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The British Indian Ocean Territory Marine Protected Area Research Strategy Workshop Report

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Executive Summary

On the 1st April 2010, the British Government declared a no take Marine Protected Area (MPA) in the near-pristine Chagos Archipelago - also known as the British Indian Ocean Territory (BIOT). The MPA covers some quarter of a million square miles and is expected to yield numerous benefits related to marine conservation due to its remote location and lack of anthropogenic pressures. Large pelagic MPAs are a potentially powerful tool in marine conservation and thus the main objective of the workshop was to develop a strategic research programme relating to how to strengthen management and optimise conservation within the Chagos/BIOT no-take MPA, in the context of the Indian Ocean.

Four broad thematic areas relating to this aim were addressed:

1. Monitoring target and non-target species inside and outside of the Chagos/BIOT MPA
2. Fishing, fisheries assessments and illegal, unreported and unregulated (IUU) fishing
3. Pelagic MPAs and highly migratory species
4. The contribution of a Chagos/BIOT MPA to a wider regional pelagic MPA network

These themes were approached in a two tier process that aimed to garner expert opinion both remotely and in person. The first stage of the process involved using two rounds of questionnaires as a stage for a broad consultative approach on '**what'** the most important questions relating to pelagic MPAs and the species that are being protected by them are. This informed a more focused two day workshop to consider '**how**' to address these questions and to explore what could feasibly be conducted over a range of timescales. Attendees of the workshop were assigned one of the four themes to address and develop appropriate methodologies.

A three layered - short term (low cost), medium term (medium cost) and long term (high cost) - strategy was developed utilising desk-based and modelling studies, as well as a range of field-based research methods, both at the species and ecosystem level. It was recognised that data may often be sparse when addressing the effects of pelagic MPAs and for a number of species that had previously been affected by fisheries i.e. elasmobranchs, that there was effectively no baseline data and methodologies would have to account for this. Indeed, one of the key questions highlighted during this workshop was how to approach a 'classic' MPA study that determined the changes in established indices of ocean health in the absence of comprehensive monitoring programmes prior to the MPA establishment.

This is the first pelagic MPA of this size and thus it is important that the relevant research is carried out to determine how effective they are in conserving pelagic species and how Chagos/BIOT specifically can provide these data. It is essential that basic monitoring to meet and understand the needs of the region should start as soon as possible. The MPA in Chagos/BIOT will predominantly prevent decline of biodiversity and habitat degradation rather than recovery of species and habitats which are the usual scenario where other MPAs have been established.

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Introduction

1.1. Workshop Objectives

The main objective of the workshop was to develop a strategic research programme which could deliver answers to key questions on how to strengthen management and optimise conservation benefits for the pelagic area and migratory species within the Chagos/BIOT no-take marine protected area (MPA), in the context of the Indian Ocean.

Specific research areas to be addressed during the workshop were identified through the initial United Kingdom Foreign and Commonwealth Office (FCO) consultation on the MPA, and refined during an expert consultation phase of the project. Four areas were identified:

1. Monitoring target and non-target species inside and outside of the Chagos/BIOT MPA.
2. Fishing, fisheries assessments and illegal, unreported and unregulated (IUU) fishing
3. Pelagic MPAs and highly migratory species
4. The contribution of a Chagos/BIOT MPA to a wider regional pelagic MPA network

1.2. Background

The Chagos Archipelago - also known as the British Indian Ocean Territory (BIOT) and subsequently referred to as Chagos/BIOT - is one of the UK's fourteen overseas territories. The archipelago comprises of about 55 islands located in the Indian Ocean and has the greatest marine biodiversity in both the UK, and its territories, by a considerable margin (Sheppard, 2000a), and is of great importance to global biodiversity (Procter and Fleming, 1999). The archipelago's remote location and very low levels of anthropogenic disturbance mean that Chagos/BIOT has some of the cleanest seas in the world (Everaarts et al., 1999). It is also a vital stepping-stone that links the biota of the eastern and western Indian Ocean. The deep oceanic waters around the Chagos/BIOT, out to the 200-mile Environment Preservation and Protection zone (EPPZ), include an exceptional diversity of undersea geological features including submarine mountains, mid-ocean ridges, trenches deeper than 6000m, and a broad abyssal plain (Williamson, 2009).

On the 1st April 2010, the British Government declared "a Marine Protected Area (MPA) in the British Indian Ocean Territory [which] will include a "no-take" marine reserve where commercial fishing will be banned". The MPA covers some quarter of a million square miles and its establishment doubles the global coverage of the world's oceans under protection. The British government recognised that "The territory offers great scope for research in all fields of oceanography, biodiversity and many aspects of climate change, which are core research issues for UK science". Specific objectives for the MPA were not stated by the FCO, but anticipated benefits related to conservation, climate change, science and development - social, economic and political dimensions were also described.

