immediate area of the core acquisition. Since the vessel will come to Madagascar fully equipped and the project is of a very short and limited duration, approximately one month, the socio-economic impacts will focus primarily on fishing and other marine activity.

5.3 Seismic History

Several seismic programs have been conducted offshore Western Madagascar, including the study area, as shown below.

Table [5.1] - Seismic Acquisition History

Year	Seismic lines (km)	Oil Company	EIA
1970	500 - offshore	Mobil	No
1976	3200 - offshore	OMNIS	No
1976	700 – offshore	Phillips-SeaGap	No
1983-4	1311 – offshore	AGIP	No
1988	10000 – offshore	AGIP	No
2001	Offshore	Vanco	Yes
2004	Offshore	Vanco	Yes
2006	Offshore	TGS-NOPEC	Yes

5.4 Physical Environment

5.4.1 General Characteristics

The study area lies 10 - 45 km from the Madagascar coast. The seismic survey will be focused on the deep offshore waters while the side scan sonar survey will focus on the shelf – slope break and the line of coral reefs that run along the outer edge of the continental shelf. It is located between the Peninsula of Ampasindava and the Baie de Narinda. The nearest population center is Analalava. Both Nosy Lava and Nosy Saba lie near, but outside of, the study area. The seismic study area is 35 km southwest of the marine protected area of Sahamalaza and Radama Islands whereas the Side Scan Sonar survey area runs parallel to the coast in water depths between 30 – 200 meters. At no time will survey operations occur in the Sahamalaza marine protect area nor will the vessel enter the park. Figure 5.1 outlines the Ampasindava Block, shows the Sifaka Seismic Study Area and highlights in yellow the area for the Side Scan Sonar survey (yellow).

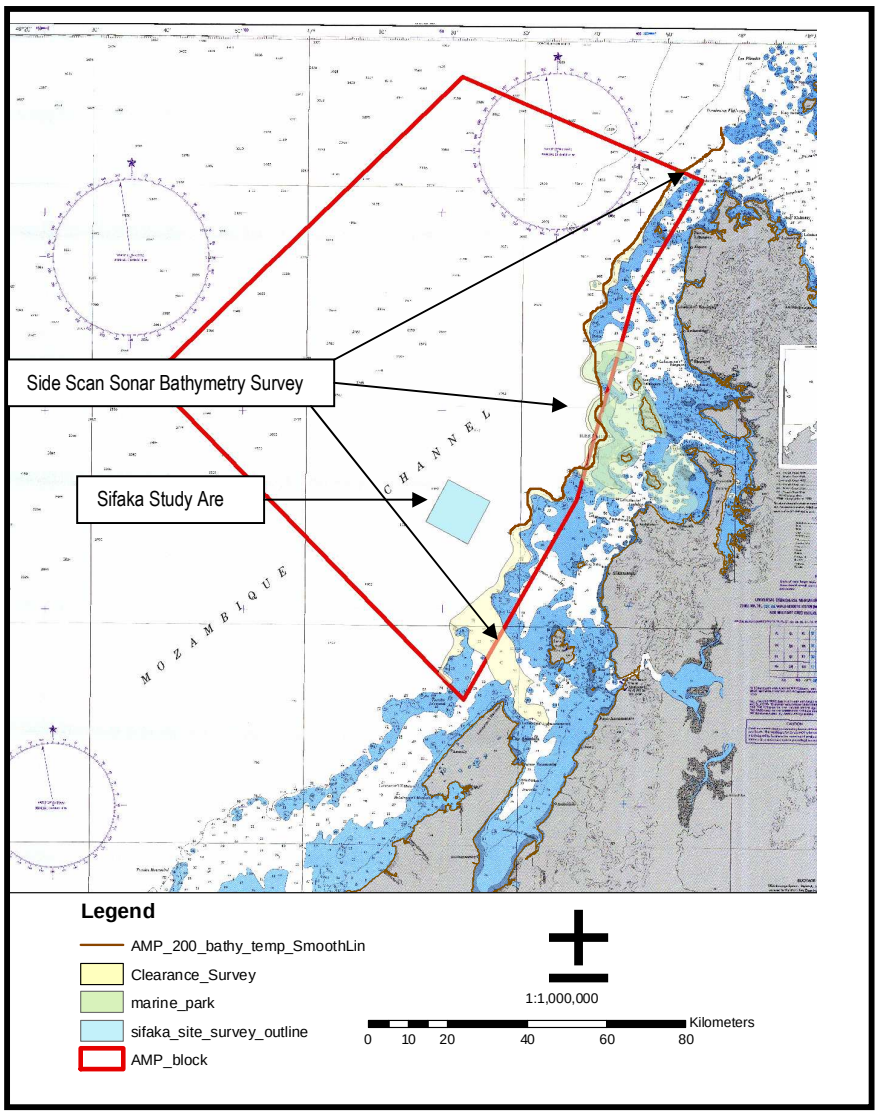


Figure 5.1: Delineation of Seismic Survey and Side Scan Sonar Survey Areas

This part of the Northwest Coast is characterised by:

- an indented coastline with numerous estuaries, bays and peninsulas.
- small islands lying offshore of the mainland
- coral reefs, both submerged and surrounding small islands.
- the presence of extensive mangrove zones;
- a relatively broad and gently-sloping continental shelf;
- a monsoon climate characterised by a wet, humid summer and a cool dry winter.

The mainland coast opposite the nearest edge of the Ampasindava Block contains a myriad of natural habitats (see Figure 5.2). Dominant vegetation cover is herbaceous and bush savannah with large and small patches of dry semi-deciduous forest, while substantial areas of mangrove forest, especially inland of the village of Analalava.

Estuaries in this region have high flow rates charged with heavy sediment loads particularly during the rainy season when erosion is most prevalent on the mainland. The marine and coastal waters have tide ranges up to 4.8 meters.

The low altitude of this coast meets an extensive continental shelf of 20 km to 40 km in width fringed along the outer edge with submerged reefs which form a barrier except in areas carrying high flow rates of freshwater and sediments.

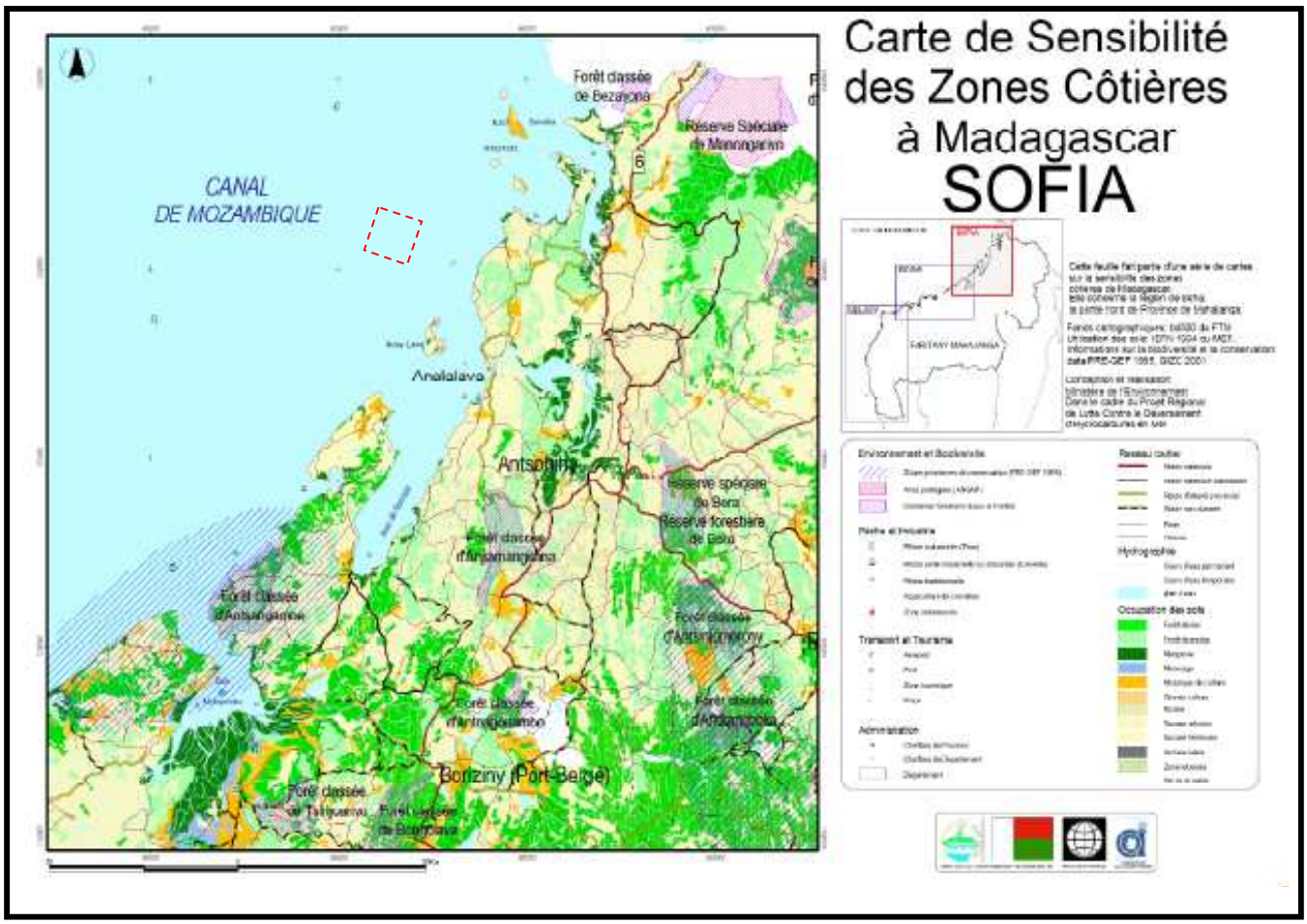


Figure [5.2]: Environmental Map of the Study Area and Adjacent Land Mass

5.4.2 Offshore Physical Environment

5.4.2.1 Climate

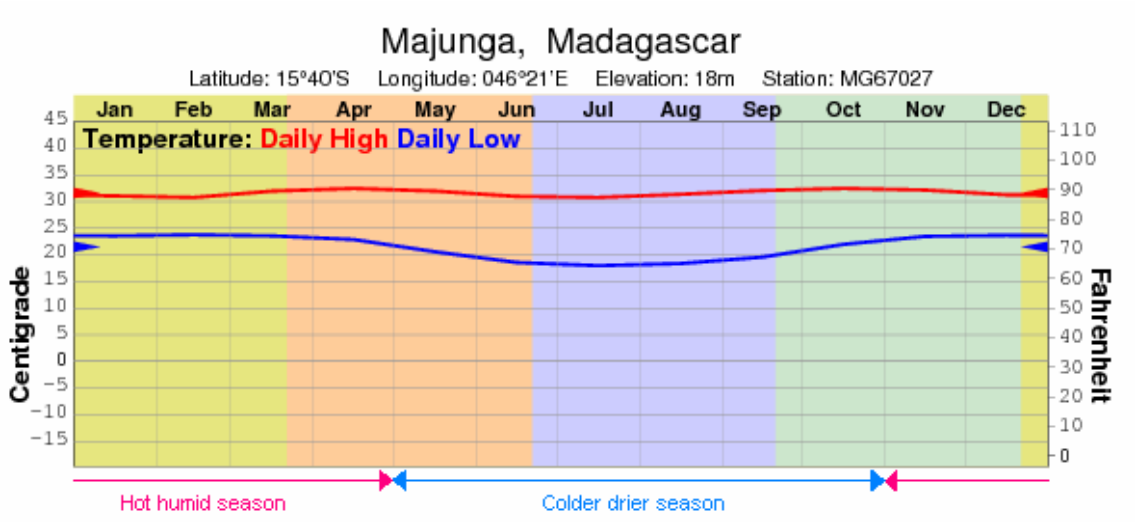
Regional Climate

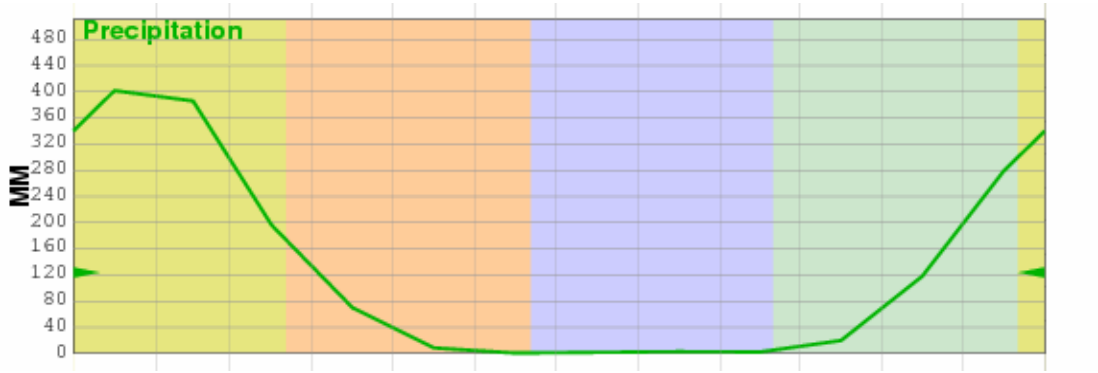
The climate in the northwest region of Madagascar is tropical and characterized by two alternating seasons. Between November and April it is the hot and humid season while between May and October there is a cooler, drier season. These seasons are the result of the combined effects of the Indian Ocean High pressure zone and the north-south migration of the Inter-Tropical Convergence Zone (ITCZ).

5.4.2.2 Air Temperature

Ampasindava Block area temperature varies relatively little throughout the year (see diagrams below). Mean annual temperature in Mahajanga is 26.4ºC, mean minimum temperature is 22 ºC and average maximum temperature is 30 ºC. Humidity can vary quite significantly reaching nearly 90% in the hot, humid season and falling to 60% in the cooler, drier season.

Fig 5.3 - *30 year average annual temperature and precipitation for Mahajanga*





Source: Climate-charts.com (2007). Data is from a 30 year average.

Figure [5.3]: Thirty Year Average Precipitation and Temperature Data for Mahajanga

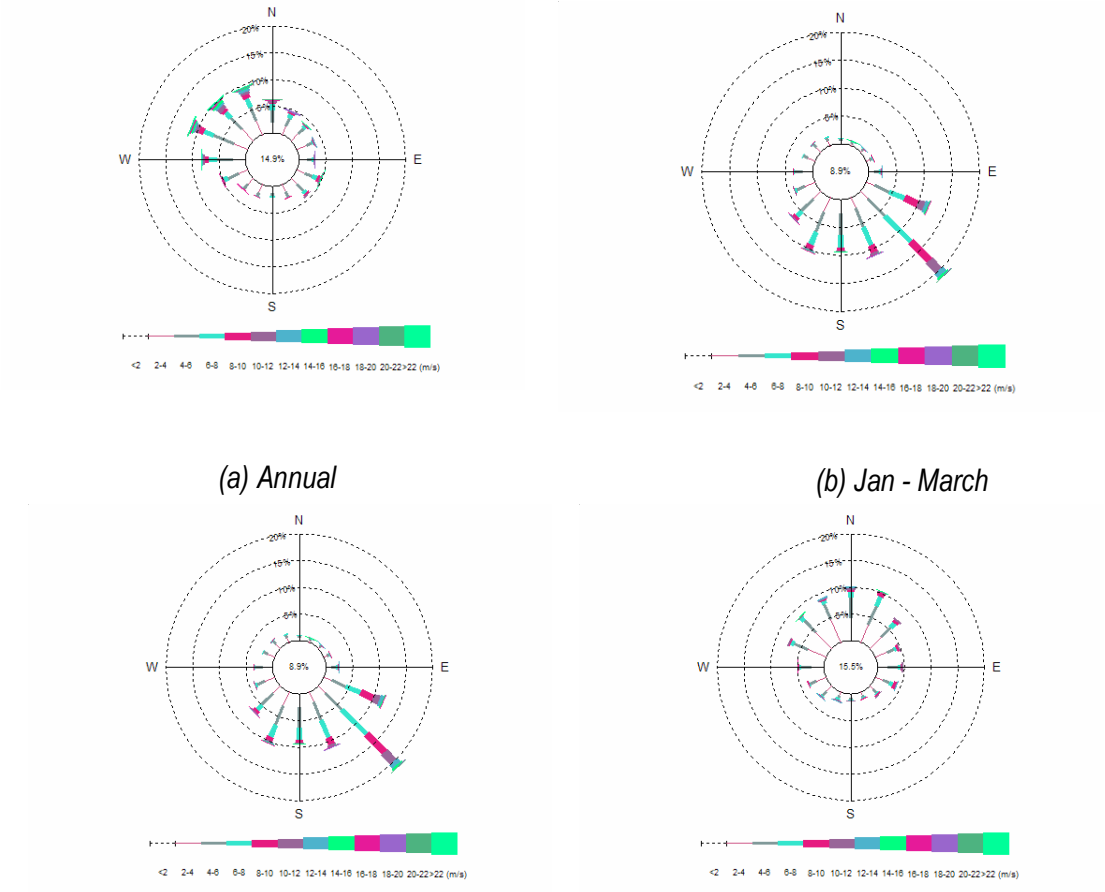
5.4.2.3 Wind

In the study area during the cool season the winds arrive from the southeast in the morning averaging 10 to 20 knots, then turn to the west in the afternoon with 5 to 10 knot winds. During the hot season the winds are slightly feebler during the day with the rains, but are often more forceful in the evening with gusting storms. The majority of winds throughout the hot season blow from the southeast, as opposed to the cool season when winds arrive from the northwest (Chaperon et al, 1993). The northwest has received winds in excess of 10 km/h for over 220 days in a year, as reported by Moal in 1974 (Cooke et al, 2000). Winds on the coast can cause sea swells, as discussed in Section 5.4.2.9. This natural power has effectively encouraged the development of sailboats for fishing and the transporting of goods by sea along this coast.

Wind rose diagrams are shown below in Figure 5.4. The wind rose diagrams illustrate wind frequency (dashed circles show percentage occurrence), speed (colored blocks) and direction (N, S, E and W orientation). [a] shows the annual wind rose, [b] shows wind between January and March, [c] between April to October and [d] November and December. Strongest winds are the south easterlies blowing between April and October and reaching up to 22 m/s for more than 20% of the time (diagram [c]). These south easterlies are the result of the Indian Ocean High pressure zone being located over South Eastern Madagascar. With the start of the southern summer in November and the southern migration of the ITCZ, the high pressure is weaker and so too are winds (diagram [d]). As the summer progresses and the ITCZ crosses the equator, the winds shift becoming dominated by northwesterlies particularly in the evenings. The northwesterlies are affected by the northern winter monsoon and can bring torrential rain.

Tropical cyclones can occur from December through to March. Madagascar experiences an average of four cyclones and 11 tropical depressions per year (data supplied by the UK Meteorological office). Typically they develop east or north of the island but can affect the Northwest, at times bringing torrential rain and flooding.

Fig [5.4] - Annual and seasonal wind rose diagrams



(a) Annual

(b) Jan - March

(c) April – October

(d) November - December

5.4.2.4 Precipitation, tropical storms and thunderstorms

Annual precipitation measured in Mahajanga, varies between 1,000 and 1,500 mm, and this is considered representative of the study area. Ninety percent of the annual precipitation falls during the rainy season, which lasts for approximately 6 months, between November and April.

Tropical storms are an important consideration for the study area. The storm season coincides with the hot, humid season between October and May. The storms normally move from north to southwest and originate in the Indian Ocean or Mozambique Channel.

Thunderstorms are frequent in the region owing to thermal instability particularly during the summer months (November – April). The numbers of thunderstorm days per month at the Mahajanga weather station (15.72 ºS and 46.3 ºE) are shown in the table below.

Table [5.2] - Number of thunderstorm days per month at Mahajanga

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
22	21	21	11	2	0	0	0	1	6	12	22	120

5.4.2.5 Air quality and noise

The Ampasindava Block is far from any industrial or urban activities. The ambient air quality is not influenced by onshore sources of air emissions. The occasional passing of marine traffic would have a negligible affect on the air quality and noise. Waves can provide a background noise level that varies with sea state and wind.

5.4.2.6 Bathymetry

Bathymetric data for the study area are relatively sparse and is one objective of the Ampasindava study. Available data indicates the seafloor has some relief and a better detailed map of the ocean floor will improve the operational and environmental aspects of the future exploration operations. Sea mounds may be present and shallow coral reefs are reported for the area. Along the continental shelf edge is a string of submerged coralline banks and shoals, corresponding to an ancient barrier reef that was subsequently submerged when sea levels rose at the end of the last Ice Age.

The seismic study area is confined to water depths >500 meters and it is believed water depth will not be a factor in the proposed Sifaka seismic program. A better definition of the shallow water features, such as sea mounds and the shallow coral reefs, are indeed the objective of the Side Scan Sonar survey. The greatest measures of safety will minimize the issues associated with the shallower water depths and under water features during the Side Scan Sonar survey. The vessel will sail only in areas that have been previously surveyed, where the water depths are already known.

Bathymetry of the seismic study area and its environs, based on current seismic bathymetry data, is shown in Figure [3.1]. The seismic area lies in open water unprotected by the coast in water depths ranging from 500m to 2000m.

5.4.2.7 Surface Currents

The surface circulation of the Mozambique Channel is highly complex. A simplified schematic of the surface circulation is shown in Figure [5.5]. The South Equatorial Current flows west with moderate constancy at a rate of about 1 knot. On approaching Madagascar from the east, the current divides into two branches. One branch is diverted north and then west around the northern end of the island. The other branch is diverted south and then west round the southern end of the island. Both branches are variable in constancy and average rates are about 1.25 knots. On rounding the northern end of the island the northern branch fans out into a anticyclonic gyre to form a fairly constant current with a speed of 1 to 2 knots in a southwest direction along the edge of an extensive bank off the northwest coast of the island. Further offshore the predominant current flow is northeasterly.

During the wet season rivers and estuary flows have a major impact on the salinity of water bodies on the continental shelf. During the wet season salinity is approximately 27‰, while during the dry season it will rise to between 35‰ and 36‰.

There are few direct current measurements taken in NW Madagascar (ExxonMobil Metocean Report, 2006). The available data suggest that a counter-clockwise gyre in the region centres on 42ºE and 13ºS in January and a smaller clockwise gyre centres closer to the coast in July. During the transition period between these two, the current in the region flows northeast. The MetOcean Report estimates currents in the region can reach speeds in excess of 1 m/s. Although these currents could have an impact on operational aspects of the seismic program by causing excessive 'feathering' of the streamer cables, it is believed there will be no impact on the environment due to sea currents.

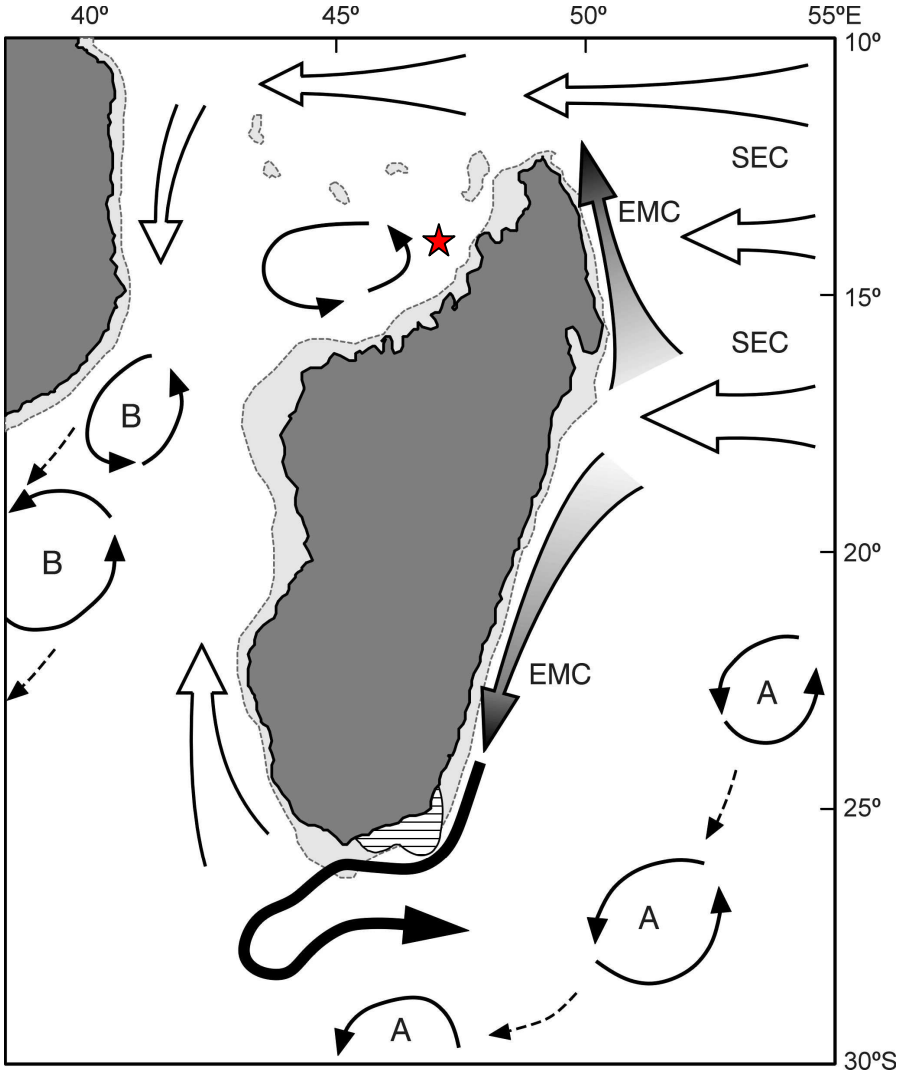


Figure 5.5: A simplified schematic of the surface circulation

5.4.2.8 Submarine Currents

There are five different water mass subdivisions in the Mozambique Channel (Sverdrup et al., 1942; Khimitsa, 1968; Wyrtki, 1971; Magnier and Piton, 1973; Burkov and Kuksa, 1977; Piton et al. 1981; Saetre and DaSilva, 1982; and Magazzu, 1985) and all are present in the study area.

- 0 – 100 meters: Surface Waters of the Mozambique Channel: temperatures more than 22^{o}C, salinity between 35.0 ‰ and 35.4 ‰, and oxygen content of 4.7 to 5.0ml/l at depths of 40m;

- 100 – 300 meters, Sub-surface Waters: temperatures of 22 ^{o}C and 12^{o}C, salinity between 35.2‰ and 35.5‰ and oxygen levels of approximately 3.6ml/l;

- 300 – 600 meters, Central Indian waters: linear temperature/salinity relationship of 8 ^{o}C/34.6‰ and 15^{o}C/35.5‰, and oxygen levels varying between 4.0ml/l and 4.5ml/l;

- 600 – 2000 meters, Intermediate Waters from the sub-Antarctic: salinity is between 34.5‰ and 34.6 ‰; these waters are separated into two layers, 'upper intermediate Antarctic' and 'lower intermediate Antarctic' in the northern section of the Mozambique Channel;

- 2000 + meters, Deep Waters: salinity of 34.8 ‰.

5.4.2.9 Tides, swells, waves

The coasts of Madagascar offer little impediment to the free movement of water so the tidal streams are weak. However, where there are narrow channels through the entrance to deep bays, tidal streams are strong. For the months of January and February during northwesterly winds, the tidal stream direction on a rising tide is between southwest and southeast at a maximum speed of about 1.25 knots. On a falling tide the stream direction lies between the northeast and the west, at a maximum speed of 1.25 knots. Along the west coast of Madagascar the tides are regular and semi-diurnal with a mean spring tidal range of approximately 4.8m at Mahajanga (Lebigre, 1990).

The coast adjacent to the study area is characterized by a high tidal range which is semidiurnal (two highs and two lows per day). In Mahajanga the tidal range is in the order of 4.1 m for the spring tides and 1.3 m for the neap tides (TGS NOPEC, 2006). In January and February when the northwesterlies are blowing, flow direction at high tide is southwest to southeast with a maximum speed of 1.25 knots (0.64 m/s). At low tide the flow direction varies between northwest and west, also with a maximum speed of 1.25 knots (TGS NOPEC, 2006).

The sea states in the region are a combination of mixed swells and seas (waves generated by local winds). The predominant swell direction is from the southwest due to the open exposure to the Southern Ocean from this direction. Since the South Indian Ocean storms are most intense during the southern winter it is in during this period that the swells are the most pronounced. However during tropical storm season (October – May) swells can also come from the northeast possibly generated by tropical storms.

Between January and March waves generated by local winds (seas) dominate the sea states while swells are lower than 2 m high. At the start of the winter season, April to October, winds are strong and so seas

are intensified but swells are also high. By the end of the year, in November and December seas and swells have similar magnitudes but are weaker than between April and October. Sea states are most disturbed between June and August. Although sea states may be an operational concern, it is believed there will be no impact on the environment due to tides, swells or waves.

5.4.2.10 Sea Water Temperature

A high surface temperature of between 24°C and 28ºC is found in the sea waters all around Madagascar. It is believed the water temperature will not impose any operational, environmental or safety risks to the Ampasindava project

5.4.2.11 Sea sediment characteristics

The physicochemical properties of sea sediment characterise the habitat of benthic communities and provide information on hydro-biological conditions, oxygenation and pollutant transportation. Sediment characteristics can indicate the presence of pollutants in the water column. The presence of hydrocarbons can allow the tracing of pollutants to specific industrial origins.

The Sifaka Environmental Base line Study will gather from 5 – 10 sea floor sediment samples. The estimated location of samples is shown in Figure 3.1. Previous studies have shown the existence of sands, silts and clays on the sea floor. Although sampling operations will disturb the environment at the site of the core, it is believed the coring operations will have a minimal effect on the environment.

5.5 Offshore and Coastal Biological Environment

5.5.1 Principal zones and components of the ecosystem

The ecosystems relevant to the study area can be described according to two main zones which themselves are further divided into sub-zones:

- Offshore / the pelagic zone: i) Offshore surface waters system and associated biota (from surface to 200 m); ii) Offshore deeper waters (200 – 3000 m); and iii) Offshore deep seabed habitat and associated biota (approximately 500-3000 m).

- Nearshore / the neritic zone: i) Continental shelf areas (including continental slope 200 – 500 m, shelf edge and shelf sea bed); and ii) Shallow marine and coastal ecosystems (including small islands, coastal coral reefs, seagrass beds, mangroves and coastal wetlands) (mostly <20 m).

  The following Figure 5.6 shows the spatial distribution of these ecosystem zones within the study area.

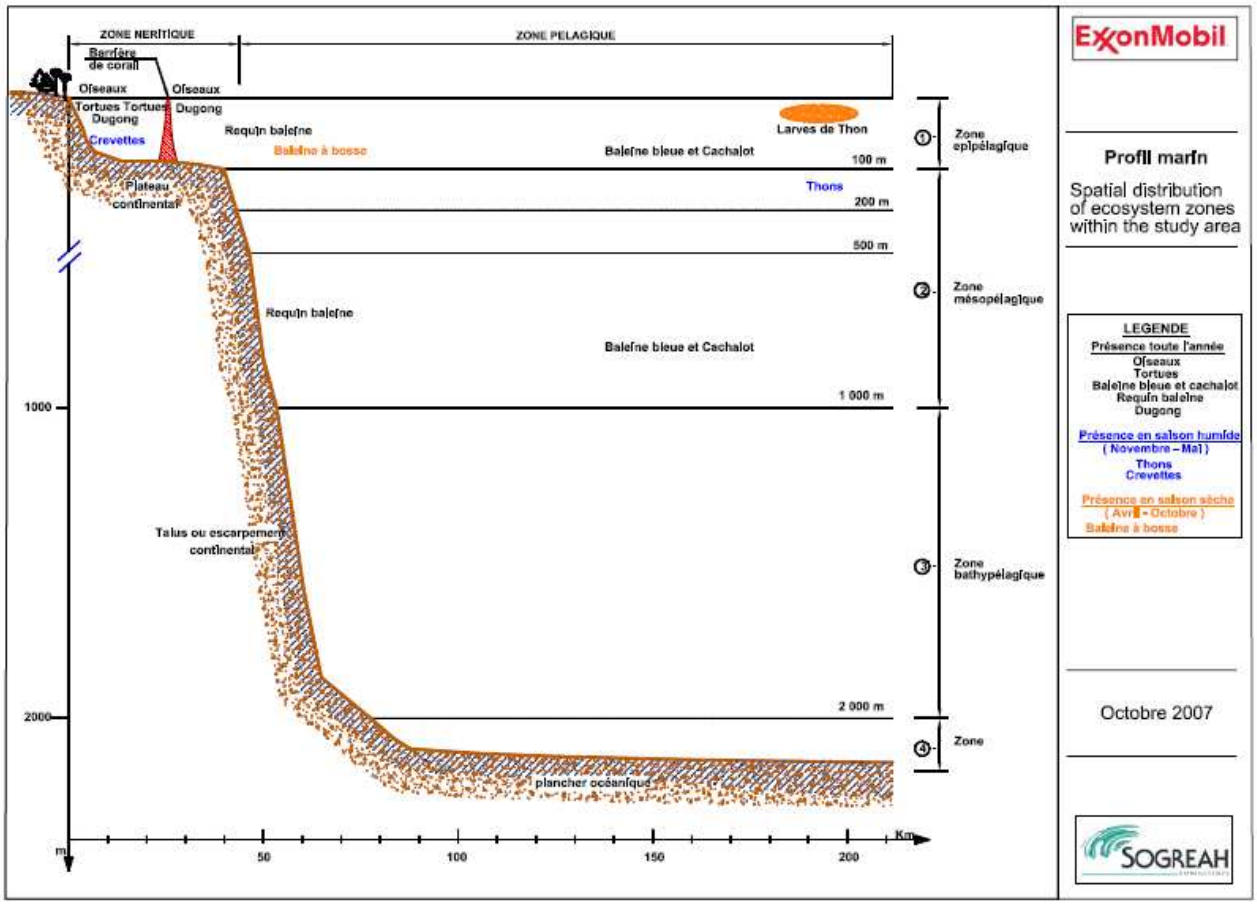


Figure 5.6: Spatial Distribution of the Ecosystems in and Around the Study Area

5.5.2 Pelagic offshore zone: The pelagic ecosystem is by far the predominant habitat of the Sifaka project area:

5.5.2.1 Offshore surface waters ecosystem: 0 - 200 m

The offshore epipelagic zone of the Sifaka seismic project and wider study area is characterised by moderate levels of primary productivity, weak currents and relatively low degrees of vertical mixing. The principal inputs of nutrients originate from river runoff to estuaries, feeding into the zone. Due to the relatively low degree of mixing, the zone of high primary productivity does not extend far offshore. This contrasts with the area to the south of Cap St André where the zone of high productivity extends offshore where the presence of substantial stocks of tuna (mainly skipjack *Katsuwonus pelamis* and yellowfin *Thunnus albacares*) migrate into the zone along with their predators (sharks, cetaceans) from November to April.

5.5.2.2 Offshore mesopelagic and bathypelagic waters: 200 - 3000 m

Below the zone where sunlight penetrates (generally >100m), the water column is usually sparsely inhabited. A gradual flow of nutrients from the surface zone to the deep sea, often in the form of “marine

snow", can be observed. Bacterial action in the form of the "microbial loop" is often an important component of this ecosystem.

A major feature of the mesopelagic zone is the "deep scattering layer", which comprises a fairly thin band of deep water organisms which inhabit the bathypelagic ocean depths during the day (up to 1,500m), and then migrate to the surface waters to feed at night. During the night these organisms rise to the surface to exploit the relatively rich resources of the euphotic zone, returning to the ocean depths before dawn. Below this deep scattering layer, organisms become increasingly sparse. Certain large organisms, such as sperm whales and whale sharks, are known to exploit the organisms of the deep scattering layer as a food source, making multiple deep dives in order to access this food resource.

5.5.2.3 Offshore deep seabed habitat and associated biota: 500 - 3000 m

With the exception of the Majunga Offshore Profond Environmental Baseline Study (Maxon, 2006), the deep sea environment around the study zone is virtually unstudied. It is therefore necessary to build up a picture of the deep sea environment of the study zone through a combination of inference and fragmentary data

The seaward side of the study area and beyond predominantly comprises deep areas of seafloor, much of which is between 1,000 and 3,000m. Sea bed habitats at such depths are typically characterized by soft sediments (generally fine silt, mud and carbonate ooze). Closer to shore, terrigenous sediments may dominate, particularly in proximity to large river systems (Demopoulos, Smith & Tyler, 2003; Ingole & Koslow, 2005).

Whilst the traditional picture of deep (>500m) seabed ecosystems is of a depauperate fauna, such environments may in fact support quite rich assemblages of organisms, including relatively sessile invertebrates such as sponges (Porifera), sea pens (Pennatulacea) and other Alcyonaria such as gorgonians and soft corals. Various anemones (Actinaria) may also be found.

More mobile organisms, such as fish, echinoderms, crustaceans, molluscs and various worms are also frequently abundant on the sea bed. Many less well known groups are also represented. Many of these groups are hidden within the sediment; a casual glance will reveal occasional fishes, burrow/tube openings and infrequent, although sometimes clustered invertebrate macrofauna, particularly Echinodermata and Crustacea. Indeed, the bulk of the biodiversity in soft sediments is typically infaunal. Thus, when the sediment itself is studied, a much greater diversity of organisms should be recorded than in a study which records only the epibenthic fauna (see section on Benthic fauna).

This abyssal community essentially relies on the input of nutrients from the surface waters, with organic matter slowly drifting down through the water column until it reaches the ocean floor, where it forms the basis of the food web on the seabed. Occasionally, exceptional nutrient inputs may take place, such as a dead whale sinking to the sea floor, or when plankton blooms in the surface waters die off and sink. Whale carcasses provide long-term (decadal) nutrient inputs to a small area of the deep sea, and it appears that entire communities of species, undergoing successional stages, exploit this resource; at least some of these species seem to specialize in exploiting whale carcasses in the deep sea (Smith & Baco, 2003). Such events contribute significant nutrient inputs; a single 40t whale carcass supplies a sudden nutrient input equivalent to that which will normally fall during a 100-200 year period to a hectare of abyssal sea. The area directly under the carcass experiences a nutrient input equivalent to 2000 years of input from the euphotic zone (Smith & Baco, 2003). Whale fall communities do not appear to have been studied around Africa, although one study mentions species found on trawled whale bones from South Africa (Dell, 1987). Being a

major route for whale migrations, the Mozambique Channel can be expected to experience whale-fall events.

The area is unlikely to harbour geothermal vent-type communities, as there are no active plate margins in the area. However it is not inconceivable that other unusual communities, such as those relying on natural hydrocarbon seeps, may be present, given the present exploration for hydrocarbon deposits.

Distribution of organisms on the deep seabed appears to be patchy and changeable in response to biological and physical factors, particularly currents and nutrient inputs (Cossona, Sibueta & Galerona, 1997). Myctophiformes, stomiiformes, small squaliform sharks and other such benthopelagic fishes are likely to be well represented throughout the deep area.

The deep sea is increasingly recognized as being more species rich than previously suspected, particularly for smaller organisms such as polychaete worms and isopod crustaceans, which may be represented by hundreds of species in an area of a few square meters (Bouchet, 2006). Meiofaunal and microfaunal organisms are still hardly known (Griffiths, 2005).

5.5.3 Neritic nearshore zone

The nearshore part of the bathymetric study area lies, in part, in the neritic zone on the continenetal slope and shelf. The sea bed and waters above the continental slope and shelf (referred to as the neritic zone) are much better known than those of the offshore pelagic zone, primarily through the conduct of fishing operations.

5.5.3.1 Continental slope, edge and shelf areas: 30 – 500 m

On the continental slope, hard substrata, with greater relief and a steeper slope are expected, and will likely harbour a very different invertebrate community. Broad scale patterns in the marine environment usually show a marked difference between soft and hard substratum communities. Because trawl and grab gear are generally ineffective on hard substrata, such communities beyond the reach of SCUBA gear (>50m) are often almost unknown. Communities present are expected to be fairly similar to those seen in Sodwana Bay; video footage from Kigombe at around 100m shows a generally very similar community to that seen in Sodwana Bay. Similar substrata in the Sifaka project area at similar depths could reasonably be expected to comprise similar species.

During the late 1960s and early 1970s, there was some research activity on the seabed of the neritic zone by French scientists. Much of this research seems to have been restricted to inshore areas around Nosy Be. The number of species recorded from the area appears to have been low, probably reflecting the relatively low sampling effort in earlier years, less efficient specimen extraction methods or less developed taxonomic knowledge.

The total diversity of organisms in those early studies (mainly from relatively shallow water) is lower than the diversity reported by Maxon (2006) for the deep sea benthos. This is possibly a result of different sampling techniques and/or improved taxonomic knowledge since shallow water (< 50 m) environments are generally expected to be more – not less – species-rich than deep water (> 500 m).

An important feature to highlight is a very steep continental slope descending to a deep sea plane at around 3000 m. The steep continental slope is likely to comprise a cline of habitats from the shelf edge at 200 m to the foot of the slope at 2000 m. The slope is likely to support the greatest diversity of benthic habitats and species.

Some trawling investigations of the continental slope were undertaken by ORSTOM (now IRD) in the 1960s, which included two sectors near the present study area – the continental slope off Majunga, and the slope between Nosy Be southwards, as far as the Radama Islands. According to reports, maps were prepared of each of these zones showing bathymetry, sedimentology and trawl results. Such trawls would have concentrated on the shallow slope, going no deeper than 500 m.

The fact that trawl surveys were undertaken provides indirect confirmation that the sea bed in these areas is likely to be primarily smooth and muddy, without rocks or other obstacles to trawling. The larger fishery operations are undertaken by private sector companies that tend not to release their data. However data were obtained from a former commercial demersal fishing operation conducted around 2001-2002 by the fishing company IPR which held licenses for 2 years to fish over the continental shelf off Mahajanga at distances of more than 8 nautical miles offshore.

The IPR commercial fish list is presented in unedited form (apart from correction of obvious typographical errors) in Annex [2]. It includes a variety of demersal species such as snappers (Lutjanidae), emperors (Lethrinidae), breams (Nempiteridae) and sweetlips (Haemulidae). The comparatively large size of the fish suggests a relatively unexploited ecosystem, at least at the time of IPR fishing operations in 2000/2001 (IPR 2000).

Interviews held with a former adviser of the Fisheries Surveillance Center (CSP) further confirmed the diversity of the demersal fish fauna and benthos of this area. Photos taken by CSP officials of fishing catches made illegally inside the 8 mile limit (typically in the zone from 5 to 8 miles at depths of 20-30 meters) reveal an abundant fish fauna, dominated by snappers and emperors. The sea bed appeared richly covered in sea fans, sponges and corals.

One (bottom) trawl at around 355m was undertaken by the ACEP project vessel, Algoa, offshore of Cap Tanjona in 2003 (15.18ºS 46.52666ºE), with 480 specimens representing 27 species of fish caught, comprising species which live either in deep mid-water (such as myctophiformes) or bottom dwelling species, often found on soft sediments (greeneyes, coffinfishes, gurnards). Such fishes are likely to inhabit the shallower areas of the Ampasindava Block and may range into the deeper areas of the Sifaka project area.

5.5.3.2 Shallow water marine and coastal ecosystems: 0 – 30 m

The nearshore / coastal component adjacent to the study area is characterised by a gently sloping seabed subject to important tidal range. Towards the continental shelf edge there are significant coral banks while inside this limit the sea bed is primarily sandy or muddy. The dominant shallow water (< 30 m) marine and coastal ecosystems located landward of the study area are coral reefs, sea-grass meadows and mangroves, interspersed with large, relatively featureless, sandy-muddy areas. Along the coast, in between mangroves, are rocky shores and beaches. The shallow marine and coastal ecosystms, including the mangroves, seagrass beds and coral reefs, will not be impacted by the proposed seismic or side scan sonar programs.

Mangroves:

Madagascar has one of the largest mangrove areas in Africa totalling approx. 3,270 km^2. (of which 3,220 km^2. is on the West Coast) spread along about 2,000 km of Madagascar's coastline. Mangrove ecosystems support a number of activities, including wood harvesting, fishing (especially prawns), salt extraction and rice culture. The largest mangrove site near, but outside of the study area is Riviere Loza ou Antambo.

Seagrass Beds

Seagrass beds are usually found below the low tide level in shallow, gently sloping coastal waters where their sunlight requirements are most easily satisfied. Like mangroves, seagrass beds may function as nursery areas for certain types of fish and invertebrates, and thus play a role in maintaining local ecosystems and commercial fish stocks. Sea grasses are also the feeding grounds for turtles, dolphins and porpoises

Coral Reefs

Coral reefs in Madagascar extend to a linear distance of over 1,000 km, primarily along the Northwest Coast. They have an important role to play as habitats and feeding grounds for reef fish and crustaceans, and numerous other species. Reefs can be found along the coast adjacent to the seismic study area and approximately 30 km to the north in the Sahamalaza Marine Protected Area

5.5.4 Benthic Fauna

Benthic macrofauna were collected during the Majunga Offshore Profond Environmental Baseline Study (Maxon, 2006). Analysis of macrofauna was carried out on the 12 sediment samples obtained at depths ranging from 1940m to 2889m. The benthic infauna data was collated and analyzed by Maxon and compiled into the Majunga Offshore Profond Environmental Baseline Study.

Benthic infaunal organisms are described as those residing on and in sediment and are designated as macrofauna at sizes larger than 0.3 to 0.5 mm. Most macrofauna live within the upper 10 cm of sediment and are small and usually number from several hundred to several thousand per square meter. The most common invertebrate macrofaunal groups found in marine continental sediments are crustaceans, annelids worms, molluscs and echinoderms.

The composition and type of benthic communities in sea sediments can provide useful information relating to quality and environmental conditions. For example, the existence of certain species indicates excess of organic inputs, hypersedimentation processes, sediment stability and the presence of pollutants. Additionally most benthic species have limited mobility allowing change in species composition and density to be easily identified. Distribution of benthic fauna may be related to factors such as sediment type, nutrients and pollutant concentrations.

Macrofauna can be described in terms of abundance (numbers or individuals) and diversity (numbers of different groups). Summary statistics for total abundance by group and species diversity are provided in Table [5.3]

Table [5.3] - Summary statistics for total abundance (animals / m²) and species density

Taxonomic parameter	Mean	Standard deviation	Minimum	Maximum	Station with maximum	Station with minimum
Abundance						
All organisms	500.8	279.2	140	1230	M09	M07
Arthropoda	205.0	98.2	40	360	M09	M12
Annelida	201.7	181.8	30	710	M09	M07
Mollusca	70	27.3	30	130	M04	M05
Echinodermata	5.83	11.6	0	40	M09	M01
Others	18.3	21.2	0	70	M11	M04
Species density*	28.9	10.9	12	51	M09	M07

** number of species per 0.1m² grab sample*

5.5.4.1 Abundance

Total abundance averaged 501 organisms per m^2 with a variation factor of 9 across the 12 stations. Total abundance was weakly correlated with depth, percentage fines and TOC. Abundance of Arthropoda and Annelida collectively comprised 81% of total abundance. Arthropoda are the most abundant group (41% of total abundance) followed by annelid worms (40%) and molluscs (14%). Six other phyla (Echinodermata, Sipuncula, Porifera, Rhynchocoela, Platyhelminthes, Brachiopoda) were collected which together comprise 5% of the total abundance.

The observed abundance is similar to that observed for lower continental slope depths off North America (Sanders and Hessler, 1969). The limited observed abundance is substantiated by general evidence that there is a reduction in abundance with increase in water depth and distance from shore. The total abundance observed from the 12 samples is approximately one order of magnitude lower than abundances reported for the Arabian Sea at similar depths (Levin et al. 2002) where sediments appeared to be organically enriched.

The Arthropod fauna was dominated by Crustaceans (97%) which are common in offshore sediments. The crustaceans were dominated by peracarids. The Annelid abundance was dominated by the polychaetes with representatives from the families Spionidae, Orbiniidae, Cirratulidae, Syllidae and Paraonidae. These families are predominantly deposit feeders and are also observed in sediments at between 1250 and 3400 m deep in the Arabian Sea (Levin et al. 2002).

The Mollusc phylum was dominated by bivalves and gastropods. Bivalves are typically dominant in the molluscan component from ocean sediments at these depths.

Beyond the benthic macrofauna identified, larger sized megafaunal species such as sea stars, urchins and sponges, are much less abundant. They are not picked up by the sampling method used for the Majunga sediments but are frequently collected in bottom trawls that sample large areas of the seafloor.

5.5.4.2 Diversity

The Maxon Report notes that 501 organisms belonging to 138 taxa were identified during the analysis of the Majunga sediments. Crustaceans, annelid worms and molluscs accounted for 91% of the organisms (126 taxa).

Taxa can be identified according to the different levels of nomenclature. Four taxa were identified at the Phylum level, eight at the class level, six at the order level, 51 at the family level, 58 at the generic level and 11 at the species level. Generally for the purpose of organism identification for deepwater faunas, only the higher levels of nomenclature are identified.

Crustaceans were the most diverse group with 62 species identified. Annelid worms were the second most diverse group with an assemblage including 41 polychaete and two oligochaete taxa, represented by 20 families. As is typical for deepwater sediments, most of the polychaete species were deposit feeders. A small complement of sedentary forms such as calcareous tube-building serpulids and sabellids suggests the moderate availability of suspended particulate matter. The cosmopolitan patterns of polychaete diversity identified in the sediments, including composition at the family level, showed an expected number of species relative to area sampled. Molluscs were represented by 23 species being dominated by bivalves. The bivalve fauna was diverse represented by 11 families which are well documented from deep sea sediments worldwide. Maxon states:

> Most of the recognized families and genera identified in the Majunga sediments are well known from other descriptions of deepwater fauna in other world wide locations. Thus the major group elements of the Majunga fauna can be described as cosmopolitan in their distribution. Speciation is likely to have occurred within these groups in the Indian Ocean, with the majority of endemic species lacking formal description. The majority of species (72) were represented by either one or two individuals present from the 12 grab samples, indicating that most species are uncommon on the spatial scale of 1 m^2. This high proportion of uncommon species (52%) indicates that increased sampling density would be required to adequately assess species richness on a local or regional scale (Maxon, 2006).

5.5.5 Marine Fauna:

The subject of marine fauna and biodiversity in the study area is very broad. Therefore it is believed best to provide an in-depth description of the most pertinent species existing in the region. These species can be recognized as those of global conservation concern and include: cetaceans, dugong, sea turtles, sharks, sawfish, rays and chimeras, whale sharks, the Coelacanth, threatened fish species and sea birds.

5.5.5.1 Cetaceans

Cetaceans comprise the baleen whales and the toothed whales (which include the dolphins). About 30 species of cetaceans are known from waters around Madagascar, including nine baleen whales and 21 toothed whales.

Cetaceans occurring in the study area

At least one species of baleen whale (the humpback whale *Megaptera novaeanglia*), two toothed whales (melon-headed whale *Peponocephala electra* & killer whale *Orcinus orca*) and six dolphin species are known to be in or near the study area (Razafindrakoto & Rosenbaum 1997). Expert opinion consulted for the purposes of the present study indicates that the Ampasindava Block and the Sifika seismic project may be important areas for the species of whales indicated in Table [5.4](H. Rosenbaum, pers. comm.)

Table [5.4]- Cetaceans of potential importance in the AMPASINDAVA Block

Common name	Scientific name	Mid-channel	Offshore	Coastal	Remarks
Blue whale	Balaenoptera musculus		X		Rare, highly endangered
Pygmy blue whale	Balaenoptera musculus	X	X		Known from Mayotte
Fin whale	Balaenoptera physalus	X			Occasional wanderers
Humpback whale	Megaptera novaeangliae			X	Migration, May-October
Bryde's whale	Balaenoptera brydei	X			Rare in West Mada.
Southern Wright whale	Eubalaena australis			X	Rare in Madagascar waters
Sperm whale	Physeter macrocephalus		X		Feed shallow & deep
Killer whale	Orcinus orca	X	X	X	Observed regularly
Melon-headed whale	Peponocephala electra	X	X	X	Substantial numbers
Risso's dolphin	Grampus griseus	X	X	X	Probably common
Spinner dolphin	Stenella longirsotris	X	X	X	Associated with tuna
Spotted dolphin	Stenella attenuata	X	X	X	Hunted locally
Striped dolphin	Stenella coeruleoalba	X	X	X	Hunted locally
Humpback dolphin	Sousa chinensis	X	X	X	Important populations
Common bottlenose	Tursiops truncates	X	X	X	Important populations

Migration & seasonality:

The best known seasonal pattern is the annual migration of humpback whales to breeding grounds in northern Madagascar and the Comoros Islands. Whales begin to pass northwards through the study zone in May and the last to return pass southwards in October, remaining close to the coast. There are no reports of humpback whales calving or residing for extended periods in the study area. Historically, sperm whales were caught in the July-November period all around Madagascar, including offshore Mahajanga. In October 2000, a 14 m sperm whale was found dead at Maintirano, confirming the likely presence of the species in the study area, which is consistent with the known seasonal pattern (Rosenbaum, H, in Goodman & Bensted 2003).

Critical cetacean habitat:

While cetaceans occur throughout the zone, there is no evidence of areas of habitat in the study zone that are critical to any particular species, such as breeding grounds.

Existing human pressures:

Direct human pressure on the larger baleen whales has been substantially reduced as a result of the global moratorium. Humpback whales in the region are recovering well, whereas other species, such as the blue whale, remain very rare.

Toothed whales (including the dolphins) are affected by industrial fishing which reduces their food source. In the study region, tuna-associated dolphins such as the spinner dolphin are likely to be affected by industrial fishing. Closer to shore, several villages on the coast near to Mahajanga are engaged in illegal hunting of dolphins, including Madirokely, Namakia, Berafia, Aranta and Amborovy. Reports also exist of hunting further north at Ampasimariny, Vilamajaha, Amboanarabe and Ambanja. The numbers of dolphins killed in this way is unknown, but likely to amount to several hundred animals per year.

5.5.5 .2 Dugong

Dugong is one of three representatives of the Sirenia order of mammals, also including the African and Caribbean manatee. In contrast to the manatees, the dugong is exclusively marine and occurs throughout the Indian Ocean. The dugong is rare throughout its range except in Western Australia, where it is effectively protected. Dugong have been legally protected in Madagascar since 1961 and are listed in Appendix 1 of the CITES convention (Convention on the International Trade in Endangered Species). However this has not prevented continued artisanal hunting which became rampant during the 1980s. Classed as Vulnerable by the IUCN, the dugong is likely the most endangered marine mammal in Madagascar, and has virtually disappeared from many parts of its former range.

Presence in study area

The zone between Cap St. André and Nosy Be appears to be one of the most important areas for dugong in Madagascar. The most recent national survey (Rafomanana and Rasolonjatovo 2004) reports persisting populations of dugong associated with Bombetoka & Sokoany bays and around Katsepy and Antrema, near Mahajanga (part of the Mahavavy-Kinkony coastal wetlands complex). An earlier report also laid claim to the year-round occurrence of dugong in low numbers around Mahajanga. (Razafindrakoto & Rosenbaum, 1997). Anecdotal reports also exist of the continuing presence of dugong around the Baie de Baly area.

Table 5.5 below summarizes the sightings of Dugong along the northwest coast of Madagascar over the past several years.

Table [5.5] - Recent Dugong occurrences in the north and northwest of Madagascar

Region	Location	Date	Nb	Event	Source
North	Nosy Hara	August 2003	1	Captured	L. Robinson, WWF
	Diego Bay	February 2003	2	Observed by fishers	Rafomanana & Rasolonjatovo 2004
	Ramena, Diego Bay	April 2003	1	Captured	Rafomanana & Rasolonjatovo 2004
	Ampasindava	2000	1	Captured (skull retained)	B. Rakotonirina / R. Ratsimbazafy (pers. comm.)
	Ampasindava	2000	3	Seen by fishermen	Metcalf et al, 2001
	Nosy Be	1990s	-	Unreported in area	Maharavo & Labouthe 1999
Northwest	**Analalava**	**1993**	**1**	**Captured**	**G. Gaultier (pers.comm.)**
	Soalala	1994	1	Captured	Durbin 1994
	Bombetoka & Sakoany Bays	2003	-	Several reports from these two nearby sites	Rafomanana & Rasolonjatovo 2004
	Mahajanga, Amborovy	1997	-	"1 animal every 2-3 months"	Razafindrakoto & Rosenbaum 1997
	Cap St. André / Ampasimariny	1997	-	Hunting	Razafindrakoto & Rosenbaum 1997

Migration & seasonality:

Little is known about the migration or seasonal behaviours of dugong in Madagascar. Dugongs generally remain in their coastal home range but are also known to undertake long sea journeys. Fishers frequently report that dugong tend to stay a little offshore (outside the reef barrier when there is one) during the day and come into shallower water to feed on sea grass beds at night. Most encounters with dugong are in the summer months (October to March) suggesting they are more active during this period.

Critical habitat:

Dugongs are strongly dependent on sea grass beds, known in the vernacular as dugong grass. While international websites indicate concentrations of sea grass along the coast adjacent to the study zone, the sea grass beds of the area have never been studied or mapped. It is likely, however, that intense nearshore

shrimp trawling since the late 1960s and intense sedimentation, particularly since the 1980s, has degraded much of the dugong's suitable feeding habitat.

Existing human pressures

Despite legal protection, dugongs have consistently been hunted by coastal peoples in Madagascar, with an apparent upsurge in hunting in the 1980s during a period of rapid population growth. Recent reports confirm that dugongs are still targeted directly in the Cap St. Andre area and at Ampasimariny (located at 15.30.940"S and 46.29.958"E). The catch numbers are unknown but one fisher in Amborovy (Mahajanga) claimed to catch one animal every 2 or 3 months (Y. Razafindrakoto, pers. comm.).

Industrial shrimp trawling in the area since the early 1970s is likely to have been a major cause of destruction to dugong habitat and also to be a severe disturbance to remaining animals due to noise, turbidity and occasional direct physical impact. Sedimentation due to upland erosion may also have led to loss of suitable feeding habitat.

5.5.5 .3 Sea turtles

Sea turtles are migratory marine reptiles that travel large distances between feeding, breeding and nesting grounds. All species are classified as critically endangered and are listed in Appendix 1 of CITES and are fully protected under Decree 2006-400 of 13 June 2006. Turtles are subject to numerous threats, including offshore fishing, industrial trawling, artisan hunting, nest raiding, the killing of nesting females and loss of suitable nesting and feeding habitats.

Presence in study area

Five species of sea turtles are known from Madagascar: green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*). All, with the exception of the leatherback, are known to nest, or have nested, in or near the study region Table 5.6.

Table 5.6 - Sea turtle nesting sites in study region

Species	Green	Hawksbill	Loggerhead	Olive ridley
North	Nosy Be (various) Nosy Sakatia Nosy Iranja	Nosy Be (various) Nosy Sakatia Nosy Iranja		Nosy Be (various) Nosy Sakatia Nosy Iranja
Mahajanga area	Andampy Marosakoa Ampasinariny Boeny	Soalala	Soalala Ankimony	Soalala Bosy Maromoka

from Rakotonirina & Cooke 1994

While nesting populations on the Madagascar mainland have massively declined due to systematic egg collection, the taking of females while nesting and hunting, certain oceanic islands in the region remain important for turtle nesting (Europa, Bassas de India, Ile Juan da Nova, Iles Glorieuses, Aldabra, Ile de

Tromelin). These islands continue to supply a source of turtles to the extensive feeding grounds around Madagascar, particularly of green turtles. Nesting also still occurs on some of Madagascar's continental islands in the study region (e.g. Nosy Chesterfield, Radama Islands and islets near Nosy Be (Nosy Iranja, Nosy Sakatia).

Green turtle *Chelonia mydas* is the dominant species in the Mozambique Channel and is by far the most frequently encountered species in the study area. Recent genetic studies of the green turtle identify four separate nesting populations in the Mozambique Channel, with one centered on the Comoros and NW Madagascar (Bourjea et al, 2007).

Migration and seasonal variation:

The study area is reported as a migratory corridor for green turtles (IOSEA sea turtle website), although the scale of migration across the zone by green turtles and other species is unknown. Available information indicates that migration in and near the study area is primarily along the coast, rather than in deeper water, and it has been observed that adult green turtles from Europa forage freely up and down the West Madagascar coast (Bourjea, pers. comm.).

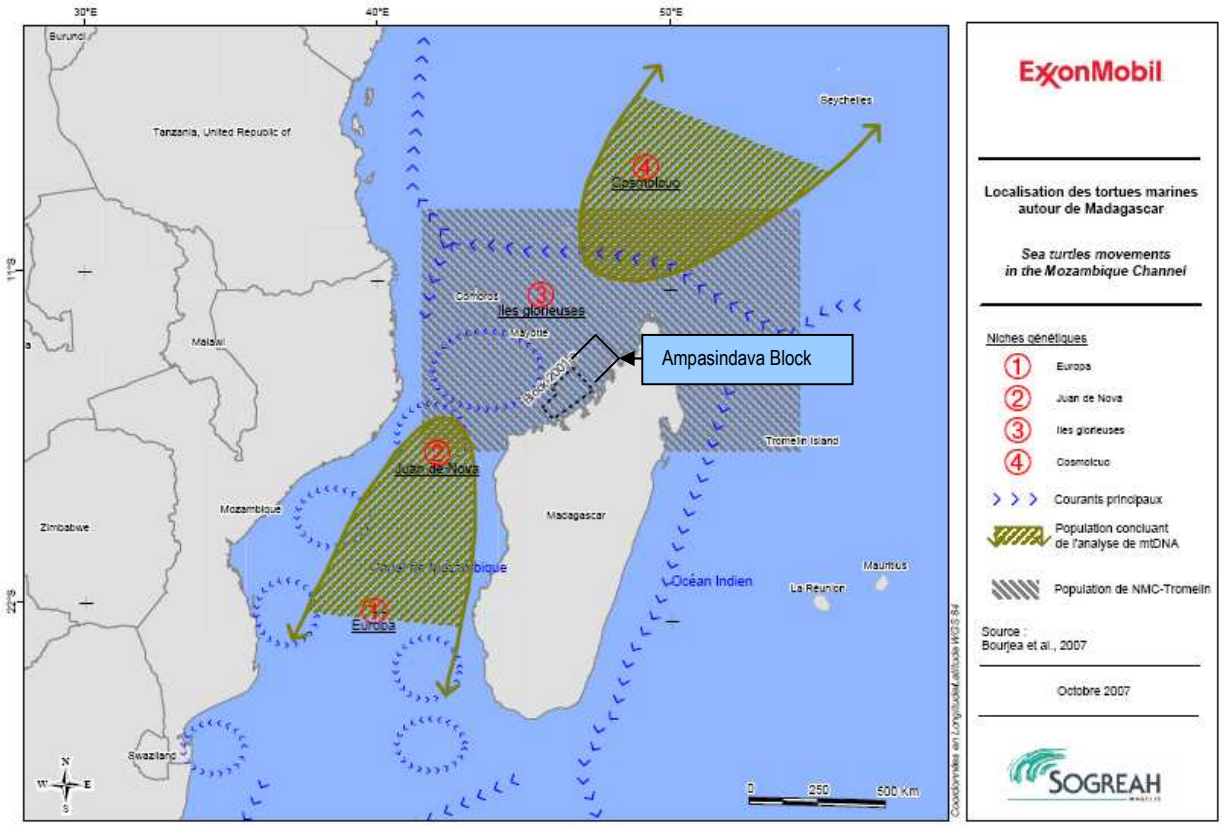


Figure [5.7]: Four separate Green Turtle nesting populations identified in the Mozambique Channel Based on genetic studies, with one centered on the Comoros and NW Madagascar (Bourjea et al, 2007).