As part of the four month government consultation process, a number of organisations, including the Zoological Society of London (ZSL) and MRAG, prepared detailed responses on the benefits and costs of a no-take MPA on the commercial fisheries within Chagos/BIOT, that included a pelagic fishery for tuna and tuna-like species, and associated bycatch species, and a demersal fishery on the reefs and banks of the archipelago for snappers, emperors and groupers. During the consultation, there was general agreement on the potential environmental benefits of MPAs for resident nearshore species, but a number of important issues and uncertainties arose relating to the conservation benefits of pelagic

MPAs to highly migratory species, such as species of tuna and elasmobranchs, and to the wider pelagic ecosystem. Addressing these concerns and uncertainties will undoubtedly contribute to protected area and fishery management throughout the wider Indian Ocean, and will build on our current understanding of the global benefits of large pelagic MPAs. The workshop to which this report relates focussed on large pelagic MPAs.

Large pelagic MPAs are a potentially powerful tool in marine conservation and it is essential we understand their benefits and limitations and how best to manage them. The current extent, distribution, sizing and spacing of MPAs globally is vastly inadequate, particularly for no-take areas, and especially in light of past, ongoing, and expected future impacts on the oceans. This is especially true for pelagic MPAs. The creation of the Chagos/BIOT MPA is particularly important considering only 0.08% of the world's oceans are no-take protected areas (Wood *et al*., 2008), while international commitments have set global marine protection targets that range from 10-30% (CBD, 2009; United Nations, 2002; Wood *et al*., 2008). In addition, there are only a limited number of sites around the world, of which Chagos/BIOT is one, where establishing a large no-take MPA is practical (Nelson and Bradner, 2010).

While it was not possible to fully address the questions relating to the knowledge gaps relating to open ocean pelagic MPAs before the public consultation for the Chagos/BIOT MPA, there is enormous value in addressing them now to understand the implications of a Chagos/BIOT no-take pelagic MPA, both within it and outside it, and therefore improve management and conservation actions.

2. Methodology

This was a two tier process that aimed to garner expert opinion both remotely and in person, with the first stage of the process informing the content of the second. A Delphi questionnaire (see below) was used as a stage for a broad consultative approach on '**what'** the most important questions relating to pelagic MPAs and the species that are being protected by them are. This informed a more focused workshop to consider '**how**' to address these questions and to explore what could feasibly be conducted over a range of timescales.

2.1 The Delphi process

The Delphi method is a systematic, interactive method that can be used to identify and explore issues through a panel of experts who remain anonymous throughout (e.g. Brown 1968). Experts are selected according to criteria used to establish their expertise in the area of interest and these experts then answer prepared questionnaires in two or more rounds. After each round, the facilitator provides an anonymous summary of the experts' responses together with the reasons they provided for their judgments. The experts are then encouraged to revise their earlier answers in light of the replies of other members of the panel.

The Delphi method is often used for forecasting on the basis that through this process of reflection, predictions by a group of experts will converge on a set of key issues and has been used for exploring natural resource management challenges (e.g. Marcot et al., 1997; Plummer and Armitage 2007; Taylor and Ryder 2003). This method is popular because it is quick, has been shown to be effective in other studies, and requires no new knowledge. As a lead in to the workshop we used the method to identify the key research questions for strengthening management and conservation benefits from BIOT's management framework

in the context of a pelagic (open ocean) marine protected area (MPA) and in the context of the aims of the UK Darwin Initiative.

2.1.1 Selecting the experts

For this application it was recognised that there were essentially three relevant stakeholder groups: scientists/researchers; managers and planners; and resource users. Criteria were established for each group that could be used to assess individuals and identify whether they qualified as an expert in relation to the pelagic system and MPA. A wide search based on ZSL and MRAG's professional knowledge, and consultation with collaborators, was undertaken for relevant experts who might contribute to the exercise. The long list of 130 individuals was reduced to 98 through the application of the criteria.

2.1.2 Identifying the issues

The starting point for a Delphi process is often open-ended, by asking the experts to identify the issues and then refine and prioritise them. However, it was felt that the consultation arranged by the FCO to explore options for an MPA that ran from November 2009 to March 2010 had effectively provided a starting point for the prioritisation. While the submissions to the consultation were widely supportive of the establishment of an MPA, the process had identified a number of key issues, uncertainties and knowledge gaps related to the area and the proposed MPA. The consultation summary document and the outputs from two workshops (Southampton, August 2009 and at Royal Holloway, January 2010) together with the MRAG and ZSL submissions were used to establish the areas that needed to be reviewed and prioritised by the experts. There were essentially three areas that the expert group were asked to consider and these were:

- Issues and effects within Chagos/BIOT of the pelagic MPA that will be important in demonstrating if rehabilitation of the pelagic ecosystem has occurred.
- Issues associated with a Chagos/BIOT pelagic MPA that would demonstrate a contribution to the wider Indian Ocean pelagic ecosystem.
- Challenges or constraints related to the management of pelagic migratory species and biodiversity that a research programme could contribute to addressing.

Associated with each of these questions were a set of statements, each based on the uncertainties and knowledge gaps that the experts could assess in terms of importance and the amount of available information.

The Delphi method was conducted through two rounds of questionnaires sent out to the participants by email and facilitated by non-participants (Appendix 1A and B)

2.2 Round 1

In the first round of the Delphi process members of the expert panel were asked to establish the importance of the issues identified from the consultation and to indicate how much information was available relating to the issue. Scores were assigned using a scale of 1 (low) to 7 (high). Questionnaires were sent out to all 98 of the people on the expert list. Some chose not to participate and a total of 26 completed questionnaires were returned (20 by scientists/researchers; 6 by managers and planners; and 0 by resource users. This represents a reasonable return rate for this sort of exercise (e.g. Skulmoski et al. 2007). Following the first round, the facilitators collated and summarised the results. The intention was to remove those questions that had scored consistently 'low' - it was arbitrarily decided that this would be if more than 75% of respondents scored the issue as less than 4.

However, no issue scored this low consistently and consequently none could be removed. Indeed the results from the first round indicated that all of the issues that had been raised were considered important, although there was more importance attributed in relation to target species than wider ecosystem services. For the majority of issues, respondents indicated that there was little available information.

2.3 Round 2

The second round was used to encourage the experts who responded in Round 1 to reflect on the results of the first round and the importance that was attached to each issue in the light of the feedback from the rest of the group. Experts were provided with a summary that included the mean score, standard deviation and their own score for Round 1. They were then asked if they would like to revise the score. Because none of the issues had been dropped and there was similarity in the importance across the issues, participants were asked to further rank the statements associated with each of the three questions in terms of the immediacy with which the issue should be addressed. This would provide an additional means to prioritise the issues. Questionnaires were sent out to all 26 of the experts who had responded to the first round and 16 were returned (12 by scientists/researchers; 4 by managers and planners; and 0 by resource users).

The responses were again collated and it was seen that there was generally a move towards consensus regarding the scores reflected in a reduction in the standard deviations for the scores. However, there were no major changes to the scores between the rounds. Combining ranking and importance scores allowed issues related to ecosystem services that had scored lower in Round 2 to be dropped because they were viewed by the participants as being of relatively lower priority. The issues that remained were related to the changes in species abundance; the performance of MPAs for highly migratory species; the effect on fishing (including displacement and IUU fishing) and the role of an MPA as part of a wider network of pelagic MPAs. These were then collated to provide four umbrella questions within which were four specific issues (see below). These over-arching questions were used to divide workshop attendees into groups and consequently frame the discussions.

3. Workshop Report

The workshop was held over two days at the Zoological Society of London (ZSL) and was attended by 34 participants from six countries representing science and conservation, management and planning, and the fishing industry. The list of participants and agenda for the workshop are listed in appendix 2 and 3. The meeting was chaired by Professor Jonathan Baillie, Director of Conservation for ZSL.

A short series of plenary presentations set the context for the workshop. Joanne Yeadon from the FCO confirmed that the management framework for the Chagos/BIOT MPA had not yet been defined, but that from 1 April 2010 no further fishing licenses had been issued. Existing licences expire at the end of October 2010 meaning that Chagos/BIOT is effectively a no-take MPA to commercial fishing from that point onwards. Pelagic and demersal recreational fisheries remain operational at present. A panel discussion followed with short presentations from Chris Mees (MRAG Ltd.), Hilario Murua (on behalf of the IOTC), Alex Rogers (ZSL), John Turner (Bangor University) that set the scene for the state of knowledge and data relevant to the workshop discussions. Presentations from this session are provided in appendix 4. Participants then developed a list of data sets and relevant projects to the Chagos/BIOT MPA which are listed in appendix 5.

After an initial plenary session, the attendees were split into four breakout groups that addressed specific subject areas that had been previously defined by the Delphi process.

This report is a summation of what was discussed during the two day work shop and was circulated to all attendees to allow comments and edits to be inserted where they felt appropriate.

3.1 Working Groups Sessions

Attendees were divided into four groups depending upon their area of expertise and each group addressed a specific topic, developed from the Delphi process. The participants of each working group are listed in appendix 6. After the first session, the synthesised results were presented to the workshop as a whole to ensure feedback was gathered from all participants before each group finalised their strategy in the second session.

3.1.1 Group 1: Monitoring target and non-target species inside and outside of the Chagos/BIOT MPA

Introduction

The subject of 'Monitoring target and non-target species inside and outside of the Chagos/BIOT MPA' was divided into sub-sections (see Box 1). Each of these sections was addressed sequentially, though there was a great deal of overlap in some of the monitoring options that were suggested.

Box 1: Questions addressed by breakout group 1

Break Out Group 1: Monitoring target and non-target species inside and outside of the Chagos/BIOT MPA.	
1a	Observation of changes in abundance and distribution of target/non-target species within the Chagos/BIOT MPA.
1b	Establish the distribution and density, and the extent and period of residence, of target/non-target species within Chagos/BIOT, and the impacts of climate change on these populations.
1c	Establish distribution, movement, residence and aggregation of different life-stages of important target/non-target species and vulnerability of life-stages to human impacts throughout their entire range.
1d	Establish the pelagic features and factors (bathymetry, oceanographic effects, etc) that determine the abundance and distribution of migratory species.

1a. Observation of changes in abundance and distribution of target/non-target species within the Chagos/BIOT MPA.