Sea turtles in the northern part of the Mozambique Channel tend to nest during austral winter, whereas those in the southern half nest during austral summer. The population on Ile Juan de Nova, a little south of

Cap St. André and roughly mid-channel, nests all year round, suggesting that the nesting season is determined at least in part by water temperature (Bourjea, pers. comm.).

Critical sea turtle habitat

Available information indicates that all of Western Madagascar is important as foraging habitat for green turtles, without any particular area standing out. Nesting sites, however, are much more limited and are now essentially confined to the oceanic islands and a few, less accessible continental islands and remote mainland sites. The marked predominance of green turtles in the zone suggests a relative lack of suitable foraging habitat for the other species. Both hawksbill and olive ridley, for example, are known to be more common to the north and south of the study zone, where coral reefs are better developed.

Existing human pressures:

Sea turtles have traditionally been hunted in Madagascar for centuries and despite legal protection (recently updated and no longer ambiguous as it had been), this exploitation continues all around Madagascar including the study area. Sea turtles are also affected by industrial trawling but this threat has now been largely eliminated by the universal introduction of Turtle Excluder Devices (TEDs) by the industrial shrimp fleet.

The mortality due to 'traditional' fisheries is high. A rough estimate based on data collected in 1988 and 1992 indicated an annual national catch of at least an estimated 12,000 turtles. Close to Mahajanga, the annual catch of a single village (Aranta) has been reported at 300 individuals (mostly green turtles).

5.5.5.4 Sharks Sawfish, rays and chimeras

The chondrichthyan fauna (sharks, rays, skates and chimaeras) from Madagascar consists of 123 species that have been recorded or are believed likely to occur. These species are made up of 81 sharks, 40 rays and 2 chimaeras. This relatively low diversity is most probably due to the lack of knowledge as few studies have been devoted to this fauna.

The rate of species endemism is rather low, only four species are known to be unique to Madagascar: *Chiloscyllium caerulopunctatum* (Pellegrin, 1914), *Bythalaelurus clevai* (Séret, 1987), *Dipturus crosnieri* (Séret, 1989), and *Fenestraja maceachrani* (Séret, 1989). More endemic species are most probably still to be discovered, however the rate should remain relatively low because the Mozambique Channel is a biogeographic crossroads on the migration routes of marine fishes between the Indo-Pacific and the Atlantic (B. Séret, pers. comm.).

Sharks, sawfish, rays and chimeras are generally recognized as species vulnerable to fishing because of their longevity, low fecundity and slow growth rates (often referred to as 'K-selected species'). In recent years the IUCN Shark Specialists Group has made major efforts to assess the status of chondrichthyan species and many have now been listed as vulnerable or endangered. The sawfish have all been listed as critically endangered.

Presence in study area:

Deep water sharks, rays & chimeras

There is a general lack of data on fishery landings of deep water (> 500 m) chondrichthyans since they are mostly taken as by-catch, and their diversity and biology are very poorly known. New species are frequently identified. They exhibit among the slowest growth and reproductive rates of the chondrichthyans.

Very little is known about deep water sharks and rays around Madagascar. According to Kyne & Simpfendorfer (2007) about 72 deep sea sharks, 28 rays and 5 chimeras are reported occur in FAO Fishing Area No. 51, which is near the study area. Most of these, and potentially many other species, are likely to occur in the continental slope and sea bed of the study area.

The Madagascar Skate (*Dipterus crosnieri*) is a relatively small and rare deepwater skate with a limited distribution in the Western Indian Ocean off the west coast of Madagascar. It is a benthic species found on the continental slope at depths of 300–850 m. Virtually nothing is known of the biology of the species, although allied species have been noted for their longevity of as much as 50 years (Kyne & Simpfendorfer 2007). Because of its restricted range of depth and habitat on the continental slope the Madagascar skate has been listed as Vulnerable by the IUCN. The species may be found in the study area.

Pelagic and shallow water sharks & rays

A rich coastal shark and ray fauna exists off NW Madagascar, with about 25 species recorded in fisheries of various types (industrial, artisan). Around 10 or so pelagic shark species are closely associated with tuna fisheries off Madagascar and are regularly taken as by-catch in tuna purse seine and long line fisheries operating in the area.

Sawfish

Sawfish are cartilaginous fishes of the family Pristidae found in tropical coastal seas and estuaries. Five to seven species are recognized worldwide of which three may occur in the study area (*Pristis microdon*, P. *zijsron* and, based on the presence of extensive suitable habitat, *Anoxypristis cuspidata*.) (Petit, 1930; Kiener, 1963 & 1964).

Sawfish share with other elasmobranchs the characteristics of longevity, low fecundity and slow growth that make them highly vulnerable to fishing, exacerbated by the ease with which the rostrum becomes entangled in fishing nets. Sawfish have suffered dramatic declines or extirpations throughout their respective distributional ranges and are classified as Critically Endangered in the IUCN Red List and as Appendix I species under CITES.

Field surveys in the last decade (e.g. Cooke, 1997) and more recent anecdotal reports suggest that sawfish still exist in reduced numbers, particularly in the West and northwest around Nosy Be, Mahavavy, Tsiribihina and Mangoky deltas.

Existing human threats:

Deep water sharks & rays – In the early 1990s a fishing company operated a deep water fishery for 'brown shark' and exported for several years. However, the fishery was later abandoned and today there are no known commercial deep water shark or ray fisheries off NW Madagascar. Along with evidence that the deep water environment is in pristine state (Maxon, 2006). This would suggest an absence of direct threats to deep water sharks, rays and chimeras at present.

Pelagic & shallow water sharks & rays – shallow water sharks are subject to intense artisan fishing and are reported to be in sharp decline in all of the major fishing areas. During the period 2002-2004, sharks were targeted by a small-scale industrial fishery and for a time they were catching and exporting entire sharks. The fishery ran into difficulties, however, and the vessels, which were based in Mahajanga, have since left Madagascar.

Sawfish - are threatened primarily by gill nets but may also be caught by harpoon, long-lines and even shrimp trawls. They are also threatened by loss of habitat due to sedimentation from erosion of the upland watershed. As a shallow water and estuarine species, they are unlikely to be much affected by the offshore activities of the present project.

5.5.5.5 Whale sharks

Whale sharks (*Rhincodon typus*) are pantropical migratory plankton feeders which tend to feed near the surface but which can dive to more than 1000 m. These sharks can tolerate temperature ranges of over 25º C to feed on plankton in response to predictable food pulses such as the mass spawning of reef fish (Graham et al., 2006). Whale sharks are listed as Vulnerable by IUCN and are on Appendix II of CITES because of an increasing trade in their fins. Whale sharks are important as flagship species, for tourism and as indicators of oceanic productivity.

Occurrence in study area:

Whale sharks occur along all the coasts of Madagascar but are most common in NW Madagascar. Whale sharks have been reported from the Majunga area (Razafindrakoto & Rosenbaum 1997) and from several locations to the north (Sahamalaza, Iranja, Nosy Be). In Nosy Be, whale sharks are present all year round, although most abundant in the wet season during November-December.

Migration and seasonal behaviour:

Whale sharks are a migratory species capable of transoceanic movements. The migratory routes and site fidelity of whale sharks in the Western Indian Ocean are not well known, but it is clear that they migrate vast distances. Three whale sharks tagged in Nosy Be were tracked to the Comoros Islands, the east coast of Madagascar and to Seychelles and the Maldives respectively, suggesting the whale shark do not reside permanently in Nosy Be. Three of five whales tagged in the Seychelles in 2001 were tracked to the Somali coast, Tanzania and the Andaman Islands while two remained in Seychelles. Evidence exists for some site

fidelity of whale sharks around Nosy Be (R Graham, pers. comm.). The highly migratory nature of whale sharks makes it difficult to assess population size, which remains essentially unknown for the Western Indian Ocean.

Whale sharks are known to migrate in response to predictable seasonal pulses such as fish spawning occurring at particular lunar phases. In Nosy Be, the maximum presence of whale sharks coincides with peaks in the productivity of zooplankton in November and December. This correlates well with Randrianasolonjanahary (1986) who reported the highest levels of primary production in the Nosy Be area during November and December, following rains (Graham 2005).

Whale sharks also migrate vertically, following the daytime vertical migration of zooplankton which descends to deeper water during the middle of the day, as illustrated in diagram 5.8 below. They undertake deep dives to as much as 1000 m, presumably searching for concentrations of plankton at these depths.

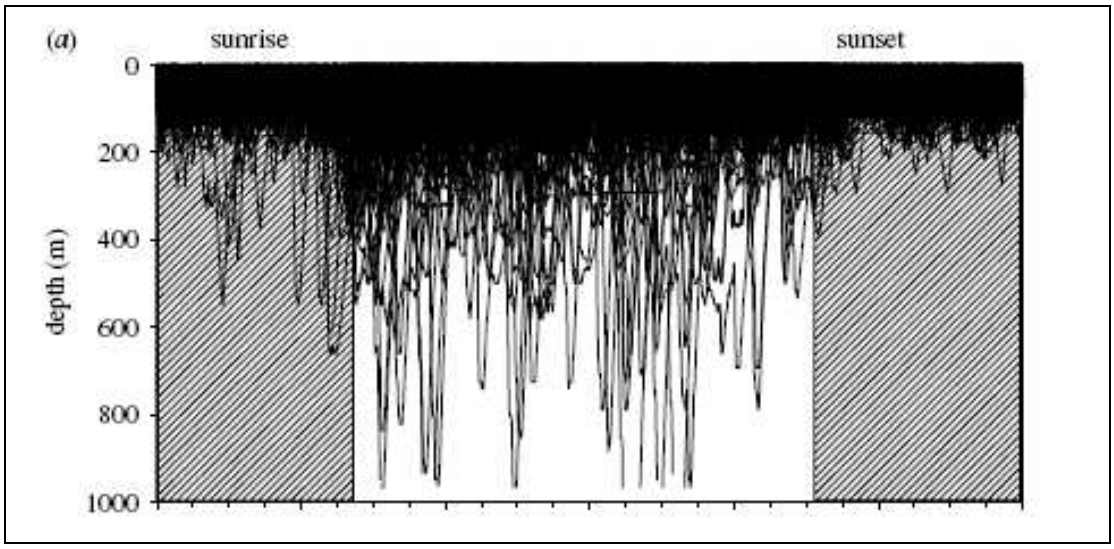


Fig [5.8] Daytime vertical migration of whale sharks

Existing human threats:

Whale sharks are not currently hunted by coastal fishers in Madagascar and, since they are plankton feeders, they generally escape incidental capture in offshore tuna fisheries. The growing international trade in whale shark fin is a potential threat, and while whale shark is listed on Appendix II of CITES (in response to a submission from Madagascar), it is not protected under domestic legislation.

5.5.5.6 Coelacanth

For many years after its first capture off East London in 1938, the coelacanth (*Latimeria chalumnae*) was unknown except from regular captures in the Comoros islands. Recent interest in the species has led to an explosion of capture records in the Western Indian Ocean, with four captures in Madagascar (one of which is scientifically confirmed – Heemstra et al, 1996), several in Mozambique, more than 30 in Tanzania and several in South Africa. These new records have much improved understanding of the coelacanth's habitat

preference, which is for caves and hollows at depths of 200-300 m (Fricke & Hissman, 1990). Subsequent studies using a submersible submarine found coelacanths to depths as great as 700m (Coelacanth fact file, SAIAB).

Coelacanths are listed in Appendix 1 of CITES which prohibits international trade in specimens. In Madagascar there is no specific additional legal protection.

Occurrence in the study area:

The majority of coelacanths have historically been caught in the Comoros Islands, where the traditional Mazé fishing technique (deep hand lining at night) has caught coelacanths for many years. Coelacanths are known from SW Madagascar, primarily in the Toliara region (Anakao, Tsiandamba, Fierenamasay), where several have been caught since 1995 (where the fish is known as fiandolo or 'ghostfish'). In 2006, a further coelacanth was caught in the Maintirano area, the closest known catch to the Ampasindava Block. It is presently unknown if coelacanths are present in the study area.

Factors which are considered to predict coelacanth habitat include temperature and bottom structure. Coelacanths are believed to inhabit water of between 16-22°C, sometimes venturing into warmer or cooler water (Hissmann et al. 2006). Coelacanths also typically take shelter in underwater caves and overhangs during the day, coming out at night to feed. They appear to keep to relatively rocky areas, rarely travelling across open sediments (probably explaining the low incidence of coelacanth catches in trawls).

In order to adequately predict coelacanth occurrence in an area, a detailed understanding of the water temperature profile through the water column and the bottom topography and structure is important. The coelacanths of Sodwana Bay in South Africa appear to inhabit caves at 96-140m, corresponding to sea level lowstands during the last glaciation (Green & Uken, 2005). It is possible that similar structures exist along the coastline of Madagascar. These caves are associated with submarine canyons. Some work suggests that oceanographic conditions of the western coast of Madagascar may be suitable (Burchell et. al., 2007).

Existing chart data from the study area cannot completely assess the likelihood of coelacanth habitat in the study area. Potential areas were found north of Morondava and around Toliara (Green et. al., 2007), where there are clear indications of sub-marine canyon environments. It is very difficult to accurately predict the presence or absence of coelacanths in the study area although, to date, none have been found in the study area.

Additional factors contributing to the knowledge of coelacanths in an area are education and communications. If fishermen know that coelacanths are particularly noteworthy, they are more likely to bring catches to attention, otherwise catches may go unnoticed; good communications make contacting authorities easier when a catch is made.

Changes in fishing methods may bring additional coelacanth populations to light; the increasing use of deep sea gillnets, together with education, seems to be responsible for the sudden discovery and continued high catch and reporting rate of this species in Tanzania.

In summary, it is not possible to predict the presence of coelacanths in the study area. They are unlikely to be in the very deep areas (>1000m), and if present, would likely be somewhere along the continental slope drop-off area, possibly somewhere between 100 and 350 m. Current bathymetric data has been unable to identify their habitat of sub-marine caves or overhangs in the study area.

Critical coelacanth habitat:

As noted previously, coelacanths appear to prefer steeply shelving areas with caves and hollows, a habitat which is not prevalent in the Ampasindava Block. However, the occurrence of coelacanths in nearby Maintirano means the presence of suitable habitat in the study area cannot be excluded.

Existing human threats:

Fishing with gill nets appears to be the main threat to the coelacanth, a threat which is likely to increase as surface water fisheries become increasingly depleted.

5.5.5.7 Threatened fish species

According to IUCN, 52 fish species are reported to be threatened in the seas around Madagascar. While the status assessments are not questioned, several of the species listed are unknown to occur in Madagascar.

The IUCN notes only one critical (CR) species for Madagascar, *Thunnus macoyi* or Red southern tuna. Although it is found to the south of Madagascar, it is likely absent from Madagascar waters. The three species of sawfish occurring in Madagasar, all critically endangered, are not mentioned in the published list for Madagascar (*Pristis microdon*, *P. zijsron* and *Anoxypristis cuspidata)*. *P. microdon* at least may occur in the study area.

Three species are listed as Endangered (EN) (Napoleon wrasse *Cheilinus undulatus*, Black Grouper *Epinephelus marginatus* and the sawfish *Pristis pectinata*. While globally threatened by the fish trade, the Napoleon wrasse is still common in Madagascar (including the study area) where it is relatively less threatened. The Black Grouper *Epinephelus marginatus* has not been reported to occur in Madagascar. The third, *Pristis pectinata*, as a southern African or Atlantic species of sawfish, and is probably a misidentification for *Pristis zijsron* (see above).

Ten species are listed as vulnerable (VU). *Carcharias taurus* has not been scientifically reported from Madagascar. *Thunnus obesus* (dogtooth tuna) is still relatively common in Madagascar, including in the study area.

Of the data deficient (DD) species, *Eurypegasus draconis, Hippocampus borboinensis and H. fuscus* have not been reported to occur in Madagascar. The remaining assessed species all occur in Madagascar.

To conclude, for the purposes of the present study, the fish species of particular concern are the sawfish (notably *Pristis microdon*), which are separately considered in the section on sharks and rays (see above).

5.5.5.8 Sea birds

The term 'sea bird' refers to purely marine birds. Other birds are treated within the coverage of the ecosystems with which they are associated.

Tropical sea birds feed off surface feeding shoaling fish species, including tunas and the smaller pelagic species associated with tunas. The generally low productivity of the Western Indian Ocean favours species able to forage over large areas with low energy costs, such as the terns and frigate birds. Heavier sea birds that feed from a fixed location, such as boobies and tropic birds, are less abundant.

Approximately three million seabirds nest on the islands of the Mozambique Channel, of which over 99% are sooty turns (*Sterna fuscus)*, which breed on three remote locations – Europa 25%, Juan de Nova 66% and Iles Glorieuses 19%. Remaining species in the Mozambique Channel are greater and lesser frigate birds, red tailed tropic birds and red-footed boobies (*Sula sula)* (Lecorre & Taquemet 2005). Figure [5.9] shows breeding concentrations of seabirds in the Mozambique Channel.

Occurrence in the study area:

About 15 species of seabirds occur off the coasts of NW Madagascar, of which by far the most abundant species is the sooty tern (*Sterna fuscus*). Two million pairs nest on the nearby Ile Juan de Nova (south of the study area) and 270,000 pairs on Iles Glorieuses (to the north of the study area).

Other species occurring include several other species of terns (Lesser Crested Tern, *Sterna bengalensis* (including 8000 pairs on Nosy Chesterfield), Common Tern *Sterna hirundo* and smaller numbers of Greater Crested Tern *Sterna bergii* and Blacknaped tern *Sterna sumatrana*. Apart from the terns, there are the highly migratory Great Frigatebird *Fregata minor* and the non-migratory boobies (red-footed boobie *Sula sula*, brown boobie *Sula leucogaster*, brown noddie and the white tailed tropic bird *Phaeton lepturus*.

Thirteen species of sea birds are known to breed off the northwest coast of Madagascar, but population sizes are low and most are threatened by poaching, particularly from egg collection (ZICOMA 1999). Breeding sea birds in Madagascar are limited to steep sea stacks or offshore islands protected by strong winds in the breeding season (July-August).

The greatest number of suitable sites occurs between Nosy Mitsio and Cap d'Ambre, where there are globally important populations of Crested Tern *Sterna bergii* and Roseate Tern *Sterna dougallii* on offshore islets, as well as smaller populations of brown booby *Sula leucogaster*, white tailed tropic bird and frigate birds (*Fregata minor* and *F. aeriel*).

In the study area, offshore winds are less strong and there are no islets, with the result that there are no important breeding populations of sea birds in the region. The area is, however, important as a foraging ground for sea birds which track the movements of skipjack and yellowfin tuna.

Migration and seasonal variation:

Many sea birds migrate large distances between breeding and foraging areas. The terns and frigate birds, in particular, are highly migratory. Frigate birds tracked around NW Madagascar may migrate between sites as far apart as Europa and the Maldives (Weimerskirch et al., 2006). Foraging seabirds track areas of increased primary productivity in ocean waters, such as those associated with eddies (Weimerskirch et al., 2004). The abundance of sea birds in the study area, in particular of sooty terns and frigate birds, is determined primarily by the seasonal presence of skipjak and yellowfin tuna.

Seabirds in the Mozambique Channel breed at different times according to location. Sooty terns, the most abundant seabird of the region, breed mainly in June and July in Europa, December in Juan de Nova and March-April in the Iles Glorieuses (Lecorre & Jaquemet 2005).

Existing human threats:

As reported in ZICOMA (1999), seabirds in NW Madagascar are threatened primarily by nest raiding, which has significantly reduced the number of breeding colonies along the Madagascar coast. Fishing may also act as an indirect threat by reducing the availability of prey species.

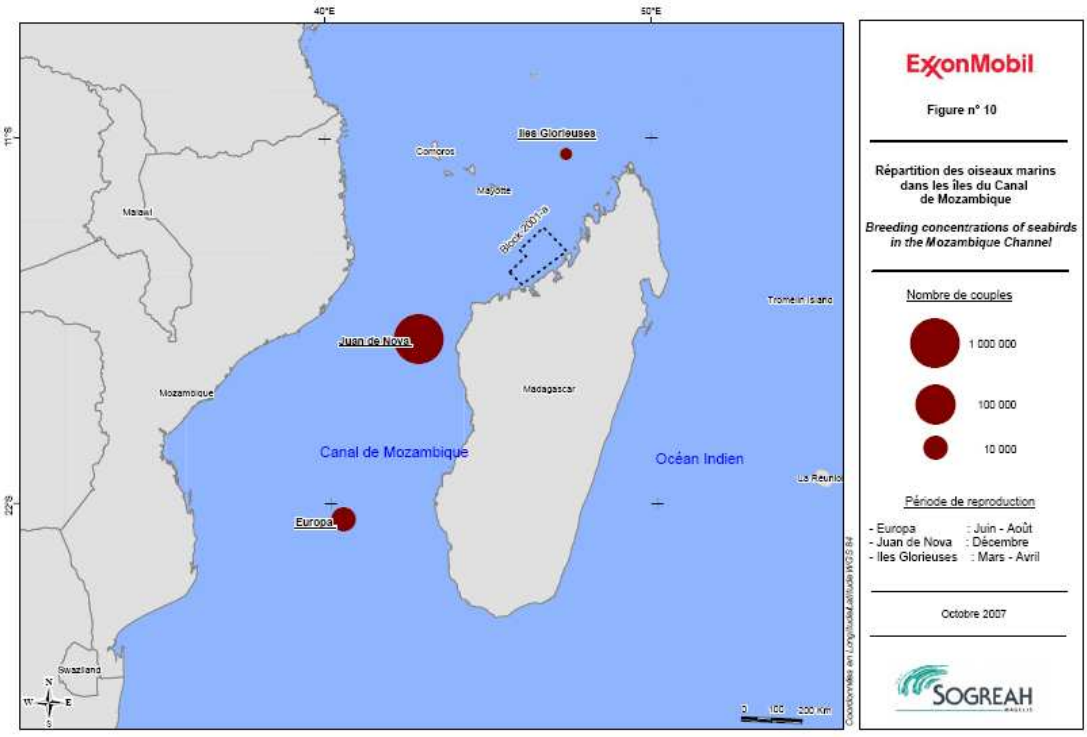


Figure [5.9] shows breeding concentrations of seabirds in the Mozambique Channel.

5.5.6 Species important for fisheries and aquaculture

5.5.6.1 Tuna

Tuna are highly migratory carnivorous fish with behavioral and physiological adaptations enabling them to exploit ocean areas of low productivity. Tuna are highly versatile feeders, hunting not only on the surface for small pelagic fish and crustaceans, but also at greater depths (100 m or more), mainly for small fish and squid (Poitier 2004 ; Poitier et al 2007).

Associated with the tuna, is a whole array of large predator species feeding off the tuna including sailfish (*Istiophorus platypterus*), black marlin (*Makaria indica*), blue marlin (*Makaria mazara*), spearfish (*Tetrapterus angulirostris*), swordfish (*Xiphias gladius*) and a variety of sharks (silky shark, white-tipped oceanic shark (*Carcharhinus longimanu*s), tiger shark, blue shark (*Prionace glauca*), mako (*Isurus oxyrinchus*) and thresher sharks (family Alopiidae) (which feed in deeper water).

Occurrence in study area

The waters off NW Madagascar are highly important for tuna, particularly stocks of skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) which migrate into the study area during the austral summer from feeding grounds around the Seychelles.

Industrial fisheries have operated in the zone since the 1960s. Five tuna fishing areas are recognized in this region, with the waters of NW Madagascar (Zone 5) being the second most important in the Western Indian Ocean for catches of skipjack and yellowfin Figure 5.10. In the region around the study area tuna are primarily daytime feeders (Roger 1994).

Numerous studies and surveys have been conducted in the area of the present study in relation to tuna. Madagascar conducted its initial surveys with Russian assistance in 1987 with the highest capture rates being obtained offshore from the Baie de Mahavavy, slightly to the south of Mahajanga (Randriambololona et al, 1987).

Migration and seasonal variation:

Feeding tuna in the Western Indian Ocean migrate between seasonal areas of high primary productivity in an area of upwelling across the Seychelles ridge, opposite the Somali coast and nutrient rich areas in the Mozambique Channel, such as near Ile Juan de Nova.

Critical tuna habitat:

As a result of favorable oceanic conditions (semi-closed circulation, warm water, low energy environment), the study area is of critical importance as a breeding ground for skipjack and yellowfin tuna. Skipjack larvae are widespread between the Seychelles and East African coast, but the waters of NW Madagascar are one of the main concentrations. While the abundance of yellowfin is lower than for skipjack, the waters off Majunga are one of two important spawning areas around Madagascar (Conand & Richards, 1982) Figure [5.11]

Evidence indicates that the skipjack larvae (listao in French) tend to be distributed towards the NW Madagascar coast, whereas the larvae of yellowfin (albacore in French) are distributed more towards the East African Coast. Nevertheless, larvae of both species occur in substantial numbers in the study area (Stequert & Marsac, 1986).

Tuna larvae are concentrated in the mixed water layer above the thermocline (30-40 m in winter and 40-100 m in summer) (Conand & Chapman, 1982). The average depth of the larvae varies by species, with skipjack larvae being concentrated at about 25 m and yellowfin larvae at about 15 m (Bohiert & Mundy 1994). Skipkack larvae tend to be distributed further offshore than yellowfin. Larvae are present throughout the year but are much less abundant in the winter months (June-September) (Conand & Chapman 1982).

Existing human pressures:

A fleet of about 80 mainly European purse seine vessels operate in the northern part of Madagascar's EEZ during January – June with peak season in Madagascar's waters being March – May. This fishery targets mainly skipjack (70%) and yellowfin tuna (25%), with smaller amounts of bigeye and albacore. The vessels are 80 m, 2000 tons, up to 5000 hp, using 1500 m nets. Vessels work an average 45-50 days in the Malagasy EEZ each year before going elsewhere. The annual capture by the region's purse seine vessels is about 400,000 tonnes, of which perhaps 10% are caught in the waters off NW Madagascar.

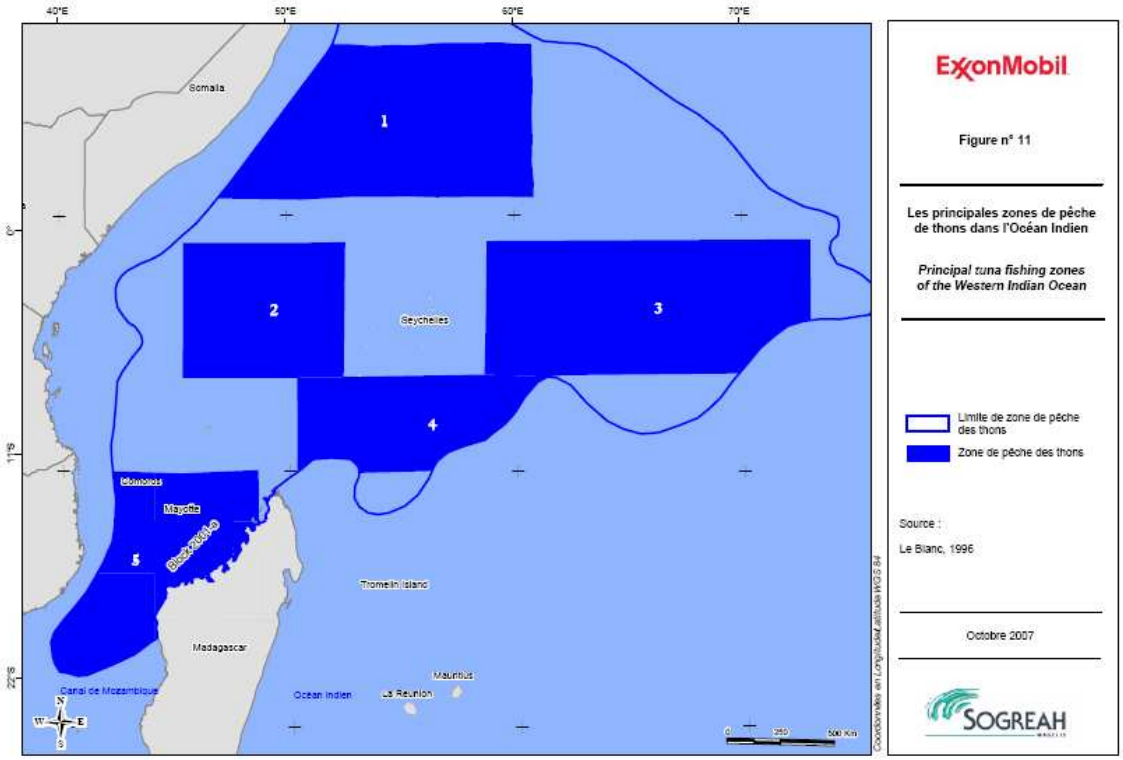


Figure [5.10]: Five tuna fishing areas are recognized in this region, with the waters of NW Madagascar (Zone 5) being the second most important in the Western Ocean Indian for catches of skipjack and yellowfin.