A suggestion that became a key output from all groups was a desk-based study to examine historic data in relation to abundance and distribution of species. This could include catch data from the IOTC database, observer reports, oceanographic data, tagging surveys and published papers. A synthesis of these data would be valuable in collating what is already known about target and non-target species, and equally what data are required and could be

feasibly collected as part of a research strategy. However, early on in the workshop proceedings it became clear that while there were some available catch data on target tuna species (predominantly bigeye, yellowfin and skipjack), non-target species – mainly sharks – were only recorded as far as presence/absence, and this was often not to the species level. Thus the starting point for different species of interest would vary enormously.

In relation to abundance, it was initially suggested that a licensed scientific fishery was initiated. Conditions of the licence would be that a vessel monitoring system (VMS) was installed on all commercial boats issued with a licence and this data was made available, and that observers were present on boats within the Chagos/BIOT MPA. In order that the collected data could be compared to historic data, a long-line fishery was felt to be appropriate in that this was a method previously used in Chagos/BIOT waters. It would also allow hook surveys to be carried out, thus giving a good indication of bycatch e.g. % of catch, species make-up, and allow shark species to be caught. However, during the feedback session to the attendees, the question of whether a scientific fishery could be justified, if so, what scale should it be, i.e. can the MPA be declared a no-take zone if we are to carry out a research fishery of a similar scope to the commercial fishery, and if not, what are alternatives? It was felt that this approach was not appropriate and thus there was discussion of what data would not be gathered as a result. Size class data would be forfeited, which would have been useful in relation to any potential resident populations and juvenile sharks, of which there is little information at present. Continuity of previous data (this would be long-lining, as suggested above) would also be potentially lost; however, the desk study would highlight how contiguous this data would be in reality.

It was discussed whether a modified fish aggregating device (FAD) or mooring could be developed to monitor tuna and sharks. It would likely require separate approaches for each species with acoustics and/or video monitoring being used to assess tuna populations, and multi-level baited video traps being used for sharks. The latter has been used successfully in the deep sea for looking at predatory species and thus it was felt could be adapted similarly for this purpose. While these methods may not offer a direct measure of abundance they could be developed to act as indices if they are repeated within and between years, and both in and outside of the MPA. This data could then be used in concert with other data sets being collected e.g. environmental parameters, and to catch data outside of the MPA. It was suggested that these structures may result in ‘false’ aggregations, which maybe the case, but again, repetitions using the same equipment would mean that the experimental design could ensure they were developed to be comparable.

The development of a tagging programme was felt to be most appropriate for monitoring distribution, and in particular how far these ‘highly migratory’ species roam. While a large scale Regional Tuna Tagging Programme for the Indian Ocean (RTTP-IO) based on mark and recapture techniques carried out off the East coast of Africa, off Madagascar, in the Seychelles EEZ and elsewhere, there have been no tagging studies with releases made within Chagos/BIOT. It was felt that archival and satellite tags would offer the best quality data in relation to time and economic expenditure, and for this a separate, most likely sports fishing vessel, would be required. It was envisaged that both tuna and sharks would be tagged in this study and that tissue samples would also be taken in order to carry out genetic population/stock structure analysis.

‘Ecological Niche Modelling’ was described by Dr John Turner during the plenary panel session as a way of estimating the favoured habitat of species using oceanographic, environmental and species behavioural data, and this provides another option for predicting

the distribution of key species in the Chagos/BIOT MPA.

1b. Establish the distribution and density, and the extent and period of residence, of target / non-target species within Chagos/BIOT, and the impacts of climate change on these populations.

Again, a desk-based analysis of historical data was felt to be the most productive starting point to this research question. Subsequently, the residence – and/or the proportion of time - of species in the Chagos/BIOT MPA could be determined as part of the tagging programme and/or a genetic study and the distribution by both tagging methods described above. It is possible that the use of modified FADs/mooring could be used to develop an index of density, but this would need to be carried out over a wide spatial and temporal scale to offer an indication of changes in density. A 'habitat suitability model' was also suggested as a way of estimating distribution and density of species, however, this may have to work on a regional scale as opposed to the fine scale, taking into consideration the distances some of them could potentially cover. Correlating these methods with environmental and oceanographic data would allow an analysis of how climate change affects the density, distribution and residence of focal species.

Obviously the use of remote tags would aid this aspect of the research programme by offering insight into distribution and therefore residency within the MPA, and while performing the tagging it may be possible to carry out dietary studies of species. By monitoring gut content, there is potential to determine whether a species' diet is changing in response to changing patterns of their movement and/or potential prey species.

1c. Establish distribution, movement, residence and aggregation of different life-stages of important target/non-target species and vulnerability of life-stages to human impacts throughout their entire range.

Historic data from IOTC (length frequency data could give an estimate of size classes of tuna species, for example) and studies that have examined the life stages of tuna, tuna-like species and elasmobranchs will be very important, due to the dearth of information on juveniles of these species, especially in pelagic elasmobranchs. Examining other fisheries, for example the Sri Lankan shark fishery, could give an indication of size classes of non-target species in the Indian Ocean as a whole, and their distribution.

The use of small trawl nets e.g. Bongo nets have been shown to be effective in collecting plankton, and could be used to determine the distribution of larvae and eggs of species of interest. This kind of sampling could also be carried out from a small boat. This would work well for tuna species, however, for open ocean elasmobranchs, some of which are viviparous or ovoviviparous, this method would not be suitable.

It was felt that this research area was the one that was least studied and the methodology least developed, making it potentially the most difficult to address.

1d. Establish the pelagic features and factors (bathymetry, oceanographic effects, etc) that determine the abundance and distribution of migratory species.

Some historic data are known to be available, and therefore a desk based study to overlay bathymetric and oceanographic data with biological data would be extremely beneficial. However, as little is known about the Chagos/BIOT area, gathering data would require a

broad-scale, synoptic research cruise using a dedicated vessel. It would be equipped to carry out oceanographic monitoring (conductivity, temperature, and depth (CTD), current etc.), acoustic surveys for bathymetry and multi-depth biological trawls. This would act as a baseline survey of pelagic ecology in the region generally, and could be linked with data gathered using other methods, such as tagging.

Synthesis

The structure of the research programme for this section was suggested as follows:

- Short term (Low cost)
  - Desk based study
  - Ecological niche modelling
- Medium term (Medium cost)
  - FAD/Mooring study
  - Tagging study
- Long term (High cost)
  - Ecosystem health research cruise

It should be noted that there was cross over with other groups' strategies.

In the short-term, and as outlined in the sections detailing the approach to questions for breakout group 1, 1a-1d above, a desk-based study collating available data on target and non-target species in Chagos/BIOT and the Indian Ocean as whole was felt to be essential to understanding the direct monitoring that is required, where this should be carried out, and what external factors may be affecting the movement of pelagic species. By synthesising data from the IOTC database (tuna catches within Chagos/BIOT; hook surveys; fisheries trends outside of Chagos/BIOT), available oceanographic and bathymetric data, tagging studies and other published literature of relevance, a targeted research and monitoring strategy can be fully developed. In addition to this, the previously discussed Ecological Niche Model would be implemented for species of interest.

In relation to cost, it is possible that these two activities (desk study/Ecological Niche Modelling) could be carried out by MSc/MRes students – possibly even beginning in the 2010-2011 academic year. Alternatively, ZSL has a strong intern programme which attracts very high quality MSc level applicants for 6 month tenures. Both of these options would require minimal costs.

Projects over the medium term would require new methods – mooring video/acoustic monitoring – and therefore, there would have to be pilot/development phases to this aspect of the programme. These methods would need further development but this technology has been used previously and we would aim to develop such monitoring in concert with those who have established similar protocols. It was noted by a participant that they had FADs in deep waters (~2,000m) off the Maldives, that they had cost $12,000 per unit (including deployment), and had a lifespan of up to 24 months, however, these costs did not include instrumentation.

The second medium term project would be the tagging study. It was agreed that satellite and/or archival tags would be preferred, and that study species should be prioritised by both threat and ecology. Consequently, species would be chosen that are threatened by fisheries, but not so scarce they can not be caught, and that are representative of ecological niches of other species. Two shark species that were discussed were the oceanic white-tip, because of their pelagic nature, and the silky, because they inhabit the transitional zone between open-ocean and shallower reefs, a habitat that little is known in Chagos/BIOT. It may be possible to set up hydrophone arrays closer to coastal areas or shallow sea mounts to allow the use of acoustic tags if certain species are known to show site fidelity. We would aim to take samples for genetic studies, and carry out non-terminal gut rinses for dietary analysis from individuals that were tagged.

Costing of this exercise should be straightforward with the price of tags being well-established and the costs for hiring sports-fishing boat and staff time also being available. It was envisaged that a grant of £250K-500K would be required for a three year study and that this would take 12-18 months to acquire.

The long term study would be to take the ecosystem health approach using a large scale baseline pelagic survey from a research cruise vessel. This would be as described above with a suite of monitoring taking place (CTD/acoustics/plankton and nekton trawls) It is also possible that a separate benthic cruise could be carried out, on which a ROV would be utilised. This would cost in the region of ~£2M and require 3 years to organise. It would need a consortium bid to develop.

3.1.2 Group 2: Fishing, fisheries assessments and IUU fishing

Introduction

Although the focus of Breakout Group 2 was broadly spread over fishing, fisheries assessments and IUU fishing (see, Box 2) the latter received by far the most attention. There was a fine line in the discussion between *management* questions and *research* questions, although it was often the case that discussion of possible management approaches or surveillance strategies prompted debate about what information was and was not available, and therefore what kind of research would be necessary to construct an effective monitoring, control and surveillance (MCS) framework. As the remit of this workshop was to develop a research agenda, the discussion was constrained to research as much as possible.

The group began by reviewing the four questions 2a-d and briefly sorting their importance and establishing commonalities between them. A logical progression was seen between 2b and 2a, and these questions were addressed in this reverse order. Consequently, discussion of 2b informed the second part of 2a. The group also felt early on that 2d was probably not as important as the other three questions, largely because the majority of the group felt they could already adequately answer the essence of the question – which is that loss of Chagos/BIOT data would have little effect on IOTC assessments - and as a result this question received only cursory attention on the first day, and no attention on the second.