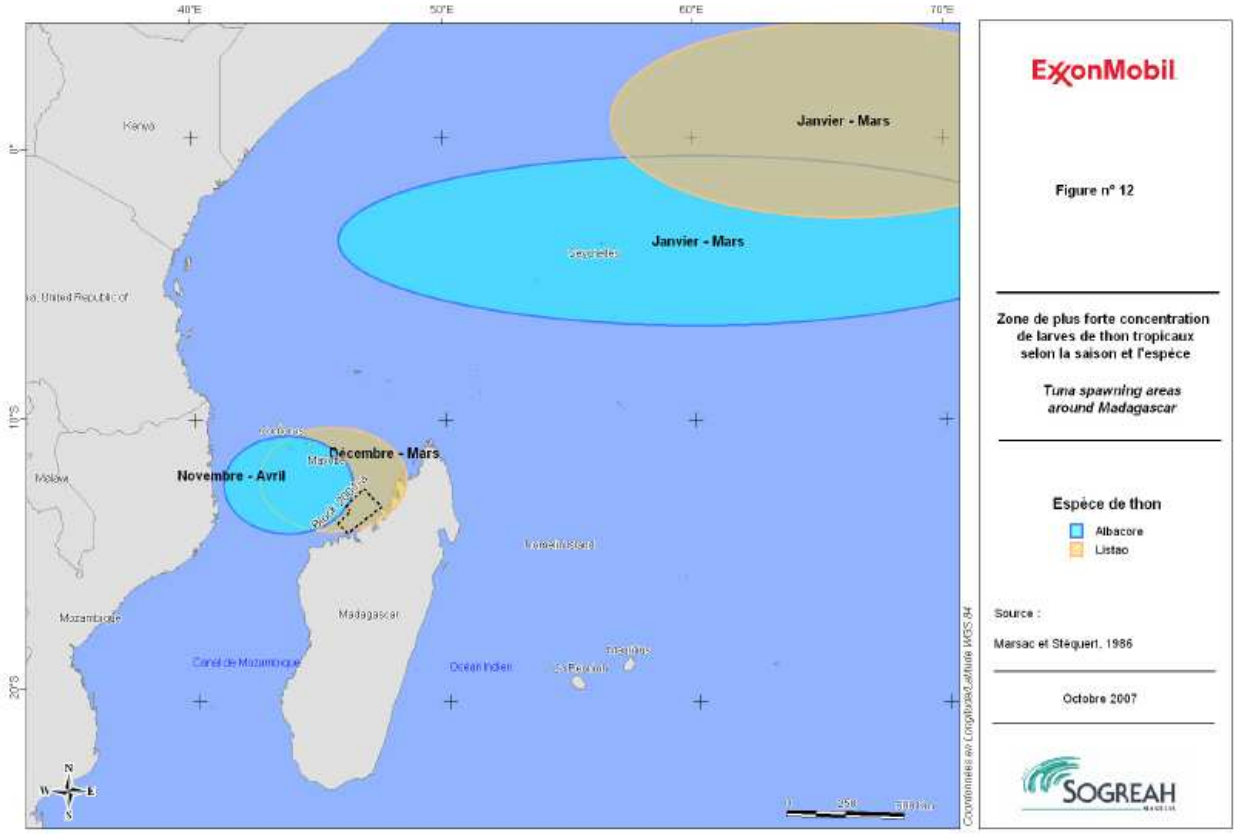


Figure 5.11: Two important tuna spawning areas around Madagascar (Conand & Richards, 1982)

5.5.6.2 Shrimp

Wild caught penaeid shrimps constitute Madagascar's single most important fisheries export, with an annual catch ranging between 7,000 and 12,000 tons. The major species are *Penaeus indicus* (white prawn) (which makes up about 70% of the catch in most years), *Metapenaeus monoceros* (pink prawn) (about 20%), *P. semisulcatus* (brown prawn) (about 10%), and *P. monodon* (tiger prawn) (< 5%). *P. indicus* is a daytime species, while the others are more abundant in night-time hauls. Also important is the scarlet deep water shrimp, found further offshore.

Occurrence in study area:

NW Madagascar, with its extensive mangroves, estuaries and intertidal areas, is the most important area in Madagascar for both shallow water and deep water shrimp. The shallow water shrimp species are seasonally abundant along the entire length of coast, with greatest abundance associated with mangroves and confined to depths up to 20 meters. Deep water shrimp occurs further offshore along the edge of the continental shelf in waters of 100-200 m, where it is fished by a few specialized trawlers of the Somapeche Company.

Migratory and seasonal behaviour:

Penaeid shrimps share a common life cycle in which juveniles enter mangroves to support the fastest growth phase before returning to deeper water to breed as adults (Le Reste, 1978). Captures are generally higher opposite mangrove areas, and at periods of peak river flow, when the stocks are swept seawards (Lhomme, 2000). Recent mark-recapture experiments on *P. indicus* and *M.monoceros* show that shrimps have an average foraging range of about 10 km off the west coast (maximum of 100 km).

Reproduction and recruitment appears to occur year-round for at least some of the species, with reproductive peaks at the beginning and especially at the end of the dry season. Larval growth and settlement proceeds in October and November and is essentially completed by the beginning of December. The closed season for the prawn fisheries is in December-March, which corresponds with the rapid growth period of newly-settled juvenile shrimps.

Critical habitats:

The cyclical presence of freshwater in mangroves is vital to the breeding cycle of several species of shrimp, notably *Paenaus indicus* and *P. monodon*. High catches by the industrial shrimp fishery are associated with years of high rainfall (Lhomme, 2000). Large stands of mangrove are associated with a high proportion of organic material in bottom sediments and high productivity of the shrimp *Penaeus indicus* (Razafindrainibe et al. 1996).

The most critical breeding zones in the study for *Paenaus indicus* and *P. monodon* are the southern end of the bay of Narinda, in the bay of Mahajamba and the bays of Baly and Soalala on the west side of Mahajanga towards Cap St André (Le Reste, undated). There is no literature on the other main species (*Metapenaeus monoceros* and *P. semisulcatus*) but experts expect them to breed in the same areas (L. Boswell, pers. comm.). Table 5.7 below summarizes the most critical areas for shrimp reproduction along the northwest coast.

Table 5.7 -Identified critical areas for shrimp reproduction

Fishing Zone	Coordinates
A	
Ambavanankarana	East of Long. 48°52E between Lat. 12°54S & Lat. 13°00S
Amkazomborona	East of Long. 48°45E between Lat. 13°15S & Lat. 13°23S
Ampasindava	South of Lat. 13°47,5S between Long. 48°13E & Long. 48°15E
B	
Narindra	South of line joining Lat. 15°00S Long. 47°29E to Lat. 15°05S Long. 47°27E
Mahajamba	South of line joining Lat. 15°21,5S Long. 47°06E to Lat. 15°28S Long. 46°30E
Marosakoa	South of line joining Lat. 15°23,5S Long. 46°35E to Lat. 15°28S Long. 46°30E
Ampanjony	South of line joining Lat. 15°33S Long. 46°24E to Lat. 15°40S Long. 46°19E
C	
Boina	South of Lat. 15°40S between Long. 46°00E & Long. 46°06E
Baly	South of Lat. 16°00S between Long. 45°17E & Long. 45°21E
Behara (Antaly)	South of Lat. 16°07S between Long. 44°50E & Long. 45°00E
Nosy Voalavo	East of Long. 44°20E between Lat. 16°30S & Lat. 16°40S
Beravina	East of Long. 44°05E between Lat. 17°05S & Lat. 17°15S
Koraraika	East of Long. 43°58E between Lat. 17°40S & Lat. 17°50S
Cap Kimby	Not defined
Tsiribihina delta	East of Long. 44°25E between Lat. 19°52S & Lat. 19°58S
Ampasilava	Between Lat.21°05S & Lat. 21°15S and to the East of the line joining Lat. 21°05S Long. 43°48E to Lat. 21°15S Long. 43°35E
Mangoky delta	East of Long. 43°22E between Lat. 21°30S & Lat. 21°40S

Existing human impacts:

As a result of declining yields and operator profitability, in 1999, shrimp fishing effort was frozen at 69 trawlers for the West Coast. After trial of a complex zoning scheme, the zoning scheme was simplified to four zones (A, B, C & D). Part of zones A and B are in the area of the present study. In recent years, yields of the industrial operators have declined severely, which in part is claimed to be due to the massive growth in small scale fishing using fine mesh nets in the estuaries and shallower areas, capturing mainly juveniles and sub-adults, which may reduce productivity of the fishery.

Most trawling is close to the shore in depths of up to 10 m over soft-bottoms, where shrimp are abundant at the start of the season. Trawls are set according to bottom characteristics and species, some species burying into the sediment more deeply than others. The ecological effects of this type of trawling have not been studied.

5.5.6.3 Demersal fisheries

Demersal species (those associated with the seabed) include a range of finfish, various sharks and rays, shallow and deep-water shrimps and lobsters (usually found in the sea at depths of a few hundred meters).

Demersal fisheries in the study area:

Studies of the demersal fishery characteristics and potential of the study area have focused mainly on tuna, tuna associated species and on the shrimp fishery. Much of this information is held by private sector interests and has not been published. However, there are extensive areas of shallow, partly coralline seas behind the reef ridge, on the ride itself and on the continental slope. The study region supports a high diversity of demersal habitats and species. Most important are the shrimp fisheries, followed by pelagic and reef-based fisheries.

Seasonality & migration of demersal fishery species:

Most of the target species of fisheries off NW Madagascar show a peak in abundance in the warm rainy season between November and March. This appears to be true for virtually all species and has been specifically confirmed for sharks and large pelagic species targeted by the large gill net fishery (Du Feu, 1998).

Critical demersal habitats:

As noted above, the general habitat for the known demersal fisheries is a complex benthic habitat structured around a mix of sea fans and sponges. However, no data are available to permit the identification of critical areas within this zone. It can be noted, however, that several of the exploited species represented in the fishery (notably the snappers (Lutjanidae) and emperors (Lethrinidae) are dependent on mangroves as nursery and reproduction areas.

Existing human pressures:

The principal human pressures on demersal fisheries are fishing itself, and degradation of critical habitat, notably mangroves and estuaries, by wood cutting, sedimentation and coastal development.

5.5.7 Special interest zones

5.5.7.1 Important bird areas - ZICOs

Important bird conservation areas (IBCA) or 'Zones d'Importance pour la Conservation des Oiseaux' (ZICO) are areas designated according to a scheme developed by BirdLife International and used globally in order to highlight zones of particular importance the conservation of wild birds and their associated habitats. The designation is purely technical, and carries no legal status, either internationally or nationally.

Important bird areas in Madagascar were identified by a project under the name ZICOMA (Zones d'Importance pour la Conservation des Oiseaux à Madagascar) which undertook surveys nationally and resulted in the publication of a book containing maps and information on all the key zones. ZICOMA subsequently merged into the BirdLife International program for Madagascar.

According to the ZICOMA project, the northwest of Madagascar is particularly important for coastal wetlands Figure 5.12. On the West coast of Madagascar, between the headlands of Cap Sainte Marie and Cap d'Ambre, BirdLife has listed 18 areas which are important for birds. These include various types of habitat, including islands some distance away from the coast, coral reefs and mangrove swamps.

5.5.7.2 Wetlands of International Importance

The International Convention on Wetlands (signed in Ramsar, Iran, in 1971) came into effect in Madagascar on 25 January 1999. Currently, six locations are classified as Ramsar sites in Madagascar, including Manombolomaty on the West Coast south of Maintirano. Although new designations are possible and some areas near the study area meet Ramsar criteria, as of September 2007 there was no Ramsar designated site in the study area, from Cap St-André to the Ampasindava peninsula.

5.5.7.3 Existing and proposed marine and coastal protected areas

Madagascar currently has three marine parks all of which are on the East Coast. However, on the West Coast there are 3 national parks which include some of the coast line, namely from South to north : the national park of Baly Bay, the Mahavavy Kinkony wetlands, and the national park of Sahamalaza peninsula and Radama Islands, Figure 5.13. Only the latter, the national part of Sahamalaza, is in the study area.

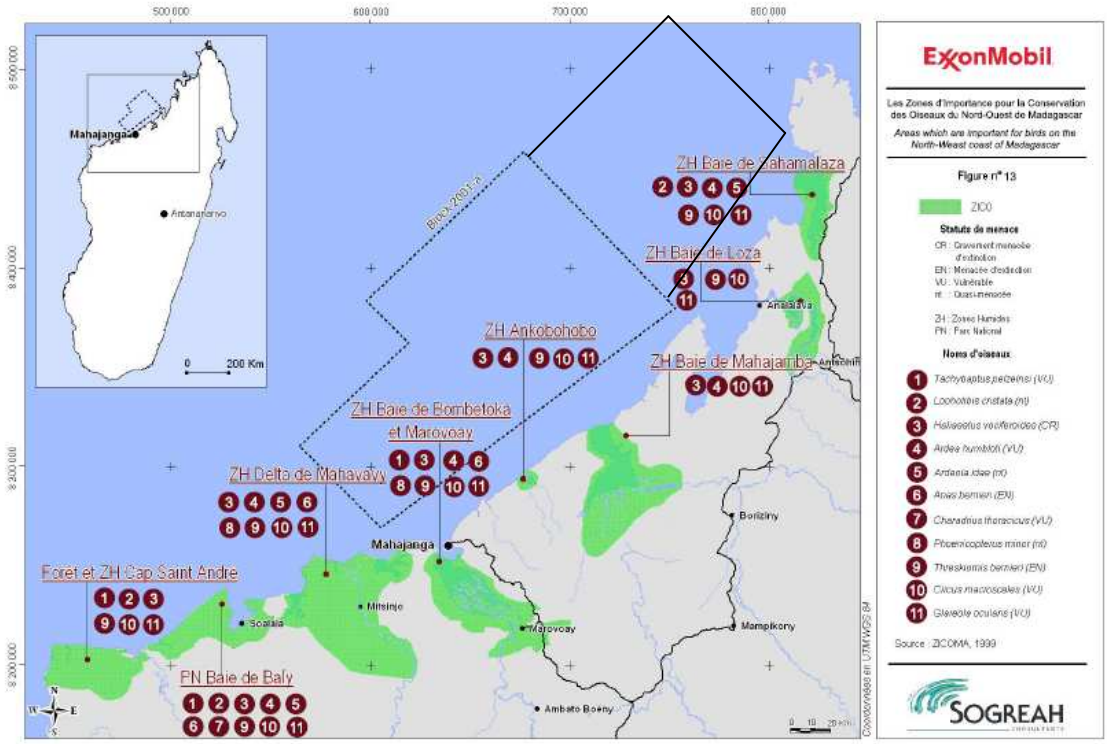


Figure 5.12: Areas listed as important for birds by BirdLife along the west coast of Madagascar.

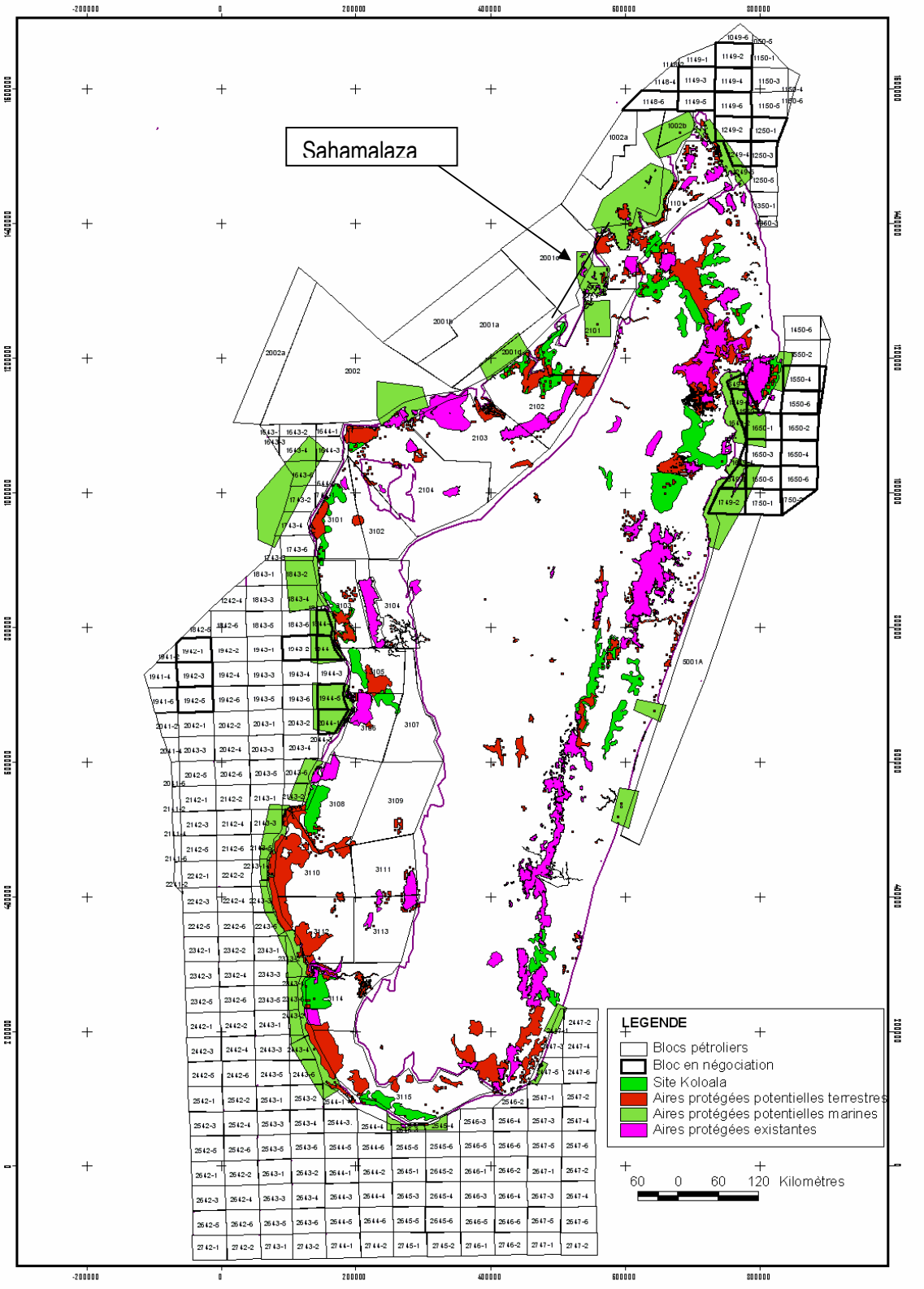


Figure 5.13 Designated and Proposed National Parks and Marine Protected Areas in Madagascar

5.5.7.4 Sahamalaza National Park

Sahamalaza-Radama was designated as a Marine Biosphere Reserve in 2001 and was recently established as a national park after a period of temporary protection and officially inaugurated in 2007. It corresponds to IUCN Category V, a protected area of sustainable managed natural resources.

The Sahamalaza / Radama Islands are located between the bays of Narindra and the Peninsula of Ampasindava and 50 km north of Analalava. The park has a surface area of 153,200 ha. Figure 5.14 overleaf illustrates the MCPA layout.

The site Sahamalaza–Radama Islands comprises the region of Sahamalaza and the Radama islands archipelago. The region of Sahamalaza (56,100 ha) is made up of the Bay of Sahamalaza (30 km long), the Mangroves around the bay (84,000 ha), the Peninsular of Sahamalaza and the coral reefs of Ramanetaka Bay to the west (> 10,000 ha). The Radama islands archipelago, which covers 3,500ha, is composed of 4 islands: Kalakajoro, Berafia, Faly and Valiha. Studies in the area have identified the possibility of possible extension to include 2 additional zones: the forest of Ankarafa in the SW and the Bay of Rafaralahy in the NE.

The **Sahamalaza-Radama Islands** site comprises three major landscape types:

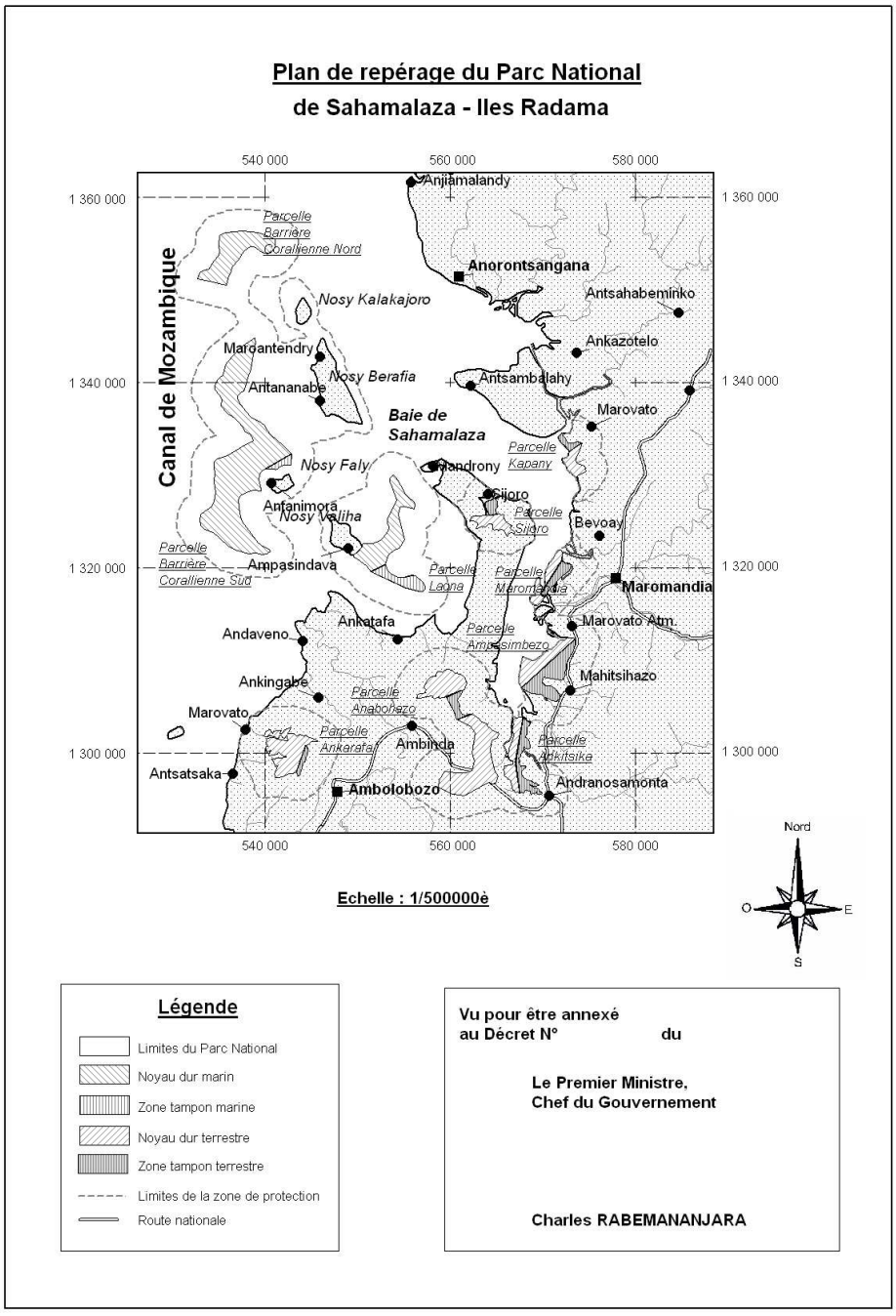
1) Marine zone which covers over 90% of the site and is made up of three distinct components:

- The bay of Ramanetaka characterised by coral reefs to an average depth of 15 to 25 m but which can reach 40 m, including many shallow coral areas used for fishing on foot.

- The bay of Sahamalaza characterised by marked turbidity, receiving waters from the three main rivers which carry large quantities of sediment into the bay: Andranomalaza in the centre, Berondra to the north and Manambaro to the south. The bay separates the Sahamalaza Peninsular and the littoral zone of Maromandia. The central channel of the bay reaches 20 m in depth.

- The outer coral reef and relict coral barrier situated 5 - 10 km west of the Radama Islands, and which on its western side forms the continental drop-off of Madagascar. The reef here rises to 5-15 meters and is made up of coral plateaux and sub-vertical drop-offs. One objective of the side scan sonar survey is to measure the water depth along this rise to ensure safe operations in future exploration activites.

Figure 5.14: *Sahamalaza Marine Protected Area.*



2) Littoral zone which makes up about 9% of the total surface area of the site. It is characterised by the presence of two main sub-components: The peninsular of Sahamalaza which is characterised by the presence of a crest line orientated north-south. The crest divides the peninsular into two contrasting parts: a degraded western slope and an eastern slope covered in dense forest. The relief is gently undulating hills rising to 100 to 170 m. The peninsular is delimited by a narrow band of mangroves.

3) The assemblage of coastal zones made up of the following natural units: i) mangroves which are best developed along the coast of Maromandia; ii) sirasira or salt pans; iii) the coastal sand dunes; and iv) the highland zone which is characterized by predominance of hills with steep slopes rising to 355 m in the southern part (Anambohazo hill) and 405 m in the northern part (Ankitsiky hill). The lowland areas are very limited in extent. By contrast, the area of mangroves and mudflats is substantial. The tops and high slopes of the hills are mainly covered in grassland, while the valleys and basins are covered in forest or bush, if not already used for slash and burn cultivation.

The Radama Islands group located in the bay of Ramanetaka, is made up of 4 islands: Kalakakoro, Berafia, Faly (or Antanimora) and Valiha. All the islands are characterized by relief with hills rising to 140 to 170 m. The vegetation is dominated by savannah, especially on the hills. The forest is almost disappeared except in a few places, notably in the south western part of Berafia and a small part of the west of Faly.

5.5.7.4.1 Biodiversity & ecosystems

The site is characterized by the presence of numerous threatened or endangered species such as marine turtles, marine mammals (dugong) and small numbers of the extremely rare blue eyed Sclater's Black Lemur (Eulemur macaco flavifrons). Three types of ecosystem are identified: i) terrestrial ecosystems composed of dense dry deciduous forest, ii) mangroves and littoral forests; and iii) coral reefs. Also found are lagoons, islets and small islands.

1. The dry deciduous littoral forest (11,100 ha) is of priority ecological interest, harbouring around 42% of endemic species of which certain are classified as endangered such as *Eulemur macaco flavifrons* (Akomba) and *Daubentonia madagascariensis*, and many other lemur species, mammals, birds and reptiles.

2. The mangrove on the Maromandia coast covers about 10,000 ha, of which 3,000 ha are in the delta of the river Andranomalaza. The mangrove is particularly intact and makes a band of variable width around the entire peninsular of Sahamalaza. It includes 8 species of mangrove trees in varying proportions according to location (*Avicennia marina* and *Sonneratia alba* on the seaward edge, *Rhizophora mucronata, Bruguiera gymnorhiza* and *Xylocarpus granatum* in the interior of the mangrove and *Ceriops tagal, Lumnitzera racemosa, Heritiera littoralis* and *again Avicennia marina* at the interface with dry land). – It also harbours species of crabs, shrimp and at least one rare and endangered bird species the Madagascar fish eagle (*Haliaetus vociferoides*) or « Ankoay ».

3. Coral reefs (about 10,000 ha) with many coral species are composed of fringing reef, barrier reef and coral banks. They are characterised by a high species diversity of fishes (168 species), sea cucumbers, and marine turtles (*Eretmochelys imbricata, Chelonia mydas*). Also occurring are several species of dolphins, humpback whales (*Megaptera novaeanglia*) and other threatened species including the dugong.

5.5.7.4.2 Environmental Significance

The justification and creation of the Parc National Marin et Cotier des Sahamalaza/Iles Radama is based on Scientific, Conservation and Economic (eco-tourism) criteria. The justification is summarized in Annexe 4: Resume des Etudes Prealables.

5.5.8 Marine Flora

In the marine environment, vegetation is composed principally of the benthic macrophytes, being large vegetative biomass growing underwater such as multicellular seaweed and phanerogame species. In addition, dominant quantities of phytoplankton are composed of microscopic algae. As these species require luminous radiation for photosynthesis, they are often more numerous on the continental shelf. Principal seaweed and phanerogame species found in the Block are listed below.

- Clorophyta/green seaweed - *Caulerpa racemosa*;
- Phaeophyta/brown seaweed - *Sargassum densifolium* and *Turbinaria ornata*;
- Rhodophyta/red seaweed;
- Cyanophyta/bluegreen seaweed.

5.5.9 Summary of offshore and coastal environments

The present chapter has provided detailed descriptions of the offshore physical environment and offshore and coastal biological environments. Important fisheries and aquaculture practices and special interest zones were described. The distribution and presence of many species remain relatively unstudied. This is particularly true of benthic environments and species such as dugongs, sharks, and sawfish and the coelacanth.

Given the mobility of many marine species, it is likely that the biodiversity of the target region is similar to that of the broader western Indian Ocean region. However, there is always a possibility for endemism; Conservation International's rapid assessment of NW Madagascar revealed several species new to the region or new to science (McKenna & Allen, 2005).

Assessment of biodiversity, even in fairly well studied areas, is very challenging; even in European waters, with the longest history of taxonomic description, new species are still being described (Bouchet, 2006). Tropical areas are generally considered to be more species rich than temperate areas, yet the western Indian Ocean still lags behind Europe in the number of described species across many diverse groups (Griffiths, 2005).

In summary of the present chapter, the study area surrounding the proposed project is seen to be characterized by the following aspects:

5.5.9.1 Oceanographic aspects

A slow, semi-closed anti-cyclonic current circulation (Comoros gyre) fed by warm waters of the East Madagascar Current coming from the north. Currents in the study area are weak and variable with the dominant influence coming from tidal variation.

Horizontal and vertical water mixing is limited with relatively long dispersion and residence times (an important aspect to consider for the dispersion of discharges to the sea)

5.5.9.2 Biological aspects

The Offshore pelagic surface zone is of considerable importance in the life cycle of commercial tuna (skipjack and yellowfin). The zone of NW Madagascar represents the second most important in the Western Indian Ocean in terms of commercial capture. The zone is rendered sensitive by its use by tuna for spawning (the most important spawning zone in the Western Indian Ocean).

The offshore deep waters are relatively unstudied. However, certain characteristics can be expected based on extrapolation from similar regions.

Continental shelf areas of mid-depth are an important zone for demersal fishes which are diverse and abundant in the zone. Sensitive seabed areas are present including coral reefs, sea grasses, and sponges.

The Coastal zone is notable as an area of significant development of intertidal ecosystems. The zone is the most productive coastal fishing area of Madagascar (shrimp, crabs, mangrove, sharks and fish). Several important shrimp farms are located in the area. The survey area does not include any portion of the Coastal zone.

5.5.9.3 Species of conservation importance

The presence of coelacanths cannot be reliably predicted. However, their habitat, consisting of sub-marine caves and overhangs, has not been identified with existing bathymetric data.

Regarding cetaceans, the study area is known for the presence of certain whales and dolphins, some of which are rare and all of which are fully protected under national law. The study area is on the migration route of humpback whales.

Five species of turtles are known to be present in or near the study area and all are fully protected species under national and international law. A small number of known nesting sites are near, but outside of the study area.

Certain vulnerable species of deep sea sharks & rays are known to exist in the survey area, distributed mainly on the continental slope. The Dugong, a highly endangered marine mammal, is present in the survey area and other nearby areas including Cap St. André area, Baie de Baly and around Mahajanga. They are a fully protected species under national law.

Sea birds use the area for feeding, while breeding mainly on small islands to the south or north of the survey area. Their presence in the survey area is linked to the presence of skipjack and yellowfin tuna.

5.5.8.4 Marine & coastal protected areas

The National Park of Sahamalaza peninsula and Radama Islands is just north of the sesimic survey area and adjacent to the side scan sonar survey area.

5.6 Socio-economic environment

EMEP(NM)L's seismic program will be carried out offshore from Nosy Lava, NW Madagascar, more than 25 km from the coast. The seismic vessel will be self-contained and will maintain its foreign crew. It will not have a social impact on any of the nearby communities and the economic impacts will be minimal. The economic impacts of the seismic activites may be on the local fishing activities where side scan sonar activities may temporarily exclude fishing operations while the vessel is present.

This section will give a concise description of the communities existing along the coast, adjacent to the study area, as well as of the economic activities which operate along the coastline or in the marine area assessed in this study. The administrative divisions of the coastal area are shown in figure 5.15.

The socioeconomic area which could be affected by the seismic operations is thereby defined as the area offshore of Nosy Lava, where the primary fishing activity is centered in the town of Analalava, in the Region of Sofia, in the District of Analalava.

5.6.1 Villages on the coast

The large majority of the coastal communities in this region, outside Mahajanga city, rely on traditional fishing as their principal source of income. However, field studies show that there are two other significant sources of income: direct and indirect employment created by fish farms, and the employment created by tourism.

Traditional fishing, fish farms and tourism are three sources of income which depend the marine environment. The following paragraphs describe three communities, each of which depends on one of these three economic sectors. Location and names of villages and communities mentioned are displayed on Figure 5.15.

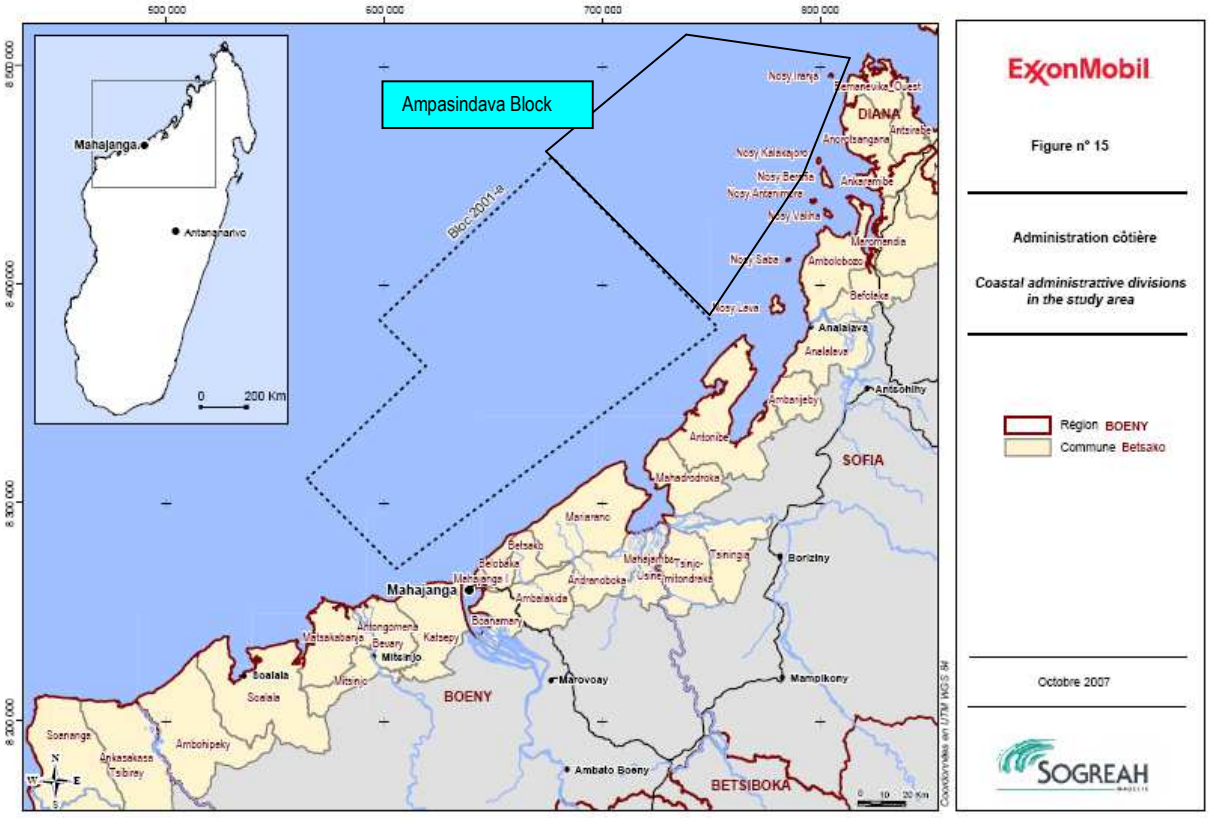


Figure 5.15: The administrative divisions of the coastal area.

5.6.1.1 Traditional fishing communities

Traditional fishing, together with agriculture, is the main source of income for the communities living in this coastal region. Fishing plays a very important part in providing the food for villagers, with the families of fishermen eating some of the fish they catch, and trading fish with other local people. The coastal zone provides an important food source with fish being the principal source of animal proteins for village people. Fish consumption is related to cultural and food traditions which are well established and would be difficult to change.

Climatic conditions play an important part in the seasonal intensity of the traditional fishing activities and in the methods used. The period from December to February (North Eastern Monsoon) is not favorable for fishing at sea, since the tides are high and the sea can be rough and subject to the occasional passage of cyclones. Fishing is carried out either along the shore, or in the small coastal rivers or backwaters, fed by rainwater. Mangrove crabs, driven out from the dense roots of the mangrove trees by strong rains, are caught with a hoop net by fishermen in canoes. This can be considered as crab fishing rather than simply collecting crabs. During this season, fishermen repair their nets and dugout canoes, without spending much time fishing.

From March to August, the sea is still warm and the winds are calmer. The climatic conditions are ideal for fishing in the open sea and in the estuaries. The frequency of fishing trips increases to as many as twenty per month. The size of catches is unpredictable but can be as much as 15 kg. At low tide fishermen can walk out across the mud flats on the shallow floors of mangrove swamps. Here, traps can be laid among the roots of the mangrove trees where crabs take shelter.

In July and August, there is little rain and the nights are cooler; this is the dry season. The rivers run dry or are at their lowest level of the year. Crabs are still collected, but fishing activities are very different in the season of December to February compared with that of July and August. In the rainy season, not much fishing is done and catches are small, whereas in the dry season, short periods of inactivity alternate with periods of intense activity.

From September to November, fishing begins again, favoured by warmer temperatures and migration of many target species into shallow coastal areas. Fishing trips at sea, both by day and by night, are frequent and the catches are large (average of 10kg per fisher/outing). In the mangrove swamps, locals continue to hunt for crabs on foot, because the water is still too shallow to use canoes.

The village of Ambenja, situated in the Mariarano district, at the outlet of the Mahajamba estuary, is an example of a fishing-dependent community adjacent to the study zone. This fishing village is isolated throughout most of the year, especially in the rainy season, because the roads are impassable, even for zebu carts. Public facilities are very limited. There is one public primary school and no basic health centre. People in need of emergency treatment are taken to Mahajanga by canoe, but the trip takes 10 to 11 hours. Fishing and farming are practised for self-sufficiency, and farming is only a supplementary activity. Fishing is practised both out at sea and in the mangroves, using traditional methods and basic fishing equipment (wooden canoes, nets, lines). During the fishing season, the fishermen do not return to the village, setting up temporary camps instead.

A socio-economic survey of traditional Malagasy fisheries conducted as part of the MAG/85/014 project in 1990 showed that traditional fishing by canoe is practised almost exclusively by men (about 94%) of an average age of 36 years. The average family unit (dependents) comprises about 8 people, 3 of them children, who are entirely dependent on the fishermen. As regards school and informal education, 88% of fishermen state that they have received school education whereas 12% say they have had only informal education. Of those fishermen, 42% finished primary school and 23% completed secondary education. Only 3% sat for their certificate of secondary education.

In most cases, fishing is done in combination with other activities such as farming and stockbreeding. However, of those surveyed, about two thirds consider themselves full-time fishermen, about one third part-time fishermen and less than 5% occasional fishermen. Most fishermen consider that fishing is a lucrative activity producing immediate cash benefits as opposed to their other secondary activities (farming and stockbreeding) which produce profits in the longer term.

5.6.1.2 Communities dependent on tourism

Communities depending on tourism are located near one or more tourist facilities. Their dependence on tourism is partly due to the direct employment provided for villagers by the tourist facilities, and also due to the infrastructure and the services available for the villagers because of tourism. Ambondro Ampasy, near the larger village of Antonibe in the district of Analalava, is typical of these communities.

Ambondro Ampasy is located less than one kilometer from the hotel "Anjajavy l'Hôtel". The Anjajavy Hotel provides work for about 100 employees including four expatriates and roughly 15 people from Antananarivo, Mahajanga and Nosy Be. There are therefore approximately 80 local people employed by the hotel. Life in the village is very much affected by tourism and the tourist season.

The local development which benefits the village is a result of the services provided for the Anjajavy hotel and the educational and development NGO 'Ecoles du Monde'. The transport infrastructure (roads, speedboats and private aircraft which can be used in emergencies), communications (single-side band telecoms, the Internet), and the social infrastructure (dispensary, primary school, street lighting, baths and showers, wells etc.) which serve the population of the village were provided and are maintained indirectly by the money brought into this region by tourism.

The Anjajavy hotel provides indirect employment for about a hundred people: i) the employees of a specialist security company, based in Antananarivo, who work as security guards for the hotel; ii) a private health centre, also based in Antananarivo, provides the hotel with a doctor for the tourists and the staff, and who also treats medical emergencies in the surrounding villages; iii) women's' associations in the villages of Anjajavy and Ambondro Ampasy supply the hotel with seafood (fish, lobsters, crabs etc.), fruit and vegetables, and local arts and crafts (embroidery); iv) nearly 80% of the food served by the hotel's restaurant to its guests is brought in from Antananarivo and supplied by a supermarket in the capital; v) the transport for tourists is provided by an airline company belonging to the Hotel Group, and this employs about ten people in Mahajanga and Antananarivo.

5.6.1.3 Communities dependent on aquaculture

Communities dependent on aquaculture are similar to those living near tourist facilities, with an important difference being the clear improvements in the way of life of the villagers being provided and maintained by the money from fish farming. This is particularly true of the shrimp farms established in this region.

The village of Besakoa-Fenoarivo in Mahajamba Bay is the site of the Aqualma company's processing factory. Besakoa is the most important *fokontany* in the commune of Mahajamba Usine, with 3,500 inhabitants. The village is Aqualma's private property. The Aqualma prawn processing factory has been in existence for 13 years and in 2007 accommodated a workforce of 590 people, about 30 of them managers. Approximately 20 people from the commune of Bekobay work there. The factory also recruits people from Ambatomanga and Mahajamba Usine. The farm and its ponds, situated further north, employ 750 people, about 100 of whom come from Besakoa (women with a family in the village) and the rest from Mahajanga (mainly single men).

The company, in cooperation with the NGO Habitats and Communities, is developing the village of Besakoa. A project for the construction of 150 houses is currently under way. Life in the *fokontany* is therefore closely linked to the activities of the fish-farming company. The heterogeneous population is made up of several of the island's different ethnic groups. Aqualma has given the village its public facilities which are managed by the company or by village committees: drinking fountains, electricity, schools and educational centers, a market, a level II basic health centre [CSB] and an outpost of the national police force. The CSB II is made up of three doctors, two of which are permanent. Various diseases are prevalent in the area, mainly acute respiratory infections such as flu, sore throat, as well as diarrhea, especially in January and February. The zone has no malaria-carrying anopheles mosquitoes and no complaints of malnutrition. Emergencies are handled by Aqualma's boats or by air. Patients can come from a radius of 10–15 km, despite the existence of the other CSB situated 12 km away. Aqualma pays the salaries of the technical staff who practise curative and preventive medicine (e.g. prenatal care, vaccinations and family planning).

Besakoa also has three private lower secondary schools [CEG]. The primary school is run in partnership with the ECM (Enseignement Catholique de Madagascar). The state schools are financed by Aqualma. Lastly, the village has a drinking-water plant which has been filtering and treating water since 1998, and has had limited access to electricity since last year, financed by the State and Aqualma. Each year, the factory opens up approximately 10 km of track to provide access to the village in the dry season.

Sea and mangrove fishing, market gardening and rice farming are the village's other, largely secondary, activities. The residents also take round timber from the mangroves for construction purposes.

5.6.1.4 Regional Centre and Political Structure, the Port of Mahajanga

Nearly 35% of the population of the Boeny region (205,000 inhabitants), are concentrated in the regional capital of Mahajanga. Population density is approximately 2,100 inhabitants/km². The urban municipality of Mahajanga, closely linked to the Sakalava kingdom, is made up of 26 *fokontanies* divided into seven districts.

The spatial distribution of the population inside the urban perimeter is uneven. The town is spread over two adjoining sites separated by the flood plains of the Metzinger valley and the Antsahambingo River. The internal site, or old town, bordered by the sea, the Betsiboka River and the small valley, is home to 55% of the urban population. The external site is home to 45% of the people and over 82% of the urban area as far as the limits of Mahajanga I.

Mahajanga's multiple functions and the recent development of the region's farming potential have led to intense and permanent migratory movements. More than 75% of the population lived outside of Mahajanga before they settled in the town.

The urban zone of Mahajanga I is relatively well-equipped, with one main hospital, two mother and child protection centers, two secondary hospitals, four medical clinics which reinforce a few private or para-public

health entities such as Antanimasaja's Lutheran medical clinic, the OSIEM and the entities attached to the town's big companies: the medical clinics of the JIRAMA, the BFV, and the CMDM. The town has 13 public EPPs, 48 CEGs and 31 grammar schools as well as 52 private primary schools and 36 secondary schools[3].

Mahajanga also has a well-developed industrial network, dominated by the fishing products processing industry, mainly prawns (destined for export). Also present in Mahajanga is the textile industry, with PGM (export), tobacco, with SOCTAM (export), fruit juice, with SVI (not exported) and fats (soap factory), with SIB (domestic market).

During the tourist season (120, 000 foreign visitors in 2000), accommodation facilities are insufficient to receive all the holiday visitors with only six main facilities situated around the port. Many trips are organized from Mahajanga to the nearby tourist sites (beaches, Ampijoroa/ Ankarafantsika National Park, Belobaka caves, etc.).

5.6.2 Economic Activities

Four main economic sectors use the sea and the shore as a principal resource in the expanded zone covered by the present study: i) sea fishing, ii) aquaculture, iii) tourism, and iv) the commercial port of Mahajanga.

5.6.2.1 Marine fishery

Essentially, two types of fishing are practised in Madagascar[4]. Industrial fishing practised by ships seeking tuna, billfish (marlin, sailfish, swordfish) and sharks (incidental catch) out at sea and, near the coast, Penaeid shrimps. Traditional fishing is practised from boats hollowed out of tree trunks and seeks practically all edible or marketable resources including marine mammals, birds' eggs, sea turtles, fish, sharks and rays, echinoderms, molluscs, crustaceans and seaweed. Non-edible resources such as aquarium fish, corals and sponges are sometimes taken. In the province of Mahajanga, an intermediary category, known as small-scale local sea fishing, should be distinguished. It is practised by small family companies or fishermen's associations using outboard motor boats.

5.6.2.1.1 Traditional fishing

Traditional fishing as the Fisheries Administration has defined it is fishing carried out by fishermen individually or in association, using different types of non-motorized boats (paddle canoe or sailing boat) or fishing on foot, with a very limited range. Catching methods are varied: fishing with various kinds of net, long lining, lobster and crab pots, collection by hand and harpooning with or without free diving.

The national data on the number of people working in traditional fishing are about twenty years old and mostly date from the master study of 1988/89. They are mentioned here only to assign an order of magnitude and help explain the relationship with marine resources of the traditional fishermen in the zone

[3] REGION BOENY, 2005, Plan régional de développement de la région Boeny – Volume 1 : Monographie analytique. 92 p.
[4] Source : RAMIARISON Cl., COOKE A., 2002, La Pêche : trouver le bon équilibre in Planete Conservation.

being studied and their vulnerability to accidental pollution. The master study conducted in 1987/88 showed the existence of 1,250 fishing villages all along the coasts of Madagascar. At that time, the trend was towards a marked rise in the number of fishermen and boats in the traditional fishing sector. It is therefore likely that there are even more fishermen and boats in 2008. The origin of the encouragement of traditional fishing is the demand for fish which has increased in recent years, and the profitability of that activity. The increase in the demand for fish is particularly linked to the growth in population in general and the urban population in particular as well as a decline in the per capita consumption of meat.

Generally speaking, fishermen are scattered and their villages comprise few families: 85% of villages are occupied by fewer than 50 fishermen. Of all the traditional fishermen counted in the country, 70% use boats and 30% work on foot. Most of those fishermen are concentrated on the West Coast because of its more favourable fishing conditions, particularly in the provinces of Toliara and Mahajanga. The boats most often used by traditional sea fishermen along the west and northwest coasts are canoes with outriggers (2/3) or simple canoes (1/3). Canoes used for fishing vary in size, their average length being between 4 and 6 m. Shrimp fishing using traps is practised in the inter-tidal zone ("Valakira" and "Poteau" fishing), in the beach zones (seine nets, "Kopikos") and in shallow water between 10 and 15 m deep ("Koakobe" encircling seine nets and "Periky" mesh nets). Traditional fishermen catch mainly immature shrimps.

The vast majority of the products caught by traditional fishermen are sold locally or eaten by the fishermen's families. About 80% of the catch is marketed. It is therefore the traditional sea fishermen who supply the population with animal protein of halieutic origin. The family of an average sea fisherman consumes about 220 kg of fish a year.

Halieutic products are sold according to the type of product and in three marketing circuits: products are sold in a structured circuit (collection and retailing companies), in a market, or directly to consumers. Bartering transactions are negligible. Half the fish and shrimps caught are sold to wholesale fishmongers and/or small local companies, 15% to markets and a third directly to consumers. Two thirds of lobsters are sold to collection companies and a quarter to wholesale fishmongers. Forty percent (40%) of crabs are sold to wholesale fishmongers, a quarter to local and industrial companies and 30% directly to consumers and/or to markets.

Most halieutic products pass through the structured circuit. However, almost 50% of fish is sold in the traditional circuit that is to say directly to consumers or markets. About 70% of products are sold fresh, while the rest is preserved, that is to say smoked/ grilled or salted / dried.

5.6.2.1.2 Local small-scale fishing industry

The local small-scale fishing industry is typified by the use of small motor boats with engines not exceeding 50 CV. The fishing methods used are trawling, long-lining and mesh nets. In most cases, boats are designed to operate in waters less than 250m along the coast and can rarely remain at sea for longer than a week. In 2004, 16 boats of this type were counted and were based in the port of Mahajanga. Of that total, 15 boats were smaller than 10 m in length and practised small-scale local fishing and one boat was longer than 10 m.

The small local fishing industry is typified by both trawling (representing ~ 40% of production) and a shrimp-collecting activity by traditional fishermen. The collectors' activity is focused essentially on prestigious products such as shrimps, lobsters and crabs and for a few sites only also includes fish. Two types of small fishing boat can be distinguished: those catching fish and those catching shrimps. The first fish with a long line or a mesh net and the second use trawls. SOGEDIPROMA (Société Générale de Distribution des Produits Marins), created in 1988 and based in Mahajanga, practises trawling for shrimps and line fishing for bottom fish and collects the shrimps and crabs caught by the traditional fishermen of Narinda Bay. Since 1996, the company PECHEXPORT has worked the areas close to the port of Mahajanga and particularly the fishing grounds of Baly Bay (Soalala).

5.6.2.1.3 Industrial fishery

Industrial fishing is defined as fishing practised by boats or trawlers equipped with a main engine greater than 50 CV. Fish production in Madagascar is the preserve of the traditional sector which supplies 95% of the country's total production: almost all the products of industrial fishing are exported. They are essentially shrimps and lobsters and tuna. Shrimps alone account for more than 50% of halieutic exports in volume and 80% of total export receipts.

5.6.2.1.3.1 Industrial shrimp fishery

Although Madagascar has 4,500 km of coastline, less than half of it offers the possibility of profitable trawling. Most of the trawling zones are along the northwest and west coasts, that is to say between Cap Saint Sébastien in the north and the Morombe region in the south. The biggest concentration of shrimps, 65% of the potential, is in the northwestern part which forms less than a quarter of the Madagascan coast. The bays and estuaries that carve into the northwest coast offer ideal conditions for shrimp development. Thanks to a two-layer circulation system, these inlets act as hatches for organic material which accumulates and becomes mineralized along the coast. This organic wealth is clearly the reason for the large quantity of Peneid shrimps found in the region.

Of a total of 89 industrial fishing vessels seeking shrimps, 83 work along the West Coast, 63 of them based in the port of Mahajanga. They vary greatly in size, generally ranging from 5m to 30m (2 vessels are longer than 40 m). Each company owns its own land equipment and installations which receive and process the trawlers' catches.

In order of importance, the three species of shrimp caught are: Penaeus indicus or "White" (about 50% to 70% of the catches); Metapenaeus monoceros or "Pink" or "Calendre"(about 30% to 45%); Penaeus japonicus or "Tiger" (<5%). The estimates of potential shrimp fishing production in the old fishing zones II, III, IV, V and VI (from Cap St-André to the Ampasindava peninsula = study area) are about 3,500 tonnes per year, or 40% of the national potential.

Figure 5.16 shows the industrial shrimp fishing zones in 2005. Fishing is done in the slimy or sandy-slimy shallows of the continental shelf at depths of between 5m and 30m, and mainly concerns adult shrimps.

Shrimp fishing stops between December and February, a biological rest period enabling the species to be preserved. This rest period is compulsory on the West Coast. During each trawling operation, shrimp fishermen catch not only shrimps but also what are known as by-catch fish. However, a large proportion of those fish of different commercial values is either thrown back into the sea (e.g. Leiognathus equulus and Secutor Insidiator) or kept on board to sell on the local market as table fish (e.g. Otolithes ruber) when shrimp yields are poor and the trawlers' storage capacities are therefore underused. The ratio between the quantities of shrimps and fish caught in the trawl varies from 1:1 to 1:5 (that is to say the fish account for 50% to 83% of the catches), depending on the zone and the season.

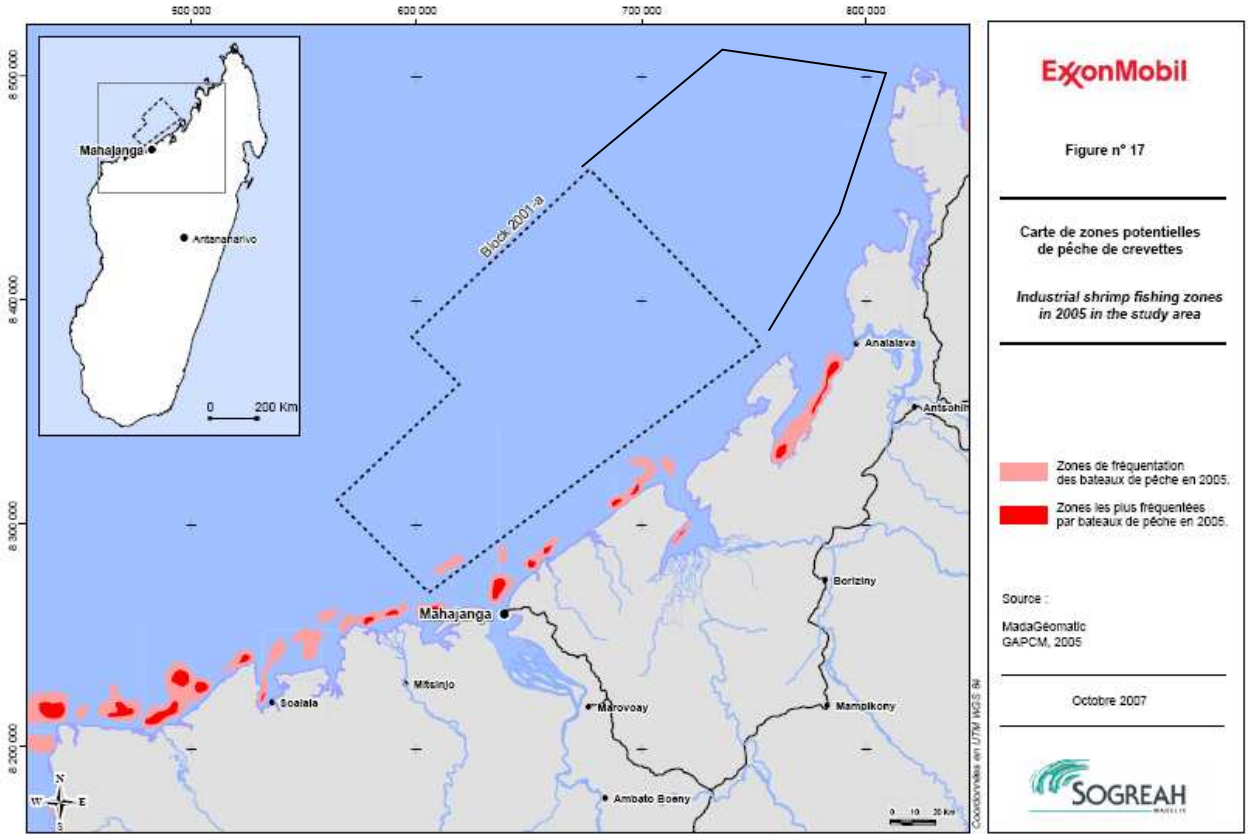


Figure 5.16 shows the industrial shrimp fishing zones in 2005.

The four larger companies operating in the industrial fishing sector in Mahajanga are SOMAPECHE, PECHE EXPORT, REFRIGERPECHE EST AND PECHERIE DU MENABE. The industrial fishing and local sea fishing industries have declined significantly over the last several years. The SOMAPECHE trawler fleet operating in Zone B has been reduced from a dozen ships in 2003 – 2004 to two trawlers in 2007. This trend is attributable to a number of reasons including the over-exploitation of shrimp larvae in the mangrove swamps by traditional fishermen. Local fishermen as well are experiencing smaller catches.

5.6.2.1.3.2 Industrial tuna fishing

Small local or traditional tuna fishing is almost non-existent. Catches of the tuna and associated species that pass into Madagascan waters during migration are estimated at 52,000 tonnes a year. Tuna is mainly fished in the waters off the island's north coast and the Mozambique Channel, outside the 12 nautical mile zone, especially between December and June. This type of fishing is done with either a seine (large net) or a long line, with a capacity of between 350 and 1,000 gross casks.

There are no Madagascan owned tuna-fishing vessels. The Madagascar government has signed specific agreements enabling foreign shipowners, mainly from Europe (Spain, France, Italy), to carry on their activity, firstly in Madagascan territorial waters and secondly in the Exclusive Economic Zone (ZEE) from which they are authorised to take 9,500 tonnes each year. All the industrial vessels working in Madagascan waters are therefore foreign tuna vessels with a licence obtained for a fee, particularly in the context of the EU's Fishing Agreement. Thus, in 2003, Madagascar authorised the entry of 40 European seine fishing vessels and 40 long-lining vessels into its waters. In 2003, Asian shipowners also bought 23 licences for long-lining vessels. According to the agreements formalised with shipowners, each vessel must carry two Madagascan seamen on board. The whole fleet of observers, whose number is fixed at a minimum of 30% of the total fleet of vessels, is also Madagascan.

The rise in tuna fishing led the "Pêche et Froid" group to install a conservation unit at Antsiranana, with tax-free status, in 1991. The PFOI factory is the only one on the island. It processes about 35,000 tonnes of tuna and employs about a hundred people. Moreover, about fifteen operators offer services needed by tuna fishermen: the Maritime District for the use of the port (harbour dues and mooring fees), Société Malgache de l'Océan Indien for offshore and inshore piloting, Compagnie Malgache de Manutention for goods handling operations (such as tuna, salt, water) with 30 to 33 people per seine vessel, and Compagnie Salinière de Madagascar for salt supplies. About thirty administration officials are involved in managing the operation of the tuna vessels (monitoring the application of agreements, issuing licences, checking and surveillance, statistical monitoring).

The tuna caught are sold on the world market both fresh and refrigerated (10%), frozen (15%) and dried, for sashimi, and deep-frozen in brine at –20°C to supply the canning factories (60 – 65%). The preserving plant of PFOI (Pêche et Froid Océan Indien) at Antsiranana buys a large proportion of its raw materials (whole deep-frozen tuna) from French and Spanish seine fishermen who work in the region, enabling it to benefit from exemption from the 20% customs duty on the European market for tinned tuna.

In 2002, Madagascar exported 13,000 tonnes of tuna, mainly tinned, for a sum of 209 billion FMG, or 3.75% of its exports. Europe is the almost exclusive market for the export of Madagascan tuna.

5.6.2.2 Aquaculture (Shrimp farming)

Prawn farming has developed since 1992 in the dry parts of the mangrove swamps in western and northern Madagascar (Morondava, Mahajanga, Soalala, Ankarana) and reached a production figure of 11,000 tonnes over 2600 hectares in 2006.

Two of the species of prawn fished in Madagascan waters are of interest to aquaculture: *Penaeus monodon* (camaron or black tiger), which grows relatively quickly and reaches a final size of 30 to 35 g, and Penaeus indicus (white prawn) which adapts well to being farmed (excellent survival rate) but whose full size is barely 12 to 14 g. From 2 to 2.2 production cycles are conducted per year. The final weight of *P. monodon* is 25 to 30 g. Productivity is between 3.5 and 4.8 tons/hectare/year when farmed semi-intensively. With greater intensification, 6 to 8 tons/hectare/year can be reached.

Six industrial companies are now operating in the field of prawn farming in Madagascar. In 2004, receipts from the aquaculture process represented about 35 millions euros on export.

Of Madagascar's big prawn farming companies, none are located in or adjacent to the study area. AQUALMA and SOMAQUA operate hatcheries near the study zone: at Ambatomifoko to the north of Mahajamba Bay and at Moramba in Moramba Bay south of Narinda Bay for AQUALMA. The shrimp farms nearest to the study area are listed in Table 5.8 below and shown in Figure 5.17.

Table 5.8 – Summarised basic data on the prawn farming industries NEAREST the study zone

Company	Production in Tonnes		Area in hectares	
	2004	2007 (forecast)	2004	2007 (forecast)
AQUALMA Mahajamba	3 000	3200	780	800
SOMAQUA Boanamary	500	900	142	280
AQUABIO Matsakabanja	nd	100	20	30
AQUAMAS Soalala	200	1000	235	235
Total	~ 3 700	~ 4200	1 177	1345

Source : GAPCM (2004) & comm.pers. (2007)

The development potential of the prawn farming industry is estimated at 10,000 hectares on the west coast of Madagascar. The prawn farming companies develop new basins every year and are increasing their production. With the progressive decrease of the shrimp fishing industry, the sector has reached a situation whereby the aquaculture industry will produce more than the fishing industry.

The industrial prawn farming companies belong to the Groupement des Aquaculteurs et Pêcheurs de Crevettes de Madagascar (GAPCM).

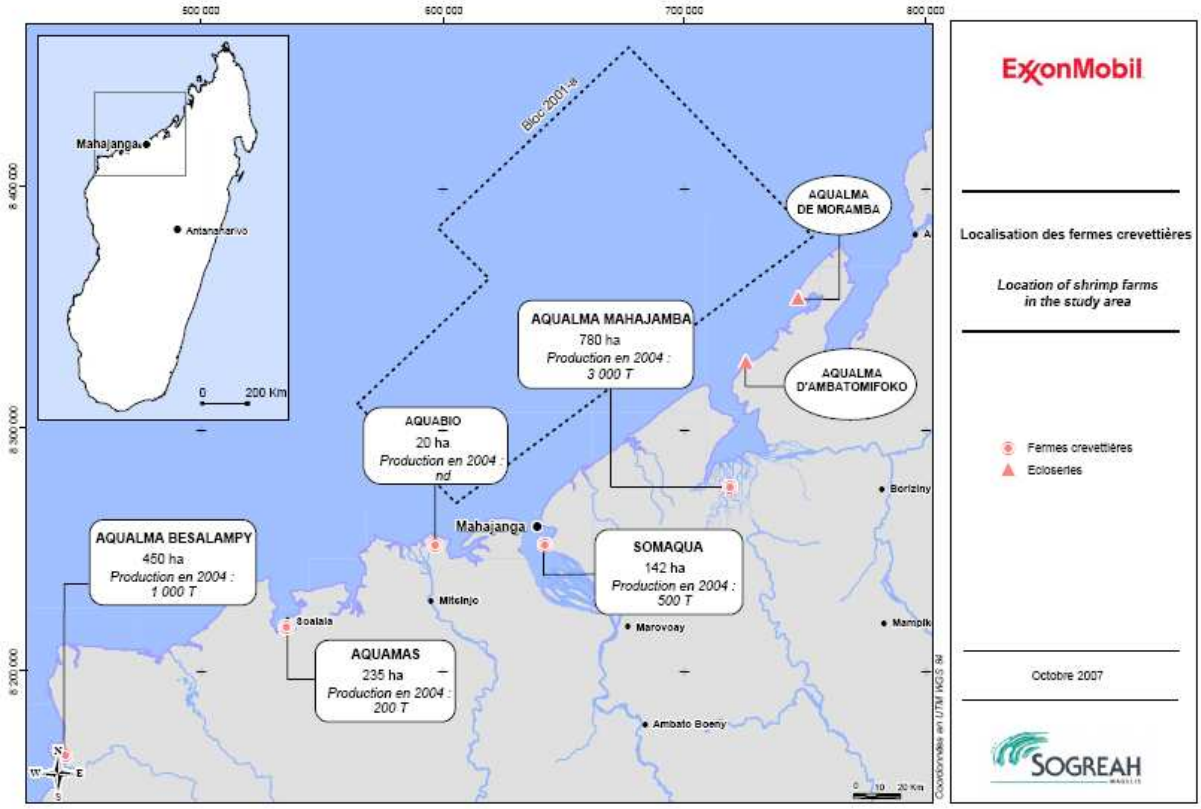


Figure 5.17 Shrimp farms along the NW coast of Madagascar. None are in or adjacent to the study area.