Box 2: The questions addressed by breakout group 2

Fishing, fisheries assessments and IUU fishing	
2b	Quantify the potential incentive value for IUU fishing created by the presence of an MPA, the risks from IUU fishing and their relative impact on biodiversity and conservation benefits of the Chagos/BIOT MPA.
2a	Determine the current efficiency of detecting and combating IUU fishing within the Chagos/BIOT MPA and define the level of surveillance needed to effectively eliminate IUU activity.
2c	Establish the effect of the Chagos/BIOT MPA on catch rates and yields in the Indian Ocean tuna fishery for both target and non-target species (including any displacement effects).
2d	Establish the data required from Chagos/BIOT to enable IOTC to assess the status of important target species in the region and to establish the effect of the loss of data and analysis from Chagos/BIOT on IOTC's assessments.

2b. Quantify the potential incentive value for IUU fishing created by the presence of an MPA, the risks from IUU fishing and their relative impact on biodiversity and conservation benefits of the Chagos/BIOT MPA.

This question was broken into two obvious parts. The second part of the question was discussed first, and was distilled down to: ***"****What are the key risks (including the most vulnerable species and areas), and what are the drivers, of IUU within Chagos/BIOT?"*
The group assumed the majority - if not all - of this research question would be approached through a desk-based study, looking at the following elements:

1. What do we know about current IUU activity?
   - Which species are targeted?
   - Who? (e.g. illegal Sri Lankan long-liners; infractions by licensed vessels within Chagos/BIOT)
   - Where? (e.g. inshore; on the Chagos/BIOT boundary)
   - How do IUU vessels operate? (e.g. vessel coordination/communication)
   - Where are IUU landings marketed?

Most of this information is already available to MRAG through surveillance reports, patrol vessel logs, data on seizures, arrests and warnings, etc. Much of these data have already been put into a database, although information pre-2002 is still only in paper reports. A researcher would need to go through this material and produce a report on past and current IUU. It was agreed that such a review might draw out trends in IUU activity, including potential IUU 'hotspots' and species caught. Identification of markets linked to IUU fishing would also be necessary. This whole process would also act as a synthesis of baseline intelligence for future enforcement operations.

2. What do we know about why IUU occurs?
   - What are the social and economic drivers for IUU?
   - What are the political and institutional influences?

Current information is based mainly on interviews with arrested fishers within Chagos/BIOT. Charles Sheppard has a PhD student working in Sri Lanka who may shed light on this subject, however, there appeared to be little substantial information offered by the group in relation to these questions.

3. How can we expect IUU to change in the future?
    - How might IUU operations change (e.g. no change in illegal Sri Lankan long-liners, greater threat from licensed fleet, once excluded from Chagos/BIOT?)
    - Shift in market demand for certain species?
    - Political or institutional changes?

Whereas historical IUU fishing has been mainly carried out by Sri Lankan illegal vessels, there was concern that the creation of an MPA will automatically increase the risk of IUU fishing by legal fleets (purse seine/longline). It was expected that if this were to happen it would mainly take the form of illegal incursions over the MPA boundary.

Opinion was mixed as to how legal fleets will respond, and to answer this question it will be necessary to engage with the licensed fishing industry further. There was some indication coming from industry representatives at the workshop that fishers are likely to comply with the Chagos/BIOT MPA and not violate the boundaries to catch fish, apparently both out of principal and through fear of reprimand. However, this is anecdotal and/or based on the assumption that licensed fishers are all naturally risk averse, and so a more scientifically plausible modelling approach, which does not make this assumption by default, would be necessary. This approach would require some form of social research e.g. interviews and questionnaires with fishers and/or industry.

Several additional issues are likely to influence future IUU. For example, piracy in the West Indian Ocean (WIO) may impact on the distribution of the licensed fleet and the area available to catch tuna. Some amount of work has already been done on the fishing displacement caused by this piracy (e.g. Kaplan *et al*. 2009; Edwards, 2009). However, it was felt by the group that this issue warrants further study as it is was though likely to be an indirect driver of IUU and should be included in any modelling (see below).

Future IUU is also likely to be influenced by the response of tuna and shark stocks (the two main pelagic species taken) to the closure, both inside and outside Chagos/BIOT. The group did not discuss how this response would be measured or monitored as this fell within the discussion of the other groups. However, the group felt there would likely be a distinction between the *actual* response of the resource and the *perceived* response, as it will be the latter which directly influences fishers' behaviour. Some studies have been published on this idea, mostly in a coastal fisheries/MPA context, which would require a literature review. However, it is likely that wider social research would be necessary to properly investigate this – again most likely based on interviews and questionnaires.

The first part of question 2b was discussed next, and was phrased as: *"How can we determine the potential incentive value for IUU fishing created by the presence of an MPA?"* The group suggested a modelling exercise be used to predict future IUU risks and ultimately inform future surveillance strategy (which overlaps in the second question 2a). The desk study detailed above would be used to generate modelling assumptions about fisher's incentives to fish illegally, and also to parameterise the models.