In 2003, the six prawn-farming companies operating on the West Coast created about 4,300 full-time jobs, 2000 of them being with the UNIMA-AQUALMA on their two farms (Mahajamba and Besalampy). These full-time jobs are distributed as follows: ~ 100 are sailors, ~ 1,000 work in processing factories, 400 in administration, ~ 300 in hatcheries, ~ 2,100 in farming operations and 400 in miscellaneous jobs. Moreover, this prawn farming creates 30,000 indirect jobs.

The contribution of industrial aquaculture to the gross domestic product is estimated at 0.5%. The SFA's tax contribution to the State budget is similar to its contribution to the GDP: its contribution to public income is small because the farms are in the free zone, but there are considerable spin-offs from aquaculture in terms of the country's community and socio-economic development.

These products are exported mainly to Europe. The prawns are exported (whole, de-headed and peeled) mainly (~ 70%) to Europe (France, Spain and Italy), Japan (~ 30%) and a small quantity to the United States. Each company has its own distribution network in Europe to large and small supermarkets where they are labeled "Farmed prawns from Madagascar", without naming the production company.

5.6.3 Tourism

Tourism is a key sector of the Madagascan economy and is developing strongly each year: since 2003, the growth rate has exceeded 10% and reached 15% in 2005. The estimated number of international visitors to Madagascar for 2006 is 330,000. Table 5.9 below presents the principal national tourism indicators (SADC, the official SADC Trade, Industry and Investment Review).

Table 5.9 – Development of the principal figures on tourism in Madagascar

Years	2000	2001	2002	2003	2004	2005	2006
Number of international arrivals (in thousands of visitors)	160,1	170,2	61,7	139,2	228,8	280,0	330,0
Average length of stay (days)	20	20	9	15	20	20	Na
Number of hotels and tourist establishments	644	695	717	768	853	950	1020
Number of bedrooms	7 779	8 435	8 780	9 325	10 230	10 900	Na
Average hotel occupancy rate	> 60%	> 60%	22%	40%	55%	na	Na

** : 2006 forecasts; na : not available.*

In 2005, receipts from tourism in Madagascar accounted for $ 190 m. Tourism is among the four leading sectors supplying foreign currency in Madagascar. The other three are the Industrial Free Zones, Fishing and Vanilla.

The National Tourist Office divides Madagascar into five tourist regions:

- The Centre, including the tourist sites served by the RN 7 from Antananarivo to Ambalavao;
- The Southeast and West, including the Tsingy of Bemaraha and the Morondava region as far as the town of Toliara;
- The Northeast and East: the Toamasina area and Sainte-Marie island in particular;
- The Southeast, a cultural centre in the Antemoro area and Fort-Dauphin; and
- The Northwest, with the principal towns of Antsiranana, Mahajanga and Nosy Be.

The study zone is in the last-mentioned tourist region, combining tourism focused on the sea and the beach with biodiversity. Nosy Be is still the most important tourist centre, for international tourism in particular, with the country's most highly developed reception infrastructures.

In 2001, the province of Mahajanga contained 7% of the hotels and bedrooms on offer in Madagascar. There is very little information available that is specific to the area near the study zone. The economic importance of tourism in the zone has been assessed from interviews with tourist operators, the Regional Tourist Office and interpolations of national data on tourism.

In the expanded study zone (from Cap St-André to the Ampasindava peninsula), there is a clear distinction, in terms of infrastructure, between the north, where almost all the establishments are situated, and the area south of Mahajanga where, in 2007, there were no hotels beyond Katsepy.

In June 2007, the expanded coastal study area contained 41 tourist establishments. Most of the establishments are concentrated in and around the town of Mahajanga. However, there is great disparity in the level of service offered by those hotels. It is estimated that about 20% of the hotels comply with international standards and are therefore classified by the star system, that 20% comply with local standards and use the "ravinala" classification, and that nearly 60% are unclassified establishments, most of which have no more than 5 bedrooms and operate as family businesses.

In Mahajanga city, there are 29 hotels, out of which a third is located on the coast. In the area immediately around it (within a radius of 20 km), there are 4 hotels on the coast. In the south of Bombetoka Bay, only 2 coastal establishments are listed, at Katsepy. Between Bombetoka Bay and Mahajamba Bay, there were no hotel complexes in 2007 north of Antsanitia Resorts. The coast between Mahajamba Bay and Moramba Bay has the following three establishments: the Jacquy Cauvin hotel, Anjajavy hotel and Charles Gassot hotel. Two other hotels were being built in 2007, between Mahajamba Bay and Moramba Bay, by Société Générale de Bâtiments whose registered office is in Mahajanga, the company that built most of the hotels on the coast, whose base has become a village near Marovazàbe.

Year	2004	2005	2006
Number of visitors	9 699	11 153	16 767
Growth rate	N/D	15%	50%
% of foreigners	25%	25,6%	31,4%

Table 5.10 - Development of the number of visitors to the shore area adjacent to the study zone in the last three years

Source : Office Régional du Tourisme de Mahajanga

Like national tourism, tourism in the study zone is growing rapidly. The percentage of foreign visitors is also growing, confirming that international tourism is increasing.

The tourist activities found on the coast are: i) sea-based activities such as bathing, diving, water-skiing, sail boarding, boat trips, coarse fishing and paragliding; and ii) land-based activities: hiking, visiting the eco-tourism sites in the Private National Reserve, VTT hikes, visiting the villages around the hotel.

The hotels in the study zone are thus highly dependent on the quality of the shore (water and beach) in their areas. Moreover, the protected areas in the study zone that are on the coast (Baly Bay, Mahavavy-Kinkony Complex) or out at sea (Sahamalaza) and the outstanding coastal sites (e.g. the red cirque and the mangroves of Mahajamba and lower Betsiboka) greatly add to the appeal of the region and hence the affluence of the town of Mahajanga and the hotels on the coast.

5.6.4 Commercial Port of Mahajanga and maritime transport

Traffic:

Mahajanga is a secondary long-haul port where long-haulers are operated in the roadstead by lighterage. As a priority, Mahajanga serves the northwest of the country. In that capacity, it is used as a trans-shipment port for all the coastal trade harbours of the West Coast. The port is also used to serve the Antananarivo region, to a lesser extent than Toamasina which, until recently, was the traditional arrival and departure point for the country's high plateaux.

The following tables indicate Mahajanga's position nationally for the various goods transported (in second place after Toamasina) and how the yield indicators have developed over the last five years. Also notable is the Port of Antisohihy, which is located near the study area. Vessels going to and from the Port of Antisohihy may cross the study area.

Table 5.11 - Traffic in Malagasy ports in 2006 in tonnes

Ports	Hydrocarbons	Conventional	Container	Botry*	Total
ANTALAHA	0	5 278	0	8 351	13 629
ANTSIRANANA	29 019	102 758	72 809	0	204 586
▶ ANTSOHIHY	10 580	12 399	0	79	23 058
▶ MAHAJANGA	46 698	69 823	116 268	9 908	242 697
MAINTIRANO	ND	ND	ND	ND	ND
MANAKARA	0	8 078	0	0	8 078
MANANJARY	0	876	0	0	876
MAROANTSETRA	567	3 085	0	2 724	6 376
MOROMBE	0	0	0	2 267	2 267
MORONDAVA	8 160	1 413	1 411	2 988	13 972
NOSY BE	11 847	33 093	21 404	667	67 011
PORT ST LOUIS	0	4 046	0	0	4 046
TOLAGNARO	10 927	20 261	127	0	31 315
TOLIARA	25 136	34 775	28 145	1 135	89 191
VOHEMAR	13 457	20 976	9 000	0	43 433
TOAMASINA	574 901	662 604	616 799	0	1 854 304
TOTAL	731 292	979 465	865 963	28 119	2 604 839

** In Madagascar Botry are local coastal boats that transport small quantities of goods from port to port*

Mahajanga airport

The airport facility at Mahajanga could serve as a point for medical care or emergency medical evacuation for the crew if necessary. It is an international airport and can support international emergency ambulance flights.

Located at 6 km from Mahajanga city (Position 15°40´01"S, 046°21´07"E, Elevation 27 m), the Mahajanga airport is equipped with a single 2.2 km-long and 45 m-wide runway (heading 14/32). Runway lighting may be activated on demand from 3pm UT (universal Time). The control tower is operated from 6 am to 6 pm, and may be operated in the night on demand. The average daily traffic is of 25 airplanes per day, with scheduled services from commercial airlines. Navigation aids include VOR-DME (Distance Measuring Equipment) and NDB but no ILS (Instrument Landing System). Safety equipments include 4 VIMP (Medium power intervention vehicle of 1,000 to 9,000 liters of water) and a FLYCO (Four-wheel drive fitted with bird scaring devices).

CHAPTER 6 - IMPACT ASSESSMENT AND MITIGATION MEASURES

6.1 Introduction

This section addresses the identification and evaluation of environmental and social impacts of seismic project activities. The overall strategy for managing the environmental performance of the project will focus on preventing, mitigating or controlling the potential significant environmental and social impacts.

Impact evaluation is undertaken by combining an understanding of the project activities, its risks and impacts, prevailing operational procedures and best practices and the regulatory environment as previously described in this document in the following structure:

Chapter 1: General Introduction
Chapter 2: Regulatory and Legislative Framework
Chapter 3: Project Description
Chapter 4: Risk Identification and Mitigation
Chapter 5: Description of the Environment

The Impact Assessment as described in this chapter integrates all of these aspects into a comprehensive analysis of the environmental effects of the project. These impacts are identified, mitigation measures are determined, implementation and monitoring measures are designed and the subsequent environmental effects of each impact are assessed.

Environmentally and ecologically important elements identified in the Description of the Environment Chapter are commonly described as Valued Ecosystem Components (VECs). The evaluation of potential impact on the VECs and social aspects identified depends on their value, sensitivity and vulnerability in terms of their environmental, ecological, economical and social importance.

Oil and Gas Industry standards and guidelines (API, OGP, IPIECA, IMO) and best practices, known to improve environmental performance, have been adopted as the base case at the planning and design stage of the seismic project and will be implemented during project execution. EMEP(NM)L will implement additional measures and project alternatives, in terms of design and operating strategies, in order to minimize the potential impacts of the seismic program.

6.2 Impact screening

Screening of impacts serves to provide an initial understanding of the potential project impacts and to appreciate their relative significance. Impact screening involves:

- the identification of the potential impact (based on an understanding of the project activities and the VECs and/or social aspects);
- the proposal of mitigation measures to prevent, reduce or control the impact; and
- the identification of the level of significance of the residual impact, following the implementation of appropriate mitigation measures.

6.2.1 Assessment methodology

In the assessment process a distinction is made between normal operations, which will predictably take place, and accidental events, which vary from unlikely to remote probability of occurrence.

The impact assessment process distinguishes three sets of ranking criteria:

- Ecosystem and amenity criteria,
- Environmental performance and management criteria for which normal and accidental events are distinguished,
- Summary significance criteria, which summarize the rankings, identified in stages 1 and 2.

Ecosystem and amenity criteria

Environmental impacts can be evaluated in terms of ecosystem and amenity criteria. The categorization according to these criteria is detailed in Table [6.1]. These criteria are applied to impacts under both normal operations and accidental events. Ecosystem criteria are based on the relative sensitivity and vulnerability of each VEC and in the case of social issues, include consideration of the economic and recreational value of certain VECs. The ecosystem and amenity criteria include consideration of the duration and extent of the anticipated impact.

Table [6.1] Ecosystem and amenity impact criteria

Impact description	**Symbol**
MAJOR – impacts which cause behavioral or ecosystem changes beyond the scope of natural variability at the population level, leading to damage with likelihood of recovery above 10 years.	■
MODERATE – impacts which cause a change similar to that caused by natural variability at population level (i.e. localized and short-term) with a good short term recovery potential by natural processes within 5 years.	■
MINOR – impacts which cause a change within the scope of the existing population dynamics but can be monitored or noticed.	■ / ■
NEGLIGIBLE – impacts which cause an effect on individuals or populations which are unlikely to be noticeable or measurable against background population activities and are transient.	■
POSITIVE – impacts which cause a positive effect on individuals or populations which are noticeable or measurable within the duration of the project operations.	■

6.2.2 Environmental Performance and Management Criteria

Having defined the ecosystem impact category, the categorization according to environmental performance and management class is evaluated. This evaluation is done separately for normal operations and accidental events as detailed in Tables [6.2] and [6.3]. It can be seen that impacts for both normal operations and accidental events include the consideration of extent of impact.

Table [6.2] - Environmental performance and management criteria for normal operations

Quantities consumed, released or disposed of	*High* *Medium* *Low*	■ ■ ■
Regulatory or project control	*Continuous non-compliance* *Potential for non-compliance* *Within compliance at all times /no control applies*	■ ■ ■
Duration	*Long term (>10 years) or continuous activity or activity occurring during sensitive period for VEC or amenity* *Activity of medium duration (1 – 10 years) of short duration (<1 year) repeated periodically over project life* *Discrete activity of short duration*	■ ■ ■
Extent of influence	*Extensive and/or encompasses an area that supports a statistically significant proportion of a VEC population.* *Moderate and/or encompasses an area supporting a moderate or minor proportion of a VEC population.* *Restricted and/or encompasses an area that supports a statistically insignificant proportion of a VEC population.*	■ ■ ■
Ecosystem and amenity criteria (identified previously in Table 6-1)	*Major* *Moderate* *Minor* *Negligible* *Positive*	■ ■ ■/■ ■ ■

Table [6.3] - Environmental performance and management criteria for accidental events

Likelihood of the event occurring	*High (e.g. > once per year globally, i.e. not per vessel)* *Medium* *Low*	■ ■ ■
Likelihood of detection	*Low (i.e. no monitoring or detection system)* *Medium* *High (i.e. continuous monitoring or inspection)*	■ ■ ■
State of preparedness	*No provision made or mitigation not possible* *Some provision made* *Detailed plans, training and exercises*	■ ■ ■
Extent of influence	*Extensive and/or encompasses an area that supports a statistically significant proportion of a VEC population.* *Moderate and/or encompasses an area supporting a moderate or minor proportion of a VEC population.* *Restricted and/or encompasses an area that supports a statistically insignificant proportion of a VEC population.*	■ ■ ■
Ecosystem and amenity criteria (identified previously in Table 6-1)	*Major* *Moderate* *Minor* *Negligible* *Positive*	■ ■ ■/■ ■ ■

6.2.3 Summary significance Criteria

The scores for each criteria obtained in Table [6.2] or Table [6.3] (depending on if it is a normal operational impact or an accidental event) are combined to produce a summary significance value. The summary significance value is produced based on the combination of colored scores in Tables [6.2] or [6.3]. For example, if a red square score is present in any of the criteria, the impact is immediately considered significant. The basis for categorization of the summary significant criteria is summarized in the table below.

Table [6.4] - Summary significance criteria

Environmental performance and management rating	*Final impact category*
At least one criteria scored as ■	*Significant*
Any combination of ■ *or* ■/■	*Acceptable*
All five criteria ■	*Insignificant*
Where the ecosystem and amenity criteria is ■	*Positive*

6.3 IMPACTS OF SEISMIC OPERATIONS

The potential environmental impact sources related to the different seismic operations are:

1. Physical presence of seismic vessel, chase vessel, and seismic and scientific data acquisition equipment
2. Air emissions
3. Noise and vibrations
4. Discharges to water
5. Solid waste

The following sections will describe these impacts in more detail.

6.3.1 Impacts due to presence of seismic vessel and equipment

Impacts sources
Transmitter and receiving systems: air gun array and streamer: The physical presence of the air gun array and the 3.0 km long streamer towed at a depth of 4 – 5 meters are sources of impacts, namely interference with the usual maritime traffic in the area, which includes hydrocarbon products, commercial goods and fishing vessels.

The potential environmental impacts associated with the physical presence of the survey vessel and equipment are:

- Delay to Shipping
- Disruption to Fishing Activities
- Negative Aesthetic or Visual Impacts

6.3.1.1 Delay to Shipping

Due to their restricted manoeuvrability, seismic vessels must have priority over vessels that are not similarly restricted. Therefore, some ships moving through the survey area may be temporarily delayed by the need to wait or divert around the survey vessel and its equipment.

A simple analysis of the likely delays to shipping is carried out below. Vessels approaching Analalava from the northwest will be most affected by activity along the SW-NE survey lines. These lines are 12 km long and constitute approximately 30% of the survey. The seismic operation should be considered to occupy a 7 km zone along any given line. This is calculated by adding in the length of the streamer and the vessel and adding in a 100% safety margin. Ships approaching the coast towards the ports of Analalava or Antsohihy from the NW will be most affected at this time. Ships travelling parallel to the coast will be most affected by operations when the NW-SE lines are acquired; however, if they are shoreward of the survey area and close to the coast or > 50km from the mainland, they will be unaffected. The NW-SE lines constitute approximately 70% of the survey.

The worst case delay in each case is if a ship has to wait for the seismic operation to pass, rather than diverting around it. The time taken for the survey operation to travel 7 km is approximately one hour, assuming an average survey speed of 5 knots. The survey area is situated in deep offshore waters 45 km Northwest of the village of Analalava. The center of the survey area lies 30 km off the Madagascar mainland. Up to six vessels per day may call on either the port of Analalava or Antsohihy.

Therefore, up to 180 commercial vessels may traverse the northwest coast of Madagascar during the 30-day survey period. Depending of the location and orientation of the seismic survey vessel and the location and direction of the commercial vessel, it may encounter up to a one hour delay while waiting on the seismic vessel to clear the path. Given the other types of delays that shipping encounters (weather, tides, engine problems, loading/unloading delays etc.) and the relatively low probability that a delay will be necessary at all, it is believed the presence of the seismic vessel will have only a negligible impact on ships travelling along the western coasts. The excellent communications capability of the survey boat, and the chase boat if utilized, will ensure that diversions and delays are minimized. In addition, the port authorities at Antsohihy, Analalava and the main port at Mahajanga will be kept informed of the survey progress.

The end of hydrophone streamer cable is marked with a tail buoy. The purpose of the tail buoy is to warn other shipping of the presence of the cable in the water and to act as a platform for surface positioning systems so that the location of the end of the cable can be monitored. The hydrophone cable could leak some volume of kerosene into the environment if it is accidentally cut, but it is not considered to be a physical danger to other vessels if it is accidentally run over.

The vessel will be towing instrumets during the side scan sonar survey. These are much closer to the vessel and would not interfere with other coastal traffic beyond the physical presence of the vessel. Although the survey vessel will be following a fixed course, it will be capable of moving away from approaching traffic if necessary for safety reasons.

6.3.1.2 Disruption to Fishing Activities

The following types of fishing activities occur within or immediately adjacent to the proposed survey programme and therefore are most at risk of suffering physical interference due to the seismic survey:

• Industrial tuna fishing: Large fleets of long liners and purse seine trawlers have the right to operate in Malagasy waters. A significant percentage is owned by EU countries, none are Malagasy owned. According to statistics from the year 2000, peak catch rates for seiners occur in April and May. Tuna are a migratory species and the industrial fishing fleets following the tuna. These movements cannot be predicted in advance; however, the seismic survey area is located within the tuna fishing area.

• Traditional fishing is carried out either along the shore, or in the small rivers or backwaters, using lines and nets. The turn-around section of the NW-SE survey lines would potentially affect activity in the shallow water areas and the side scan sonar activities may also potentially affect traditional fishing activities. Since the turn-around section of the seismic lines will be in deeper waters >15km from the mainland and the side scan sonar equipment is towed relatively close to the vessel, the chance of disrupting local fishing activity in the survey area is quite low.

• Industrial trawling for fin fish other than tuna: IPR operates a small fleet of Thai trawlers and one factory ship on the West Coast in waters greater than 8 nm from the coast and water depths between 30m and 200m, i.e. along the continental shelf edge. The turn-around section of the NW-SE survey lines and the physical presence of the vessel in these waters during the side scan sonar survey could potentially affect these activities. However, due to the short duration of the seismic survey and the distance the vessel will remain from shore during the seismic survey , the chance of disrupting these activities during the seismic survey is low. The vessel will be operating in these waters

during the side scan sonar survey but it will remain relatively manouverable (if needed) so the chance of disrupting these fishing activities is low. No impacts are anticipated on the valuable shrimp fishery.

The following mitigation measures are proposed to minimize impacts on fishing in and adjacent to the survey area:

- Seismic survey is concentrated in deep waters off the continental shelf in water depths ranging from 500 – 2000 meters, away from most traditional and artisanal fishing areas.
- Survey duration is short
- Fishing companies and local authorities based in Madagascar have been consulted regarding the survey and therefore are familiar with the proposed operations.
- The Ministry in charge of Fisheries and Marine Resources and Port of Antsohihy, Port of Analalava and Port of Mahajanga will be notified of full survey details at least 2 weeks before the survey commences.
- Fisheries Adviser will provide advice to the seismic contractor regarding fisheries issues. He will be involved in any communications with fishing vessels encountered during surveying.

In conclusion, deep water fishing for tuna and fishing on banks along the continental shelf edge are the fishing activities most likely to be impacted by the survey, however, the mitigation measures proposed above, together with the short duration of the survey, will reduce the potential impact on their activities to Insignificant.

6.3.1.3 Negative Aesthetic or Visual Impacts

The survey area is more than 15 km from the coast therefore the survey vessel will rarely be visible from land. Apart from the tail buoy, none of the survey equipment is visible above the water. The survey operation will therefore have no negative aesthetic or visual impact on the area.

Table [6.5] - Summary of Impacts due to Physical Presence

Impact	Impact Assessment	Mitigation
Delays to shipping	It is estimated up to 15 commercial or fishing vessels may be affected during the survey period, with an estimated delay in their sailing of about an hour. Although this impact is negative, it is believed to be Insignificant.	Vessel communication capabilities and the use of marine observers. Regular communications with port.
Disruption to fishing	Potential effect on commercial tuna fishing, little or no affect on shrimp fishing. Effects are localized, short term and temporary Although the impact is negative, it is believed to be Insignificant	Consultation, notification and regular communication with port and fishing authorities Use of Fisheries Advisor Survey concentrated in deep waters, seaward of the coral shoals.
Aesthetic / visual impacts	No impact.	Survey area is primarily >15 km from shore. Survey equipment is mostly underwater.

6.4 IMPACTS DUE TO AIR EMISSIONS

6.4.1 Impacts sources

Air emissions are limited to the exhaust gas of the ships' diesel engines. The engines will be fueled with the low-sulphur diesel fuel available in Madagascar, so the sulphur emission to the atmosphere will be minimized.

Diesel consumption from the survey and support vessels and equipment engines is estimated to generate 432 tons of CO_2 for the entire survey. In 2005 Madagascar produced an estimated 2.52 million tons of CO_2 (U.S. Energy Information Administration, 2005), thus the seismic survey operations in this offshore for such a short duration represents <0.02% of the national annual CO_2 emissions. In addition, the vessel will operate in the open seas, usually no less than 10 km from shore, far from land and any population centers in Madagascar.

Emissions to air are generated primarily by the burning of fuel to power the engines, compressors and electrical generators on the vessel. Estimated fuel consumption for the *Teknik Perdana* during normal surveying operations is 4.5 tonnes per day, equivalent to approximately 5,300 litres per day.

Table [6.6] . Fuel Consumption

Unit	Number	Specification
Main engines 6 EUT 45/75 Mitsibishi diesel	2	3,800 bhp
Electrical generators (FC5356-4TA45-Z)	3	450 volts, AC 3 ph 60 Hz
Total fuel consumption (average) 4.5 tonnes/day (5,300 litres/day)		

Gases emitted from the combustion of fuel in the vessel's engines, compressors and generators include:

- Carbon dioxide (CO_2),
- Nitrogen oxides (NOx, N_2O),
- Sulphur oxides (SOx),
- Methane (CH_4),
- Volatile organic compounds (VOC),
- Carbon monoxide (CO), and
- Particulate material.

Calculated total atmospheric emissions produced over the estimated 30-day duration of the survey are presented in the table below. The methodology for the calculation of emissions is based on the International Exploration and Production Forum's Tier Three method (E&P Forum, 1994).

Table [6.7] Estimated Total Atmospheric Emissions for 30-day Survey

Emission Type	Amount (tonnes)
Carbon dioxide (CO_2)	432
Carbon monoxide (CO)	0.285
Nitrogen oxides (NOx, N_2O)	1.285
Sulphur dioxides (SO_2)	1.08
Methane (CH_4)	0.105
Volatile organic compounds (VOC)	0.225
Particulate material	Not known

The seismic vessel is not equipped with an incinerator. Therefore all disposable waste such as paper, plastic and metal, will be compacted and / or stored for disposal of at a proper land facility in either Madagascar or a future port of call. These facilities will be evaluated by EMEP(NM)L prior to approval for use. Recycling will be utilized over disposal whenever possible.

Impacts due to the chase boat, if utilized, will result in discharges to air due to burning of fuel in the ship's engines and a small physical presence. There are no emissions types or impacts which are unique to the chase boat. Its impacts will be much lower than those for the seismic vessel, and therefore they are not considered separately in this impact assessment.

The survey vessel will remain in offshore waters and normally will come no closer than 10km to the Madagascar mainland during survey operations. Therefore it will have no effect on the local populations along the coast during the survey operation. The survey area is a large area offshore that is frequented by other vessels which are also contributing similar air emissions. It is therefore concluded that the survey will have no impact on local or regional air quality and no impact on greenhouse gases.

Table [6.8] Summary of Impacts due to Air Emissions

Impact	Impact Assessment	Mitigation
Reduction of air quality due to emissions of CO, NOx, N_2O, SOx, VOC and particulates.	Emissions are far from populated areas, spread over a large offshore area. No impact.	Engines, generators and compressors are well maintained to maximize their efficiency.
Increase in greenhouse gases due to emissions of CO_2 , N_2O, and CH_4	Negligible contributor of greenhouse gases No impact.	Engines, generators and compressors are well maintained to maximize their efficiency.

6.5 IMPACTS DUE TO NOISE AND VIBRATIONS

6.5.1 Impacts sources

Seismic prospecting presents a number of risks for marine organisms. Throughout the next sections, the impacts likely to affect marine species are described separately. The impacts are incremental to the numerous other impacts caused by human activities. Furthermore, they occur in a cascade effect, since the repercussions on a group of organisms are very often reflected in the entire food chain. As a result, it is important to realize that the problem of marine impact is an ecosystem problem.

The vessel acquisition and its equipment emit sounds that vary in frequency and intensity. They can be divided into two types of noise:

1. Continuous sound vibrations produced by engines and the speed of the ship. Like any other ship, the seismic vessel emits vibrations due to the engines used to propel it. At full power, these vibrations have a noise level of around 150 – 160 dB per 1µPa (50 – 90 Hz) (reference for the marine environment) measured at 1 meter from the source. They are continuous over time, but are never stationary since the ship moves at approximately 5 knots during survey and up to 15 knots at full speed. The vibrations compared to a given point of the marine environment move away or come closer, but are never in the same location.

2. Discontinuous but repetitive acoustic waves produced by the successive firings of the seismic and acoustic sources. These discreet sound waves are emitted regularly by the seismic and acoustic sources, which in this case will be the air gun, the multi-beam echo sounder and the side scan sonar. Effectively, the air gun source sends its train of sound waves approximately every 8 - 10 seconds, which corresponds to a physical distance between two firings of 18.75m; this corresponds to 53 firings for 1 km travelled, approximately 3,733 shots a day (assuming an acquisition rate of 70 km per day). The noise level of the seismic source at full power is 180 – 200 dB per 1μPa at 1 meter from the source with frequencies generally below 200Hz. Because the seismic source moves at the same rate as the boat, the emission noise level will increase and decrease progressively with respect to a fixed position in the marine environment as a result of the increasing distance.

3. The multi-beam echo sounder and side scan sonar send transmit and record an acoustic signal but more on a continual basis. The noise level of the multi-beam source is approximately 235 dB with a frequency range above 12,000 Hz. The noise level of the side scan sonar is 220 – 230 dB with a frequency of >50,000 Hz.

The position of the air guns with respect to one another inside the geometry of the source makes it possible to focus and direct the maximum power vertically to the source and to reduce the propagation of the sound wave laterally and horizontally.

These sound waves will be attenuated in two ways: in the first case (engine noise) by reducing the speed of the ship and in the second case (air guns) by using special layouts of the seismic sources at the time of firing. The multi-beam echo sounder and side scan sonar signals are high frequency signals and will attenuate more rapidly than the air gun signal. They will also be inaudible to some species.

6.5.2 Reference information for the marine fauna

The key potential impacts with respect to underwater noise are:

- Pathological effects (lethal or sub lethal injuries): potential injury or fatality of marine fauna from exposure to significant levels of noise.
- Behavioral disturbance leading to behavioral changes or displacement.
- Disruption to feeding, mating, breeding or nursery activities of marine organisms in such way as to affect the vitality or abundance of populations.
- Interference with the use of acoustic communication signals or naturally produced cues used by marine animals.
- Indirect effects, such as changes in the abundance or behavior of prey animals for marine mammals, seabirds and fish.

Immediate pathological effects would be restricted to short ranges and high sound intensities. Experiments with individual airguns and arrays of guns have demonstrated lethal effects for plankton. To cause immediate serious pathological damage, sound levels need to be very high. The sound intensities required to produce pathological effects are largely unknown for most marine animals and what is known is based on limited number of experiments of varying quality (Richardson et al., 1995). High sound levels are found only close to the source and hence the area where damage may occur is limited to close proximity to the source.

Pathological effects will be unlikely to occur for the majority of species, as most free swimming animals will practice avoidance maneuvers well before they get within the range at which these effects may occur. Animals which do not flee the approaching survey vessel because of behavioral or physical constraints will be at risk of pathological effects. Such animals include plankton, fish eggs and some site-attached (i.e., non-mobile) organisms such as marine benthos.

6.5.3 Impacts on Wildlife

Noise levels associated with seismic surveys may cause direct impacts on marine wildlife: behavioural disturbance (could be manifested as localised avoidance, abandonment of feeding areas or any other human-induced behavioural change), physical injury and mortality. Behavioural effects may include disturbances to feeding behaviour and repulsion from the vicinity of the vessel. These direct effects may lead to indirect effects on fishermen and wildlife populations, for example, due to changes in fish and other prey in the vicinity of the seismic vessel. There is also masking effects (macro environmental), where noise interferes with an animal's ability to hear other members of its species or detect its prey.

Physical injury and mortality are limited to organisms which are in very close proximity (within 5 meters) of the airguns when they are discharged. This impact will mainly affect eggs, larvae and other very small, effectively immobile organisms which would normally suffer a high mortality rate due to predation.

Short term impacts, compared to long term impacts are less likely to result in significant biological impacts as long as they are managed in a way that does not cause irreversible long term damage.

The seismic contractor will be "soft starting" the airguns at the start of each line, a practise which allows mobile species close to the guns to move away before they are brought up to full power thus mitigating against the possibility of damaging mobile species which happen to be close to the airguns at the start of a survey line. The "soft start" method is described in more detail in the "Prevention , Monitoring and Mitigation Measures" section of this chapter.

The airgun array for the proposed survey has a power rating of 66.1 bar – m and will be fired at 18.75m intervals along each survey line, i.e. approximately every 8 - 10 seconds. This amounts to an average of 3,733 shots per day (assuming a survey rate of 70 line km per day) and a total of approximately 56,000 shots over the duration of the seismic survey. Sound output from the airguns is estimated to be 200 dB (re: 1 µPa at 1m) depending on direction. Sound levels in line with and below the seismic source are higher than those abeam of the array due to its directivity. In addition to three dimensional variations in sound levels around the array, sound attenuates much faster in shallow water than in deeper water due to absorption, interference and scattering effects .

Wildlife which is considered to be potentially most affected by the survey or which is protected due to their vulnerable conservation status are:

- Turtles: (loggerhead, green and hawksbill - protected under national and international law)
- Cetaceans: (dolphins and whales - protected under international law)
- Dugong: protected under national and international law)
- Fish : (especially those with a swim bladder)
- Small effectively immobile pelagic organisms (including eggs and larvae)
- Benthic organisms

The following sections give a summary of the potential impacts by organism type

6.5.4 Impacts on marine turtles

Green turtle *Chelonia mydas*, as dominant species found in the Mozambique Channel is the most frequently encountered species in the study area.

The study area is reported as a migratory corridor for green turtles, as noted in Chapter 5. It is possible that the turtles may be affected during their migration toward the nesting zones. The maximum auditory sensitivity of marine turtles is around 100 to 700 Hz (Wever, 1978, cited in McCauley, 1994). Since the air gun emits low frequency sounds between 50 – 900 Hz, it is therefore likely that they will detect the noise from the guns. McCauley (2000, cited

in Landon and Pannozzo, 2001) states that, in general, turtles begin to demonstrate erratic behaviour as soon as they are exposed to noise at a level of 166 dB, which can be as far as 50 meters from the source. On the other hand, the multi-beam and side scan sonar signals are at a frequency that is too high to be audible by most sea turtles.

A study of loggerhead turtles found in Japan with auditory function between 250 and 1000 Hz, demonstrated that they suffer a temporary hearing loss within a 65m radius of a large noise source. Their conditions returned to normal within two weeks (Whitford,2003).

Available information (Bourjea, pers.com.) indicates that migration in the study area is primarily along the coast, rather than in deeper water, and it has been observed that adult green turtles from the islands of Europa forage freely down the Madagascar western coast.

A soft start will be used to minimize acoustic disturbance to turtles. Lines are mainly in deep water, away from possible feeding grounds on the continental shelf. Disturbance to sea turtle behavior may well occur up to a range of 500 meters, but it is likely that sea turtles may avoid the sound field of the airgun arrays by swimming away. Since source arrays are already operating (as the vessel moves along an acquisition line), individuals would be expected to avoid the area before entering ranges at which pathological damage might take place. The impacts on turtles, if present, would be minor. In as much as the prospecting area is adjacent to marine turtle nesting zones (Nosy Lava and other islets of the northwest coast), the impacts would be greater if turtles are present; however, since the chance of this occurrance is low the impact on sea turtles is assessed as insiginificant.

6.5.5 Impacts on Cetaceans

Certain marine mammals frequent the waters of NW Madagascar. They include species classified as endangered and likely to be found in the study area (Dugong and Whale). Whale migration through the Ampasindava block occurs from June to November. An article published in *Science* mentions the whale population in the area are much smaller than the optimal populations (Roman and Palumbi, 2003).

Dolphins reside in the study area year round. Little is documented on some of the species present, which means that their biological cycle, their movements and their cycle are poorly known and that it is difficult to assess their status.

Among the 30 species of Cetaceans known from waters around Madagascar, at least one specie of baleen whale (the humpback whale *Megaptera novaeanglia*), two toothed whales (melon headed whale *Peponocephala electra* & killer whale *Orcinus orca*) and six dolphin species are known to be in or near the study area.

With respect to disruption of marine mammals, the potential physical/physiological effect with the highest possibility of occurrence in relation to a seismic survey is thought to be a temporary shift in hearing thresholds. Owing to the good swimming abilities of marine mammals and their avoidance of either the vessel or an operating airgun array, it is unlikely that marine mammals will be exposed to levels likely to cause pathological damage from continuously operating arrays.

Behavioral responses, including flight, avoidance and changes in behavior and vocal behavior have been observed in *Mysticetes* (baleen whales) and *Odontocetes* (toothed whales and dolphins).

Seismic airguns are designed to produce low frequency noise, generally below 200 Hz. Low frequency noise is more likely to disturb baleen whales than toothed dolphins. Baleen whales communicate at frequencies mostly below 3,000 Hz, which are likely to overlap with the dominant frequencies used by seismic air-guns, (JNCC, 1998). The sensitivity of dolphins to sound falls sharply below 1,000 Hz, and sounds below 200 Hz are probably inaudible to them. The sounds used by dolphins for communication are often above 4,800 Hz, and echolocation sounds can occur up to 200,000 Hz, (JNCC, 1998).

Although the effects of low frequency sound on marine mammals have increasingly become the focus of research, some uncertainty remains. Considering the water depth within survey area, any of the cetaceans species described as occurring in the Madagascar waters may be potentially exposed. With respect to the high frequency noise of the echo sounder and side scan sonar, they will be inaudible to most whales but will be audible by dolphins.

6.5.6 Impacts on Fish

Among the species of fish in the survey area and their surroundings, presence of tuna species is noted along with sailfish, swordfish and a variety of sharks.

The waters off NW Madagascar are highly important for tuna, particularly stocks of skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) which migrate into the study area, ref. Chapter 5.

There is a wide range of susceptibility among fish. However, those with a swimbladder will be more susceptible than those without this organ (McCauley, 1994). Many adult fish, including the elasmobranches (sharks and rays), do not have a swim bladder and are not susceptible to swimbladder-induced trauma. Most pelagic fish are expected to swim away when seismic noise reaches levels which might cause pathological effects. However, the presence of open sea fish near operating vessels suggests that some of these species are hardly affected by the sound.

Available literature regarding the potential for fish injury and fatality as a result of acoustic impacts and associated pressure effects indicates that direct injuries to fish, fish eggs or fish larvae are predicted to occur when the fish are within a few meters of the operating airguns. Significant numbers can only be affected in situations where the survey line passes directly over fisheries in shallow waters where large numbers of fish eggs or larvae exist. Since the seismic survey area is limited to areas with water depths >500 meters, this will not occur.

Several studies have been performed to determine whether seismic airguns cause damage to adult fish. The pressure pulse generated by airguns is considered to be the most important factor leading to tissue damage in fish at short ranges. Fish detect the sound of airguns at long distances, and healthy adult fish will exhibit avoidance behavior, moving away from the sound source.

The findings of these studies indicate that injuries and mortality to eggs and larvae are highest at close range, within 2 m of the source, and decrease rapidly with distance from the airgun. Outside a range of 5 m, no effects are demonstrated. Furthermore, mortality of fish larvae in the plankton is considered to be insignificant compared with stochastic factors that cause natural mortality to fish larvae (McCauley, 1994).

Effects of airgun pulses on fish also include avoidance behavior, possibly at the range of several kilometers. Only fish in the immediate vicinity of the airguns on commencement of the firing are expected to suffer injury, as the majority of fish are predicted to be driven away by the approaching sound source, the 'soft start' procedure and the movement of the vessel. Levels of injury and fatality are considered to be negligible in the context of local species populations. Considering the limited period of seismic activity (15 days), the capacity of adult fish to avoid the area; and the short range of potential effects over larvae (if at all present), the potential impact on fish species is considered to be *insignificant*.

6.5 7 Impacts on Small Pelagic Organisms

Except for larvae, fish eggs and other minute planktonic organisms within a few meters of an airgun, no planktonic organism populations are likely to be significantly affected by airgun array discharges (McCauley, 1994). For a large seismic array, known effects have been demonstrated only to five meters. However, studies show that the fraction of fish eggs and planktonic larvae potentially impacted is insignificant compared with the size of the planktonic population in a proposed seismic survey area or natural mortality rates for planktonic organisms (McCauley, 1994). The potential impact on plankton related to the proposed seismic survey is considered to be *insignificant*.

6.5.8 Impacts on Benthic Organisms

There are few studies on the effects of seismic surveys on benthic organisms. The seismic program will be conducted off the continental shelf in deep waters from 500 – 2000 meters depth. Therefore the impacts on benthic organisms are anticipated to be insignificant.

6.5.9 Impacts on marine Birds

Although about 15 species of marine Birds are encountered and breed off the Madagascar western coasts (ref. Chapter 5). Population sizes are low and threats from poaching are known. There is little information available on the impacts of seismic surveying on avian fauna. Since marine birds dive under water quickly to feed, they do not have the opportunity to experience gradual exposure. Therefore they cannot flee or foresee the high noise level created by the air guns. Since their auditory system is similar to that of other vertebrates, they may be vulnerable to over-simulation and to auditory damage (Whitford, 2003). Indirectly, the impacts on the distribution of plankton and fish (food of marine birds) may have indirect negative effects on marine birds due to the temporary loss or relocation of their food source. Therefore, the flight and dispersion reactions of their food source associated with sound detonations can adversely affect the feeding of certain bird species. It can be concluded that the seismic program will have indirect and potentially unfavorable impacts on marine birds but they are temporary and insignificant.

6.5.10 Impacts on Humans

Direct Effects

Noise impacts on humans either onshore or working on vessels in or near the survey area are judged to be insignificant. This is because underwater noise does not transmit well across the water/air interface. Most noise is reflected back into the water due to the high acoustic impedance contrast across this interface. Consultations with tourism and fishing organisations in Mahajanga and Analalava have confirmed that diving does not occur within the survey area. Tourist diving occurs north of the study area, mainly in the Nosy Bé area, while commercial diving for sea cucumbers (trepang) occurs in shallow waters where there is a rocky substrate, mainly west of Cap Tanjona. Therefore there will be no direct noise impacts on humans.

Indirect Effects

The direct effects of underwater seismic noise on fish may give rise to indirect effects on fishing within about 10 km of the survey vessel. Depending on the reactions of individual species to the seismic noise, fishermen operating within or close to the behavioural threshold zone around the survey vessel may experience a decrease or increase in their catch rate. Fish which are repelled from the immediate vicinity of the survey operation will cause catch rates close to or within this area to be lower, but potentially higher catch rates may occur away from this area. This effect will be short term and localised and fishing vessels will be excluded from the immediate around the survey vessel. Therefore, no adverse indirect effects of the survey on humans are anticipated.

6.5.11 Prevention, Monitoring and Mitigation Measures

In order to reduce the survey impacts identified above to the extent possible, the following mitigation measures are proposed:

Adjustment of the speed of the seismic vessel

The cruising speed of the seismic vessel is around 15 knots or around 22 km/ hour. However, during the data acquisition phase, it is reduced to 4 – 6 knots, which results in cutting back the engine speed, and therefore the propulsive power, by half. Mitigation of the impacts of noise on the marine environment follows the reduction of speed

and of the engine speed during the data acquisition phase. Thus, the noise and vibrations linked to the vessel's presence are greatly reduced, minimizing the noise impact of the vessel engines.

Layout of the seismic sources and firing array

According to the results of the observations and studies cited above concerning the response of marine animals to sound waves and vibrations, fish, marine turtles and cetaceans have tolerance thresholds for acoustic noise beyond which behavioral and physiological interference is noted. Beyond these threshold values and depending on the species, temporary or permanent damage may occur in the event of exposure to an excessive acoustic source. EMEP(NM)L will carry out offshore seismic campaigns following the guidelines of the UK JNCC in accordance with IAGC, in order to minimize acoustic disturbances due to a seismic acquisition programs. By complying with these guidelines, the impacts of seismic and acoustic waves on marine fauna are significantly mitigated. These precautions are as follows:

- Observance of safety distance: this safety zone is defined by a radius around the source of emission within which the intensity of the sound causes a temporary weakening of the hearing capabilities of marine mammals. According to the specialists, the sensitivity thresholds vary based on the species encountered, however, we can use 180 dB re 1 µPa as the maximum tolerance limit for marine mammals (for Mysticeti and 210 dB re 1 µPa for Odontoceti.) . This means that a distance must be maintained between the ship and the marine mammals so that the intensity of the source reaches them only with a power less than or equal to 180 dB re 1 µPa. In an open ocean, deep sea, marine environment, sound attenuation of around 60dB/km is expected. In order to shift from a power of 200 dB re 1 µPa, the level of the source itself, to a level of 180 dB re 1 µPa or less, the distance separating the boat and the animal must be a minimum of 10 meters from the air guns. In order to ensure the effectiveness of this safety zone, observers are placed on the seismic vessel to ensure, among other things, that no cetaceans are present within 500 meters. This observation occurs before and during activation of the seismic sources in order to apply the appropriate mitigation measures in real time. The observers' role is also to collect data concerning the species, the number and behaviour of the animals observed.

- Progressive startup (or soft start procedure): in order to reduce the acoustic disturbances for marine mammals and any other marine fauna in the seismic survey area to a minimum, the seismic vessel will follow the procedures described in the UK JNCC guidelines when proceeding with a low-power start of the air guns. The details of these procedures is described below. The low-power start or "soft-start " procedure involves the slow and progressive intensification of the power of the air guns over a period of 20 minutes, starting with the lowest intensity and progressively increasing the source strength until the source reaches the maximum power required. In accordance with the responses of marine animals to seismic waves and vibration discussed in the preceding sections, the soft start procedure gives mobile species in close proximity to the vessel enough time to move away before the source is activated to maximum power. This acquisition technique, taking into account the progressive startup of the source, which is now standard, is the result of the desire on the part of the IAGC - International Association of Geophysical Contractors to develop a seismic emission system that minimizes the acoustical effects on marine fauna and more specifically on cetaceans to the greatest extent possible. The "Soft Start Procedure" can be summarized as follows:

  - 20 minutes before maximum firing; for 30 seconds, a cycle with combination of 150, 90 and 40 cubic inches for a firing pressure of 500 Psi;
  - 15 – 10 minutes before maximum firing; for 30 seconds, a cycle gradually using all the gun lines, still a reduced charging pressure.
  - 10 - 5 minutes before maximum firing: for 20 seconds a cycle using all the guns at effective working pressure: 2,000Psi.

The protocol requires that the progressive startup of the air guns at effective working pressure take place at a rate not to exceed 6 dB / minute, between 160 dB and the operating level for the start of acquisition in order to optimize the distance the animals travel.

Marine Mammal Observer: a dedicated Marine Mammals Observer (MMO) will be aboard the survey vessel. The MMO's role will be:

- To provide advice on the application of the JNCC Guidelines;
- To monitor adherence to the Guidelines during airgun operations;
- To keep watch for cetaceans during daylight hours;
- To record and report sightings of marine mammals and turtles; and
- As an additional role, to keep records of fishing activity observed.

Sighting efforts, records of operations and marine mammals and turtle sightings during the pre start-up, soft start and 10 minutes per hour visual observations will be recorded.

In addition to the measures mentioned above, technical measures will be taken to minimize the impact of noise and vibrations, namely:

- Use of firing sequences by synchronous firing of four guns with different volumes, which mitigates the bubble effect through interference that destroys the out-of-phase wave fronts of the different guns;

- Geometry of the source to ensure that the energy is directed vertical to the source and that the energy decreases laterally.

It is important to note that the probability of impact to a marine mammal (i.e., the probability of an actual interaction between the seismic operations and a marine mammal individual) is low. It is expected that these individuals will avoid the areas in which seismic operations are occurring. Furthermore, the noted best management practices will both enhance the animals' ability to avoid the area prior to the onset of full operations as well as enhance the ability of the seismic vessel to alter its operations should an individual be observed in proximity to the vessel. The potential environmental impact of the proposed seismic survey on marine mammals, considering the short duration of the proposed seismic survey, the low probability of interaction with marine mammals, and the implementation of the mitigation and monitoring measures recommended (e.g., visual checks before starting shooting, and use of "soft-start" procedures) is considered to be *insignificant*.

Surface Marking of Streamer

The end of the hydrophone streamer is marked with a tail buoy, the purpose of which is both to give warning to shipping and fishing vessels about the presence of the cable in the water. Additionally, the tail buoy acts as a platform for surface positioning systems so that the location of the end of the cable can be monitored and recorded. The hydrophone cable is not considered to be an environmental hazard, but represents a necessary obstacle for fishing activities.

Impacts Summary and Mitigation measures

Table [6.9] - Summary of Impacts on Wildlife and Humans due to Noise and vibrations

Impact	Impact Assessment	Mitigation
Disturbance to turtles	Possible behavioural effects including avoidance of immediate vicinity of source. Localized and temporary effect, withon 45m of source Insignificant impact.	Soft start minimizes risk of injury. Bathymetry survey frequencies inaudible to most turtles
Disturbance to cetaceans (whales and dolphins).	Behavioural effects (including avoidance behaviour) within up to 46 km of the source (est 105 dB depending on direction and water depth). Temporary and localised effect as vessel moves on. Insignificant impact.	Soft start minimizes risk of injury Observers used to ensure no presence of cetaceans within 500 meters of seismic vessel
Disturbance to dugong	Habitats where dugongs occur in the side scan sonar survey area. Possible behavioural effects including avoidance of immediate vicinity of source. Localized and temporary effect Insignificant impact	Soft start of multi-beam echo sounder and side scan sonar equipment. Observers used to ensure no presence of dugongs within 500 meters of the survey vessel
Disturbance to fish	Localised behavioural effects (including avoidance behaviour) within up to 6 km of the source (est 125 dB). Effect is temporarily due to survey vessel moving on. Insignificant impact.	Soft start minimizes risk of physical damage.
Damage and mortality to eggs, larvae and other effectively immobile pelagic organisms.	Damage and some mortality likely within a few meters of the airguns each time they discharge. Temporary with rapid repopulation Insignificant impact	Wide spacing of survey lines minimizes this impact.
Damage and mortality to benthic organisms directly under survey lines.	Est. Maximum noise level 150 dB at 500m depth. Insignificant impact Few studies show impacts believed to be insignificant	Survey predominantly in very deep water.
Disturbance on marine birds	Food sources may be temporarily relocated for some species Insignificant impact	
Direct disturbance to people	Temporary exclusion of fishing activities in the immediate area of the vessel. Insignificant impact	Sound does not transmit well across air/water interface. Diving does not occur in the survey area.
Indirect effects on fishing	Fishing within or close to the behavioural effects zone may experience temporary changes in catch rate as fish are repelled from the immediate vicinity of the source. Effect is temporary due to survey vessel moving on. Beneficial or adverse depending on fishing location relative to survey and individual species behaviour Insignificant impact	Fishing boats will be advised to move away from the survey line

6.6 IMPACTS DUE TO DISCHARGES TO WATER

6.6.1 Routine Discharges

The following discharges to water will take place from the survey vessel as part of normal vessel operations:

- Domestic waste water (showers, basins)
- Sewage
- Food waste
- Effluents: bilge and/or ballast water, water used to clean the decks,

An estimated total volume of domestic wastewater and sewage produced per day aboard the vessel is 10,000 litres. This is based upon a crew of 50 and an average of 200 litres of waste water and sewage generated per crew member per day. During the course of the 30 day survey approximately 300,000 litres of waste water and sewage will be discharged from the vessel. The *Teknik Perdana* is equipped with a sewage treatment system which will treat all sewage before it is discharged. The residual chlorine content from the sewage treatment system will be between 0.8 and 1.5 mg/l. Biological wastes must be treated to meet the following requirements: BOD_5 50mg/l; and faecal coli forms 250 MPN/100 ml, and suspended solids do not exceed 50 mg/l.Due to the large area, deep water and short duration of the survey there will be no adverse impact on water quality and wildlife due to discharged waste water and treated sewage.

Bilge water passes through an oily water separator before being discharged. Concentration of oil in water discharged is less than 15 ppm in accordance with MARPOL 73/78 Annex 1 requirements for disposal of oil or oily mixtures at sea. Oily water separators are equipped with sensors and an alarm to ensure that the discharge limit is not exceeded. Waste oil recovered from treated machinery space bilge water will be stored for later management at an appropriate shore reception facility or recycled at an apprppriate oil recycling facility in Madagascar. Volumes and rates of bilge water discharge are not known, however due to the large size of the survey area, the bilge water discharge will be spread over a wide area and therefore there will be no adverse impact on water quality and wildlife.

Ballast tanks of the survey vessel will be separated from any hydrocarbon storage areas and no drainage streams contaminated with hydrocarbons will be routed to the ballast tanks. Ballast water is not contaminated with hydrocarbons (or contains less than 15 ppml hydrocarbons) and is discharged away from environmentally sensitive areas is considered to have negligible impact on the marine environment.

Food waste is macerated and discharged overboard in accordance with MARPOL 73/78 Annex V requirements. Once again, due to the large area and deep water in which the survey vessel is operating, there will be no adverse impacts due to the discharge of food waste.

Trash will be compacted and disposed of at a proper waste disposal site on land. Recyclable materials, eg lead batteries, oil, etc, will be processed at proper facilities on land or stored on the vessel for later processing at the vessel's next port of call.

6.6.2 Non-routine (accidental) Discharges

Other potential accidental or non-routine emissions to water are:

- Kerosene spill due to damage to the streamer
- Other oil spill (fuel, lubricants, hydraulic fluid)

The streamer contains approximately 8,000 litres of kerosene. It is divided into 40 sections of 75 meters, each containing approximately 200 litres, so spill sizes are limited to 200 litres per damaged section. Damage to the streamer may be caused by tangling in rough weather, snagging with floating debris, animal bites, rupturing from abrasions, and collisions. This phenomenon occurs infrequently. Streamer depth is an important seismic acquisition parameter which is monitored closely from the vessel, and therefore leaks (which cause the streamer to be less buoyant) can be detected and corrected quickly. Kerosene spills of this magnitude are considered to be of insignificant toxicity to aquatic organisms. It is not inherently biodegradable, but oxidises rapidly by photo-chemical reactions in air. It evaporates rapidly, especially in high temperatures, and so will not form a long term slick on water. Spill modeling shows it evaporate at sea, and then avoid any shore line pollution. Its integrated environmental half life is expected to be approximately 10 days. The main hazard of kerosene is that it is a flammable solvent which may form an explosive mixture with air. Survey vessels follow strict procedures for the handling and storage of kerosene to minimize spills and explosion hazards on the vessel.

Marine diesel is the fuel for the seismic vessel's engines, generators and compressors. Fuel capacity on the seismic vessel *Teknik Perdana* is 620 tons, which is equivalent to approximately 737,000 litres. The vessel also carries approximately 8 tonnes of lubricants and 2 tonnes of hydraulic fluid. All these oils are stored in tanks or drums on board the vessel in accordance with maritime safety requirements.

The vessel will have in place Shipboard Oil Pollution and Emergency Plans (SOPEPs). MARPOL requires vessels to have a system in place that deals with any actual or probable discharge of oil spilled into the marine environment. The SOPEP contains the necessary reporting procedures, actions required to control discharge, and the steps necessary to initiate an external response for any oil-related discharges.

The probability of these oils being spilled at sea is very small for the following reasons. The activity with the highest associated risk of oil spill is refuelling of the vessel. The *Teknik Perdana* has an endurance of 60 days, with 25% fuel reserve still remaining. Since the vessel will take on fuel at the Port of Antsirinanana prior to commencement of the survey, it will not require refuelling during the survey, which effectively removes the risk of refuelling at sea. The only other way that oils could be spilled is through a major accident which ruptures the fuel or other storage tanks, for example a collision or grounding of the vessel. The *Teknik Perdana* is equipped with radar to detect other vessels and a fathometer to monitor water depth as well as a range of facilities for alerting and communicating with other vessels. The *Teknik Perdana* draft is only 5.3 meters which is approximately the same depth as the towed equipment. The water depths in the survey and study area are in excess of 500 meters. When all these mitigating factors are taken into consideration, the probability of an oil spill is extremely small. Although the impact of such a spill has not been assessed and would have the potential to be significant, this risk is effectively mitigated to insignificance by the location of the survey and the mitigation steps taken to avoid such an occurrence in the first place.

Table [6.10] Discharge Summary: Routine and Non-routine

Volume		Source
Routine Discharges		
Domestic waste water and sewage	Estimated 10, 000 liters per day	Laundry, kitchen, showers, basins, toilets
Bilge water	Unknown	Vessels' machinery spaces.
Macerated food waste	Unknown	Kitchen, dining area.
Domestic Trash	Unknown	Domestic
Non-Routine Discharges		
Kerosene (provides buoyancy for streamer)	Typical streamer capacity 8,000 litres. approx. 200 litres per streamer section.	Damage to streamer from fish bites.
Fuel (marine diesel)	Fuel capacity 620 tonnes, approx. 737,000 litres.	Fuel tanks`.
Lubricants	8 tonnes	Storage tanks or drums.
Hydraulic fluid	2 tonnes	Storage tanks or drums.

Table [6.11] Summary of Impacts due to Discharges to Water: Routine and Non-routine

Impact	Impact Assessment	Mitigation
Discharges of waste water and sewage	Small volumes entering a large body of water spread over a large area. Short duration No impact	Sewage is treated in a sewage treatment system before discharge.
Discharge of bilge water (up to 15 ppm oil content).	Small volumes entering a large body of water spread over a large area. Short duration No impact	Oily water is passed through an oily water separator Oil content does not exceed 15 ppm in accordance with MARPOL 73/78 Annex I requirements.
Discharge of food waste	Small volumes entering a large body of water spread over a large area. Short duration No impact	Food is macerated before disposal in accordance with MARPOL 73/78 Annex V.
Possible kerosene leaks from the streamer	Small volumes entering a large body of water, rapid oxidation and evaporation. Short duration. No impact.	Procedures for handling the streamer to minimize spills onboard the vessel. Streamer is divided in self-contained sections to minimize spills at sea. Streamer is monitored by telemetry to ensure leaks are detected and rectified early.
Possible spill of fuel, lubricant, or hydraulic fluid	Potentially significant but can be mitigated to insignificance	Refuelling at sea not necessary Maritime navigation and communications measures safeguard vessel from risk of collision or grounding.

6.7 IMPACTS DUE TO SOLID WASTE

Impacts sources

The following solid wastes are expected to be generated during the course of survey operations:

- Garbage (clean packaging materials, waste paper, wood, glass, plastics, metal containers from domestic and work activities on the vessel)
- Food waste (excess or spoiled food from the kitchen and dining areas of vessel which is not suitable for disposal overboard)
- Restricted or special waste (waste oils, paints, batteries, empty restricted material containers)

Vessels are required by MARPOL 73/78 Annex V regulations to have a garbage management plan and a garbage record book where garbage volumes, types and disposal routes are recorded. A Waste Management Plan – a WMP will be developed by the *Teknik Perdana* owner, TL Geohydrographics Sdn Bhd. The seismic acquisition contractor will prepare an adequate WMP that is consistent with ExxonMobil's current waste management strategy to minimize the generation of waste, and whenever possible, the options of reduce, re-use, and recycling should be preferred to disposal.

The implementation of an effective Waste Management Plan will ensure that wastes are correctly collected, sorted, transported and disposed of and that the marine environment and onshore human populations will not be affected by the treatment and disposal of the waste. The planning and implementation of an effective Waste Management Plan (WMP) will include the investigation of available waste management facilities and contractors within Madagascar and other ports of call. Minimally, all wastes are sorted, compacted and stored according to type and disposal route. All clean packaging materials, waste paper and other clean combustible materials are compacted and stored in bags prior to incineration. Larger food waste that cannot be disposed overboard is stored in bags prior to disposal as garbage. Restricted or special waste is stored in appropriate containers separately from non-restricted wastes. It is disposed at an appropriate certified reception facility during port calls.

In summary, no impacts will arise from inappropriate disposal of solid wastes due to responsible waste management procedures on the vessel. It is worthy to note that successful waste management will depend on a correctly implemented WMP and the availability of appropriate treatment and disposal facilities onshore Madagascar or other ports of call. Where these facilities are not available in Madagascar, the export of waste to the proper facilities in other ports of call should be done.

6.8 IMPACTS DUE TO ENVIRONMENTAL BASELINE SAMPLING

The sampling methodology uses standard operations to reach the seafloor and to sample.

The sediments corer is made with a stainless steel box to collect sediment aliquots. Sampling equipment is decontaminated beforehand. After collecting the sample, the core tube will be carefully sealed. There are no discharges associated with this activity. There is no potential impact due to this sampling method.

For water sampling, the collector, made of Teflon-lined polyvinyl chloride Niskin™ bottle, does not allow any outflow or leakage from targeted depth up to the surface. As seawater is collected, there are no issues of impact.