One possible approach would be to use agent-based models - constructed within a Bayesian Belief Network - to represent the different fleets involved in fishing the areas adjacent to Chagos/BIOT. There was discussion as to whether this approach would have equal facility to model both the legal purse seine and long-line fleet *and* the illegal Sri Lankan fleet, or whether modelling the latter would prove too difficult. The group did not reach a consensus on this, although further investigation under the earlier desk-based study would help to elucidate this.

VMS data is not readily available for detailed spatial modelling of the licensed fleet (and completely absent for the illegal Sri Lankan fleet), and anyway there are issues with how to control for the annual variation in spatial distribution of the fleet (discussed later under displacement). Therefore, modelling the risks of future IUU spatially was thought to be unfeasible. Consequently any modelling would be restricted to predicting: 1) the likelihood of illegal fleets entering Chagos/BIOT, or of licensed vessels violating the MPA boundary; 2) the trend in volume and composition of species taken illegally. The former could be based on instrumental theory of behaviour (e.g. cost/benefit analysis of fishing illegally – akin to Control of Foreign Fishing project [MRAG, 1995]), taking into account the range of social and institutional drivers reviewed in the desk-study.

Needless to say, any kind of modelling approach still requires substantial development and planning.

2a. Determine the current efficiency of detecting and combating IUU fishing within the Chagos/BIOT MPA and define the level of surveillance needed to effectively eliminate IUU activity.

Regarding the second part of this question there is clear overlap with the question 2b. The question was phrased as "*How would we define the level of surveillance required to effectively deter IUU activity?"*

The group made a logical connection between 2b and 2a, with much of the output from the former informing the latter, but it was made clear very early in the discussion that "*effectively eliminate IUU activity*" should be changed to "*effectively deter IUU activity*"

The modelling approach outlined above would provide an indication of the risk from IUU from various fleets, even if it could not provide explicit spatial predictions of where IUU might occur. However, this might be inferred from historical and ongoing logbook catch records. The group agreed that this process would be useful to define at the least the order of magnitude of IUU likely to occur within Chagos/BIOT, and to identify the high risk fleets and the IUU-vulnerable species.

The group also discussed how evaluation and analysis of on going surveillance and enforcement operations might allow for adaptation of management in response to changing IUU concerns. For example, periodic aerial audits of IUU activity could be used to evaluate and re-distribute conventional vessel-based enforcement. However, this issue was not discussed further as it is more relevant to the development of a management framework. Furthermore, a key output of the desk-based and modelling studies, and something the group felt would be crucial in defining the level of surveillance required at any given time, would be the creation of a series of indicators of IUU.

The remaining part of the question was *"How to determine the current efficiency of MCS in Chagos/BIOT?"* Clearly understanding how effective current surveillance is in detecting and combating IUU is very important in determining how future MCS might operate. Two methods were suggested to review the current MCS performance.

1. A method based on Agnew & Kirkwood (2005), who developed a method for IUU catches of fish and bycatch of birds which utilises fisheries protection vessel (FPV) cruise data. The method takes explicit account of both 'seen' and 'unseen' IUU fishing

by using a simulation model which provides statistic estimates of, and confidence intervals for, fish and bird catches by IUU vessels.

A similar modelling technique would presumably be possible for application in Chagos/BIOT, using cruise data from the Chagos/BIOT patrol vessel (BPV). This would take the form of a desk-based/modelling study and be undertaken over the short term.

2. An audit-style method, using aerial or satellite reconnaissance alongside the current BPV to gauge its actual surveillance capacity. This method has obvious limitations and costs associated with it. Satellite or aerial imagery would be difficult or, in some areas, impossible to obtain, and would also be very expensive. There was also mentioned the option of using military drones to survey the inshore areas, although the group's knowledge on this was extremely limited, and it costs and feasibility were uncertain.

Another aspect of current enforcement was also discussed is the effect of a network of licensed vessels acting as surveillance net. This extent of this activity is currently unknown, although MRAG and the FCO hold some information on 'tip-offs' both from licensed fishing vessels and recreational yachts. Further investigation would be necessary, presumably through a desk-based review of the available records.

2c Establish the effect of the Chagos/BIOT MPA on catch rates and yields in the Indian Ocean tuna fishery for both target and non-target species (including any displacement effects).

The group focused on displacement effects, but had reservations from the start about how this question might be answered, or indeed if it could be answered adequately at all. The group questioned the need for research into how tuna catch rates and yields would respond to closure of the Chagos/BIOT FCMZ. If tuna are not solely resident in Chagos/BIOT, and remain 'available' to fishing activity outside of the current closure, Indian Ocean tuna yield may not be significantly affected. The same argument was put forward for highly mobile shark species, currently taken as by-catch and this issue would require greater attention to determine what the period of residency in the Chagos/BIOT MPA for target and non-target species is.