6.9 SUMMARY OF IMPACTS AND MITIGATION MEASURES

Table [6.12] – IMPACTS FROM PHYSICAL PRESENCE

Impact producing factor	***Mitigation measures***	***Residual Impact (Ecosystem and amenity impact significance)***
The physical presence of the seismic vessel *After mobilizing the vessels to the survey area, the establishment of an exclusion zone is necessary and will prohibit movement of other marine traffic in this area* *The seismic acquisition and coring is estimated to take approximately 30 days* *Potential hindrance to shipping and fishing activities* *Delays to shipping ; Disruption to fishing ; aesthetic or visual impacts* *Potential duration only during the survey period is 30 days*	*Notification and consultation with marine authorities to establish best available navigation route, position and communication information and timing* *Use of safety zone with navigational markers and use of navigation lights (SOLAS and DNV/MRS as standard)* *A program for the monitoring of shipping traffic and fishing activities in the vicinity of the survey area will be described* *Regular communications with port* *Mark the end of hydrophone cable with a tail buoy, in order to give warning to shipping about the presence of the cable in the water* *The excellent communications capability of the survey vessel will ensure that diversions and delays are minimized* *Survey area is primarily >15 km offshore, in deep waters with wide line spacing* *Survey equipment is mostly underwater*	*INSIGNIFICANT* *(Negligible)* *The seismic vessel presence is temporary* *Size of exclusion zone is 1 km radius and its effect on marine traffic is therefore negligible*

Table [6.13] – EMISSIONS GASES OF CONCERN TO THE ENVIRONMENT

Emissions Gas	***Environmental Concern***
Carbon dioxide (CO_2)	*An important natural component of the carbon cycle. It is a component of greenhouse gas.*
Carbon monoxide (CO)	*Derived from incomplete combustion of fossil fuels. It can be toxic at sufficiently high concentrations and is a precursor of ozone, a Green House Gas. Carbon monoxide can be toxic to humans at high concentrations.*
Nitrogen Oxides (NO_x)	*Consists of two gasses, nitrogen dioxide (NO_2) and nitric oxide (NO), formed in combustion processes from both the nitrogen present in fuel and from the oxidation of nitrogen in the air. NO at sufficiently high concentrations can reduce plant growth and may cause visible damage to crops; it can contribute to acidification and the formation of troposphere ozone. Acute exposure to high concentrations of NO_2 can cause breathing problems in humans.*
Nitrous oxide (N_20)	*Is a greenhouse gas and plays an important role in the production of troposphere ozone.*
Methane (CH_4)	*Is a greenhouse gas and plays an important role in the production of troposphere ozone.*
Volatile Organic Compounds (VOCs)	*This term covers thousands of chemical species, some of which are toxic to health at sufficiently high concentrations or are precursors of photochemical pollution, greenhouse gases or stratospheric ozone depletion.*
Sulphur dioxide ($S0_2$)	*Is released during the combustion of sulphur-containing fossil fuels and from certain industrial processes. It can have effects on human health at sufficiently high concentrations and as one of the principal contributors to acidification has an impact on ecosystems and buildings.*

Table [6.14] – IMPACTS FROM AIR EMISSIONS

Impact producing factor	***Mitigation measures***	***Residual Impact (Ecosystem and amenity impact significance)***
Air emissions from seismic vessel, power generation (diesel combustion), logistic and support vessels (diesel) and equipment *The study area is more than 15 km from land therefore air emissions will have no effect on local populations along the coast* *The emissions are spread over a large area that is frequented by other vessels which are also contributing air emissions* *Potential degradation to local air quality and contribution to greenhouse gas* *Estimated project duration: 30 days*	*Use the best available technology to minimize all activities duration* *Ensure regular maintenance of power generators and other engines* *Support vessel and equipment use to be optimized*	*INSIGNIFICANT* *(Negligible)* *Any potential degradation to air quality will be localized to the offshore location and will be rapidly dispersed to the atmosphere by wind*

Table [6.15] – IMPACTS FROM NOISE

Impact producing factor	***Mitigation measures***	***Residual Impact (Ecosystem and amenity impact significance)***
Noise associated with seismic survey *Survey vessel and air guns will generate sub-sea noise throughout the survey area. The noise intensity could be sufficient to cause disturbance to marine fauna.* *Potential sub-sea noise disturbance to marine fauna, particularly marine mammals* *Marine mammals rely heavily on the use of underwater sounds to communicate and to understand their surroundings. The impact of noise generated will be dependent on the characteristics of the noise signal (intensity, frequency, spectrum of sound) and the type of marine mammals present in the study area within hearing range and their sensitivity to underwater noise* *Potential duration: estimated to be 30 days (15 days of seismic, 8 days coring, 7 days of side scan sonar survey plus potential delays)*	*The Shallow Hazard Survey does not require an acoustic source as strong as a normal seismic survey; therefore the noise level of the souirce has been reduced to 200 dB.* *The frequency level of the multi-beam echo sounder and side scan sonar will be inaudible to may species* *Progressive start-up of air guns and other acoustic equipment will be implemented. This soft start will encourage sensitive species to leave the project area, thus minimizing the risk of injury* *Cetaceans, fish, and turtles will likely avoid areas of excessive noise,inimizing the impact* *The vessel will survey at a speed of approximately 4-5 knots. This slow speed will allow most species time to move out of the affected area* *Marine Observers will be placed on the vessel to look for the presence of cetaceans and other sensitive species prior to the start of sound sources. Soft start and survey will not begin if cetaceans are observed within 500 meters of the vessel.* *Wide spacing of survey lines minimizes acquisition time and the impacts* *Diving does not occur in the survey area* *Fishing boats will be advised to move away from the survey line*	*ACCEPTABLE ■/■* *(Minor ■/■)* *A weaker source will have injurous impacts on marine wildlife only within a few meters of the source.* *Noise levels associated with seismic surveys may cause direct impacts on marine wildlife: behavioural disturbance (could be manifested as localised avoidance, abandonment of feeding areas or any other human-induced behavioural change), physical damage and mortality* *The study area is known for the presence of certain whales & dolphins, some of which are rare and all of which are fully protected under national law. The zone is also known to contain rare species of deep sea sharks and ray as well as being on the migration route of humpback whales. However, there are no known feeding or breeding grounds in the study area. Humpback whale migration occurs approximately June – Novemeber, after completion of the survey.* *The duration of the project operations are short (days) and the effects are likely to be localized and temporary, and therefore the impact is classified as 'acceptable'.*

Table [6.16] – IMPACTS FROM DISCHARGES TO SEA

Impact producing factor	***Mitigation measures***	***Residual Impact (Ecosystem and amenity impact significance)***
Non routine discharges from technical / mechanical failure or oil spills *Routine discharges from domestic waste water (showers, basins), sewage, food waste , effluents (bilge water, deck wash)* *Potential impact on sea water quality (chemical characteristics) which could affect marine fauna.* *Potential duration: during 30-day survey period*	*Procedures for handling the streamer to minimize spills onboard the vessel.* *Streamer is divided in self-contained sections to minimize spills at sea. Streamer is monitored by telemetry to ensure leaks are detected and rectified early.* *Sewage is treated in a sewage treatment system before discharge.* *Food waste is macerated before disposal* *Maritime navigation and communications measures safeguard vessel from risk of collision or grounding.* *Use of Marine Observer.*	*INSIGNIFICANT* *(Negligible)* *Good operating practices will ensure that no entrainment of residues from the separator occurs* *(Max.15 ppm in accordance with MARPOL 73/78)*
Discharge of bilge water. *Bilge water collects in the seismic vessel engine room and can contain hydrocarbons. This water is discharged to the sea.* *Potential impact on sea water quality (chemical characteristics) which could affect marine fauna.* *Potential duration: during 30-day survey period*	*All vessels must comply with MARPOL regulation (discharged bilge water must be treated and have <15 ppm oil content).* *Use oily water separator to clean up bilge water*	*INSIGNIFICANT* *(Negligible)* *Discharged bilge water with <15 ppm oil content does not leave a visual trace on the sea surface and will be rapidly dispersed and diluted without affecting marine fauna.*

Impact producing factor	*Mitigation measures*	*Residual Impact (Ecosystem and amenity impact significance)*
***Discharge of ballast water may occur from the survey vessels**.* *Ballast water is taken on and discharged from vessels to compensate for changes in cargo weight thereby maintaining stability. Where the source of ballast water contained in a vessel differs from the local marine environment, the discharge of this ballast water may cause the introduction of foreign marine organisms (e.g. types of phytoplankton, bacteria and larvae) that are not normally present off the northwest coast of Madagascar.* *Potential degradation to seawater quality (biological characteristics) by introducing foreign marine organisms to the environment which could affect indigenous marine fauna.* *Potential duration: during 30-day survey period*	*Ballast tanks of the survey and escort vessels will be separated from any hydrocarbon storage areas and no drainage streams, contaminated with hydrocarbons, will be routed to the ballast tanks.* *De-ballasting shall be undertaken offshore in accordance with IMO guidelines (Convention for the Control and Management of Ships Ballast Water & Sediments, 2004) and away from sensitive environmental areas.* *Ballast water inlets will be fitted with strainers to stop fish entrainment.*	INSIGNIFICANT ■ *(Negligible ■)* *Ballast water is not contaminated with hydrocarbons (or contains less than 15 mg/l hydrocarbons) and is discharged away from environmentally sensitive areas is considered to have negligible impact on the marine environment.* *IMO guidelines reduce the risk of introducing foreign marine organisms to the environment.*
***Discharge of sanitary and domestic waste**.* *An estimated 3962 tons of sanitary and domestic waste will be discharged during the survey campaign.* *Potential impact on aesthetic seawater quality in the survey area and non-compliance with regulation (MARPOL).* *Potential duration: during 30-day survey period*	*The survey vessel will be equipped with sanitary wastewater treatment units. The residual chlorine content will be between 0.8 and 1.5 mg/l.* *Biological wastes must be treated to meet the following requirements: BOD_5 50mg/l; and faecal coli forms 250 MPN/100 ml.* *Biological wastes must be treated to meet the requirement that suspended solids do not exceed 50 mg/l.*	*INSIGNIFICANT ■* *(Negligible ■)* *The discharge of treated domestic waste water will have a negligible impact on water quality and will be rapidly dispersed and diluted without affecting marine fauna.*

Impact producing factor	Mitigation measures	Residual Impact (Ecosystem and amenity impact significance)
Discharge of food wastes *Food waste will be generated on the survey and escort vessels.* *Potential degradation of visible surface water quality Potential duration: during 30-day survey period*	*Food waste will be milled and ground to a size of < 15 mm in diameter prior to discharge (in compliance with the MARPOL convention).*	*INSIGNIFICANT* *(Negligible)* *Milled and ground food waste will rapidly disperse in the marine environment and will be a source of nutrients for fish.* *There will be no visible trace on the sea surface.*
Discharge of small spills and leakages on board. *Fuel and lubricants will be stored onboard* *Risk spillage or leakage if not stored properly.* *Potential impact on sea water quality (chemical characteristics) which could affect marine fauna. Potential duration: 30-days during survey period*	*All storage containers will be segregated and securely stored in accordance with manufacturer's instructions.*	*INSIGNIFICANT* *(Negligible)* *Correct storage and management will ensure no discharge of such substances occurs to the marine environment.*

Table [6.17] – IMPACTS FROM RESTRICTED AND NON-RESTRICTED WASTE DISPOSAL

Impact producing factor	Mitigation measures	Residual Impact (Ecosystem and amenity impact significance)
Restricted waste handling and disposal. *Restricted waste generated during the project may include:* • *liquid hydrocarbon waste (oils, hydraulic fluid and fuel);* • *solid hydrocarbon waste (grease, residual wastes from cleaning);* • *medical waste (sharp/cutting waste);* • *liquid restricted waste (chemical products);* • *solid restricted waste (oil filters, used rags, paint*	*The generation of waste will be minimized wherever possible and the options of re-use and recycling will be preferred to disposal.* *Presence of available waste management facilities and contractors will be investigated prior to the start of the survey project.* *Restricted waste will be collected, sorted and transported to shore (to be defined) for storage and disposal in authorized facilities or taken to a future port of call for disposal. .*	*INSIGNIFICANT* *(Minor/)* *The implementation of an effective Waste Management Plan will ensure that wastes are correctly collected, sorted, transported and disposed of and that the marine environment and onshore human populations will not be affected by the treatment and disposal of the waste.* *Successful waste management will depend on a correctly implemented WMP and the availability of*

residues, aerosol, ink cartridges, empty former chemical product containers); and • *other special wastes (lead acid, mercury from batteries and lamps, nickel/cadmium batteries.* *Potential contamination to the onshore and/or offshore environments leading to risk to flora, fauna and human health.* *Potential duration: during 30-day survey period*	*The use of a local waste disposal sub-contractor may be possible but will be audited prior to contracting and operations monitored thereafter.* *Seismic survey contractors will prepare and implement adequate WMPs that are consistent with ExxonMobil's current waste management strategy.*	*appropriate treatment and disposal facilities onshore Madagascar. Where these facilities are not available, the export of restricted waste will be required.*
Non-restricted waste handling and disposal. *Non-restricted waste generated during the project may include:* • *Biodegradable food waste (see discharges to sea impact),* • *non-metallic waste (cardboard, paper, plastic and wood) and* • *metallic waste.* *Potential direct or indirect pollution of onshore environment. Potential duration: full survey (30 days).*	*Non-restricted waste will be appropriately stored and shipped to land for disposal in an authorized and appropriate land facility.*	*INSIGNIFICANT* *(Negligible)* *The use of proper and verified waste disposal facilities will ensure that no negative impacts reach the marine environment or onshore environment.*
Seafloor sediments samplimg and sea water sampling	*NO IMPACT*	

Table [6.18] – SOCIO ECONOMIC IMPACTS

Impact producing factor	*Impact significance*	*Residual impact*
No employment, even temporary is related to either direct or indirect services required by the seismic program . No Potential direct or indirect impact on local employment opportunities.	*NO IMPACT*	

Socio-economic impacts due to shore operations: the vessel will utilize existing shore facilities in the Port of Antsirinanana and will therefore have no negative socio-economic impacts due to shore based operations.

7.0 CHAPTER 7 - ENVIRONMENTAL MANAGEMENT PLAN

7.1 Intorduction

The Sifaka Geohazard Seismic Project Environmental Management Plan (EMP) that implements the OIMS at a project level, and applies to all activities of the project management team and contractors undertaking the project to ensure adequate management of environmental, health and safety risks. The principal objectives of the process are to provide procedures assign responsibilities and instigate measurement and feedback processes to ensure compliance with the corporate environmental policies and objectives and to ensure that all mitigation measures identified in the present EIA (Chapter 6) would be fully implemented within the required time frame.

EMEP(NM)L fully recognizes the ecologically sensitive character of the Madagascar northwestern coastal and marine environments and is fully committed to take all measures required to develop a responsible and sustainable project in this area.

EMEP(NM)L utilizes its Operations Integrity Management System (OIMS) to provide a systematic foundation and approach to the management of operations, technical standards and all aspects of health, safety and environment for all its activities.

EMEP(NM)L conducts its seismic survey in accordance with the requirements of its OIMS Guidelines for seismic operations as documented in the seismic OIMS Manual. This document complements the Corporate OIMS Framework for its use in the management of seismic operations. The OIMS implements the health, safety and environmental (HSE) policies and objectives set by ExxonMobil to ensure that high operational standards and practices are established and maintained through 11 Elements as shown in table 2.1.

This EMP is applicable to the seismic program for the Sifaka geohazards project and the upper slope bathymetric survey and will serve as a foundation for future seismic programs during the life of the exploration project in the Ampasindava Block. It is also intended to provide an appropriate framework for continuation of environmental management into any subsequent operational phase and guide EMEP(NM)L towards continuous improvement in future seismic operations.

The EIA and EMP contain the following key procedures:

- document the corporate environmental principles and policies relevant to the project;
- identify relevant regulatory agencies and environmental laws/regulations;
- identify the key environmental aspects (including emissions and waste generation) of the project facilities and activities during both the planning and operations stages of the project;
- measure, qualitatively evaluate, or estimate the identified environmental aspects to assess their significance from both a regulatory and a responsible standards perspective;
- establish and regularly update environmental performance objectives/targets consistent with the policy of continuous efforts to prevent pollution;
- develop procedures and programs for the prevention of incidents, responding to accidental releases, controlling to acceptable levels all aspects of the project identified as having potentially significant environmental impacts;

- establish environmental and socio-economic baselines for comparison and assessment of environmental impact;
- assess and mitigate the risk to the environment arising from ongoing, temporary, and planned new activities;
- identify and provide, as needed, training on health, safety and environmental matters;
- ensure adequate communication of environmental issues with both internal and external parties; and
- provide periodic review and assessment of actual performance against environmental performance objectives / targets.

The EMP which will be implemented for the Sifaka Geohazard Seismic Program, Environmental Baseline Study and side Scan Sonar Survey program in the Ampasindava Block and specific Management Plans, such as Waste Management Plan and Monitoring Plan, will be developed in compliance with this EIA and EMEP(NM)L's OIMS. The plans will be distributed to key seismic vessel crew and team members and to sub-contractors, management and others responsible for implementation.

In this Chapter of the EIA, EMEP(NM)L presents an outline of the components of the environmental management system and health and safety policies.

7.2 Summary of potential impacts and risks

Potential impacts generated by the project activities were discussed in Chapter 6. The potential risks are described in Chapter 4.

Project impacts that may occur during normal operations include:

- Physical disturbance from presence of the survey vessels and support equipment;
- Atmospheric emissions from vessel power generation, from logistic and support vessels and equipment engines;
- Noise and vibrations from survey and escort vessels (if utilized) as well as from air guns;
- Routine and non routine discharge to sea of fluid waste, such as bilge and ballast water, sanitary waste water, food waste, cooling water;
- Restricted and non-restricted solid waste disposal.

Potential project impacts that may occur during abnormal operations include:

- Spills due to damage to the streamer or other oil spill (fuel, lubricants, hydraulic fluid)
- Accident & injuries.

The residual impacts identified have been brought to insignificant or acceptable risk levels with the implementation of mitigation measures. The mitigated significance of the non routine discharge impact is evaluated as insignificant.

7.3 Environmental mitigations

The mitigation measures adopted for the geohazard seismic program have been developed in Chapter 6 with particular reference to international industry practice, equipment design constraints and current understanding of the Western Madagascar offshore and Mozambique Channel specific seismic hazards that may be encountered during the planned survey program. The mitigation measures reflect the special sensitivities of the western Madagascar offshore environment.

The activity and operations-specific measures for control and mitigation of effects on the environment resulting from the seismic of the Sifaka Seismic Project, presented in Chapter 6. include design and operational procedures and processes for monitoring, assessing and reporting on the actual impact of the program.

EMEP(NM)L will conduct the seismic survey program in a manner that aims to minimize the adverse impact and optimize the positive impacts of its operations on the natural and social environment. This will be achieved largely through the controlled acquisition techniques, proper handling and disposal of materials and generated wastes, discharges and emissions.

7.4 Preparation for the survey

- Environmental permit and any attached conditions will be obtained from the Office National of Environment.
- At least two weeks before the survey is due to commence, notification of survey details will be sent to the Ministry of Transport (Marine Services); Ministry of Environment, Forest and Tourism through ONE; Ministry of Fisheries and Marine Resources; and Ministry of Mines and Energy through OMNIS.
- Notification of the operations will also be sent to government and fishing authorities in the Region of Sofia, the Port of Mahajanga, and the villages of Analalava, Antsohihy, Nosy Be, and Antsirinanana.
- Survey contractor will be provided with details of the environmental sensitivities of the survey area and procedures they must follow while operating in these waters.
- A suitable candidate for a Marine Observer will be identified.

7.5 Operational Controls and Procedures

The seismic survey vessel will operate in accordance with all applicable laws, standards and conditions while in Malagasy waters, including:

- MARPOL 73/78 standards for waste management and discharges to the marine environment;
- SOLAS requirements for maritime safety;
- Any requirements attached to the Environmental Permit from the ONE;.

In addition, the guidelines below will be adapted to the specific needs of the project

- E&P Forum Health, Safety and Environmental Schedules for Marine Geophysical Operations' (Report No. 6.34/206);
- IAGC 'Marine Geophysical Operations Safety Manual' published by the International Association of Geophysical Contractors (most recent edition);
- IAGC 'Environmental Guidelines for Worldwide Geophysical Operations' (most recent edition);
- UK JNCC 'Guidelines for the Minimization of Acoustic Disturbance to Marine Mammals from Seismic Surveys'.

These recommendations give detailed rules concerning the assembly, stability and safety of the equipment used during the campaign, concerning the personal safety of the personnel, concerning

overall safety on the vessel and concerning the appropriate conduct in case of threat of an incident or in case of an incident. All crew members, including any escort boat crew, will be made aware of and comply with laws, standards and controls applicable to the conduct of this survey before surveying commences.

All equipment on board (including engines, compressors, generators, sewage treatment plant, and oily water separators) will be regularly checked and maintained in accordance with manufacturer's guidelines in order to maximize efficiency and minimize malfunctions and unnecessary discharges to the environment of the survey area.

Wastes will be appropriately segregated and stored onboard prior to disposal at properly equipped port reception facilities. Should such facilities not exist in Madagascar, then wastes will be kept onboard until suitable facilities are found at a future port of call.

7.6 Responsibilities

- Ship's Captain is ultimately responsible for the safety of the vessel and crew.
- EMEP(NM)L Representative onboard the seismic vessel is responsible for ensuring that the seismic contractor abides by the terms of their contract with EMEP(NM)L and meets the requirements for operating in Malagasy waters, including reporting requirements.
- Safety Officer on the vessel is responsible for all HSE incidents logging and reporting and for maintaining a good standard of HSE management on the vessel.

7.7 Rules of conduct to be followed

EMEP(NM)L will make Health, Safety and Environment - HSE- a priority in all survey activities. It also requires that all contractors and subcontractors share this commitment and that they have similar HSE programs in place.

EMEP(NM)L believes that this conduct guarantees the quality and operational efficiency of the work. The following principles direct personnel conduct:

- promote its conviction that all accidents can be avoided;
- train the personnel in all appropriate procedures for safety and environmental conservation;
- supply the vessels with needed systems and facilities; information, documentation and training; and safety equipment;
- develop appropriate emergency and contingency plans with authorized authorities and/or its contractors, conduct drills as needed;
- provide measures to minimize the consequences of accident;
- develop new measures that improve public health, safety and environmental protection;
- support recommendations made by the members of the team;
- service equipment and provide training in order to prevent accidents;
- support the accepted standards for health and safety and appropriate conduct of operations with respect to the environment norms of the oil and geophysical industries and environmental agencies.

7.8 Reporting

In addition to technical and survey progress reporting required by EMEP(NM)L, it is recommended that the seismic vessel carry out the following reporting/documentation:

- Daily contact with the Centre de Surveillance de Peche, the Ports of Antsohihy and Analalava as well as the main port of Mahajanga to update on survey progress and vessel position.
- Logging of all sightings of and contacts with other vessels (e.g. fishing or cargo vessels).
- Logging of all health, safety and environmental accidents and incidents, including any incidents involving cargo ship or fishing vessels in Malagasy waters.
- Logging of any fishing or other equipment removed from the sea for the purpose of clearing a path for the survey vessel. Details to include: location, date, type of equipment and any identifying marks.
- End of survey report to include details of HSE accidents and incidents, and fishing equipment removed as described above.

7.9 Operational Discharge Management Plan

An operational discharge management plan is developed to ensure that the variety of different discharges generated on the seismic survey and on escort vessels are in accordance with national and/or international standards, before their release to the environment. These discharges were discussed in Chapter 6 and include such substances as used fluids, cooling water, sanitary waste water, deck runoff water etc.

Current Malagasy legislation does not contain specific regulation on operational discharges for offshore oil and gas operators. The Malagasy Maritime Code stipulates that the release of waste to territorial waters is not permitted without approval from the authorities. Beyond national legislation, the principal international regulation applicable to operational discharges is that described in the MARPOL convention, signed and ratified by Madagascar Government.

Operational discharge management plan will be developed jointly by EMEP(NM)L and the survey contractor to ensure that responsibilities are appropriated at all necessary levels and management measures are continuously developed as a function of technological and regulatory developments.
The operational discharge management plan will address the following points:

- Identify and indicate the operational discharge points and environmental concerns associated with the discharge;
- Define the objectives for operational discharges in terms of quantities and characteristics (e.g. to be in compliance with MARPOL specifications and EMEP(NM)L standards);
- Define the resources, tools and methods to be used for measuring recording and reporting the operational discharges; and
- Define the means (equipment and procedures) by which operational discharges are treated in order to comply with the discharge limits.

7.10 Waste Management Plan

Solid wastes will be categorized and segregated onboard the seismic vessel.

For the purpose of waste disposal, the waste products produced during the survey operations shall be properly disposed of in accordance with the following guidelines.

EMEP(NM)L will establish waste management contracts, if necessary, in Madagascar. Availability of approved waste treatment facility will be confirmed in close collaboration of ONE, then compliance with international and EMEP(NM)L standards will be done through auditing. The final disposition of waste will reflect international best practice objectives and EMEP(NM)L standards, and ensure that the contractor is licensed to undertake those operations. It is EMEP(NM)L's commitment to ensure that the waste contractors chosen are licensed and capable to carry out the necessary waste treatment or disposal.

Options and time scales for waste disposal or waste storage will be determined by the volumes, types and frequencies of waste shipments to shore and the waste inventories.

The waste management system will meet current Malagasy Law that is consistent with widely accepted international western standards.

Waste Lube Oil

Waste oil shall be contained in the Waste Oil Tank or in properly labeled and sealed drums. It will be recycled or disposed of at a proper facility in Madagascar or transported to a future port of call in properly sealed drums or tote tanks for treatment / disposal at an approved facility.

The empty waste oil drums will be cleaned prior to being released for further use or crushed and sent to a scrap metal facility.

Chemical Drums

Used chemical drums shall be returned to the supplying contractor where possible for re-use or disposal. Drums not returned to the vendor will be rinsed and then crushed or otherwise rendered unusable for carrying liquids by cutting or perforating holes in the drum prior to disposal. Crushed metal drums will be sent to a scrap metal facility. Plastic drums will be perforated and sent to a general waste site.

General Wastes

General garbage will be compacted and disposed of at an approved facility or taken to the next port of call for proper disposal. Used buckets and paint cans shall have their usable contents consumed and shall be crushed in the vessel's trash compactor or by other means prior to being placed in the trash skip.

Lead Acid Batteries

Spent lead-acid batteries shall be recycled or disposed of at a suitable facility on land or remain on the vessel for recycling or disposal at a future port of call. .

Restricted Waste

Wastes that cannot be treated on the vessel or in Madagascar may remain on the vessel for future disposal or be exported following Basel's convention rules.

7.11 Evaluation, Monitoring, Auditing and Reporting

Exxon Mobil Corporate - Reporting Approach

Exxon Mobil Corporation recognizes the importance to communicate clear and consistent disclosure to stakeholders on how its most significant risks and issues are being managed. Exxon Mobil issues reports on Environmental, Health and Safety Performance and on Social Responsibility. Many of selected indicators are applicable to Exploration – Production activities such as:

Table [7.1] - Environmental Performance

Category	Indicator* (aspects)
Discharges	Controlled discharges to Water
Wastes and Residual Materials	Restricted Waste
Emissions CO_2, N_2O, CH_4 …	Greenhouse Gas Emissions

* *Indicators are related to Environmental, Health & Safety, Social and Economic Performance Indicators proposed by OGP – IPIECA – API in Oil & Gas Industry Guidance on Voluntary Sustainability Reporting. April 2005*

The Seismic Survey and EBS Project

A specific Environmental Plan will be developed for this project. The aims and objectives of the Seismic Survey and EBS Project Environmental Management Plan are to consolidate the findings and requirements of the environmental assessment process and technical and contingency planning processes.

The purpose of an environmental monitoring plan is to measure the project impacts and the effectiveness of the mitigation measures implemented. Environmental monitoring is normally carried out before, during and immediately following the completion of each phase of the project activities. Monitoring at these stages allows for the evaluation of the impact of the project activities on the environment and the existence and nature of any residual impacts.

Environmental monitoring involves:

- planning and conducting a survey and sampling program for systematic collection of data relevant to environmental assessment and project environmental management;
- Analysis and interpretation of samples and data collected; and
- Preparation of documentation to support environmental management.

Procedures for monitoring environmental aspects will be developed as follows:

- Identify environmental key indicators and document monitoring information and specify accuracy;
- Specify and document monitoring procedures, locations and frequencies;
- Establish, document and maintain measurement quality control procedures;
- Establish and document procedures for data handling and interpretation;
- Establish and document actions when there is deviation from acceptable environmental performance;
- Incorporate a feedback procedure which allows for improvement of the monitoring procedure where necessary.

The seismic survey and EBS last approximately 30 days. Monitoring documentation will contain presentation and interpretation of the results obtained as well as a record of any actions necessary for the mitigation of deviations from acceptable environmental performance.

7.12 Environmental Objectives and Targets

The key environmental objectives and targets established by EMEP(NM)L for the seismic program are summarized below:

- Apply ExxonMobil standards for exploration activities. Demonstrate compliance with these objectives and standards;
- No fuel or chemical spills into the sea from operations;
- Minimize solid and liquid waste generated from operations;
- Minimize air emissions through appropriate use of fuel and energy generation;
- Record, investigate and learn from all health, safety and environment incidents;
- Implement a health, safety and environment audit program appropriate for the operations. Regular environmental assessments will be undertaken to assess performance and operations; and
- Prepare a final Health, Safety and Environmental report and document all findings from the project for evaluation regarding implementation for subsequent seismic and EBS operations.

7.13 Public consultation process

Order n°6830/2001 defines the methods and procedures for public consultation in environmental evaluation, in application of the provisions of order n° 99-954 (MECIE), and in particular articles 15 to 21, 24, 25 and 27. The fundamental points of this text, which must be emphasized by this EIA, are described in the following paragraphs.

The participation of the public in environmental evaluation is intended to inform those members of the public affected by the project of its existence, and to obtain their opinion on the matter. This can be done either through onsite consultation of the documents, or by public inquest, or by public hearing, and includes a phase for giving information about the project and a consultation phase, during which the opinions of the members of the public affected by the project are gathered.

The ONE will notify the developer of the decision regarding the form that the public participation in the environmental evaluation is to take at least 2 weeks before the public evaluation. For the purpose of information, the decision criteria are as follows:

- A public inquest may be required if the investment of the project in question is of more than 10 billion FMG, or if the geographical area covered by the project affects at least two municipalities, or if the population at the project site location exceeds 10,000 people;
- A public hearing may be required for projects which could give rise to a specific agreement in accordance with the provisions of article 49 of this order, or if the completion of the project requires expropriations for reasons of public use, or population displacements affecting more than 500 people.

7.14 Regulations and requirements

Order n°6830/2001 defines the methods and procedures for public consultation in environmental evaluation, in application of the provisions of order n° 99-954 (MECIE), and in particular articles 15 to 21, 24, 25 and 27. Keys elements for the EIA are reported in Chapter 2.

Based on ONE's determination, EMEP(NM)L may organize a public consultation that will include the following steps:

1. Disclose the nature of the Project and the Public Consultation's organization through legal

publication: notice board or other means;

2. Disclose the Executive Summary of the EIA in Malagasy and French;

3. Create a register in order to collect: statements, remarks and suggestions from the Public;

4. Organize information meeting between Public and EMEP(NM)L.

Based on above decree, the local Authority (with the support of CTE and ONE) shall organize the Public Consultation including documents disclosure. A public organization will designated by ONE as the "local Authority". In order to allow the Public Consultation, ONE or CTE shall remit the following documents to the local Authority: 1) The EIA report; 2) The executive summary into Malagasy and French; 3) All others documents that are compulsory, such as register and notice boards.

CTE should decide which documents should not be disclosed to the Public. Oil & Gas Exploration Production is considered as a strategic national industry.

At the end of Public Consultation, local authority shall confirm the Public Consultation closure into the register and put forward his own opinion. The register should be disclosed to EMEP(NM)L for appropriate answers to public concerns through a memorandum to be established by EMEP(NM)L and sent to ONE within 10 calendar days as from the closure date of the public consultation.

If required, the public consultation cannot be shorter than 10 days and should not exceed 30 days.

All pieces of the Public Consultation file are received by the Ministry of the Environment who gives its approval for the environmental permit.

7.15 Stakeholders identification

One of the major objectives of stakeholder engagement is to establish clear and common mutual understanding to resolve issues and manage expectations with critical stakeholders that are identified for their ability to influence the project and their vulnerability to potential negative impacts.

Communities, private companies and NGOs are among these key stakeholders:

- Local communities along the coast (e.g. fishing activities)
- Private companies using coastal resources: a) four mariculture centers (shrimps); b) Tourism (10 hotels); c) Port and docks activities in Antsohihy, Analalava and Mahajanga (industrial fishing, transport, dock work…)
- Association such as ANGAP and NGOs involved in biodiversity preservation: WCS (Sahamalaza), Birdlife (Mahavavy-Kinkony), Durell (Baie de Baly), MBG (mangrove of Mahajamba), WWF (Oil & Environment program coordinator).

7.16 Former and on-going public engagement

Stakeholders consultation were initiated in November 2007 in the frame of seismic survey EIA preparation. Other meetings could be organized as required. A list of public consultation meetings is shown in Annexe 3.

7.17 Communication Strategy and Policy

A communication strategy will be developed prior to commencement of operations, based on collaboration with

local communities and other stakeholders. .

Information disclosed to public

The EIA Executive Summary (Malagasy & French) should be disclosed at the following locations: i) Sofia and Boeny region offices ii) Districts offices: Analalava, Mahajanga II,. At national and international level, this Executive Summary (Malagasy, French, English versions) will be also available on the ONE web site.

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