Given these concerns, the effect of displacement on bycatch species following a shift in gear type was thought to be a more appropriate research question. The argument for this is the greater use of FADs outside of Chagos/BIOT, which have been shown to have a higher rate of by-catch associated with them (mainly shark) tend to facilitate the catch of smaller age classes. However, the group highlighted the issue of noise in the data which might mask the impacts and effects of a displacement in fishing effort/shift in gear type. The major confounding factors are:

- Natural variation in fishing area and in annual catches of tuna and non-tuna species;
- Piracy from Somalia spreading further into the WIO, or alternatively contracting back toward the East African coast;
- Poor or absent data from artisanal fleets meaning that changes in catches or effort go unnoticed;
- Changes in data collection/resolution within IOTC fleets (e.g. observer coverage, reporting of by-catch species).

There was discussion on how to overcome some of these issues, although no real solutions were forthcoming in the time available. The issue of displacement is an important one, and it is clear that a feasibility study is necessary.

2d Establish the data required from Chagos/BIOT to enable IOTC to assess the status of important target species in the region and to establish the effect of the loss of data and analysis from Chagos/BIOT on IOTC's assessments.

This question received the least attention from the group as it was deemed to be relatively unimportant. This view was based on largely on the option of industry (Michel Goujon and Julio Moron) who were most informed about the type of data coming from Chagos/BIOT and IOTC stock assessments. Although information on commercial fishing would no longer be available from Chagos/BIOT, the same vessels may continue fishing outside of Chagos/BIOT - and may be reporting the same information. However, this is assuming that target and non-target species are not spending all or most or their time in the Chagos/BIOT MPA and that if the vessels would be catching the same tuna as they would have been catching within the MPA, there would therefore be no effect on IOTC assessments.

There would be more of an issue for shark assessments, which the IOTC-WPEB has recommended should begin[1]. In particular (taking into account their importance to fisheries and declines in their catch rates) the WPEB considered that immediate research and assessment efforts should be directed towards blue, oceanic white-tip and silky sharks. WPEB also recommended that information of potential value for stock assessment of whale sharks should be compiled. Work of this kind will very likely be carried out under the research strategy suggested by Group 1 e.g. tagging of pelagic sharks. Although the same arguments regarding fishing effort being displaced outside the Chagos/BIOT MPA might be applied to sharks, the level of reporting outside of the MPA is currently not as great as it is under the conditions of license within it. This is likely to mean a reduction in information available to the assessment process, although the group debated what real impact this would have given the small proportion of shark historically taken within the Chagos/BIOT MPA compared to the entire IO area, and the poor quality of data that were gathered during the fishery.

Synthesis

The output from Group 2 indicated that two main studies had to take place:

- Short term (Low cost)
  - Desk based study
- Medium term (Low cost)
  - Modelling study
  - Socio-economic study

In several of the questions that were raised it was clear that work developed by Group 1 in relation to the residency of target and non-target species would inform the medium term study.

[1] http://iotc.org/files/proceedings/2009/wpeb/IOTC-2009-WPEB-R%5BE%5D.pdf

As with Group 1 it is key that a data gathering and analysis, desk-based study is carried out as a first step. In relation to Group 2's questions this would apply to information such as surveillance reports, patrol vessel logs, data on seizures, arrests and warnings, etc. Examining published research on IUU generally would provide background to the data we have available and identify where potential gaps may lie.

In the medium term it was strongly suggested that using the desk-based study, and the data yielded to inform a modelling project would prove beneficial. Outputs would include determining how likely IUU would be in the future and what the volume and species composition may be; prediction of future IUU risks; development of future surveillance strategy; and spatial predictions of where IUU might occur. Another option, which would yield information that is presently lacking would be to carry out interviews with and/or develop questionnaires for fishers / fishing companies.

3.1.3 Group 3: Pelagic MPAs and highly migratory species

Introduction

The questions Group 3 examined related to the impacts of pelagic MPAs for highly migratory species, looking at the 'performance' (3a), 'effectiveness' (3b), and 'benefits' (3c) of the MPA. A fourth question examined the contribution of the Chagos/BIOT MPA relative to other forms of management, and it was considered that answers to this question would be informed by the previous three (see Box 3). The group noted overlap with the questions of Group 1 (see questions 1a, 1b and 1c) and Group 4 (see 4a, 4c and 4d). Group 2 Question 2c was also relevant. However it was noted that the emphasis of the groups was different and particularly with Groups 1 and 4 being more focussed on monitoring whilst Group 3 would look at means of evaluating the impact parameters (performance, effectiveness, benefits). It was also considered that information arising from monitoring activities related to the questions of the other groups would inform this group and help parameterise models.

Whilst the group initially discussed the questions separately, it was clear that the issues for each question were similar and cross cutting issues are presented in the synthesis.

Box 3: The questions addressed by breakout group 3

Pelagic MPAs and highly migratory species	
3a	Establish the performance of open ocean no-take areas compared to other management applied separately or together.
3b	Establish how effective the Chagos/BIOT MPA is as a scientific reference site for highly migratory species that can be exploited throughout their range.
3c	Identify the size of MPA/proportion of migratory population required to provide conservation benefits for highly migratory species.
3d	Establish the extent that the Chagos/BIOT MPA adds to the protection already in place or planned (through IOTC, through Chagos/BIOT fisheries and environmental legislation) for target and non-target species.

3a. Establish the performance of open ocean no-take areas compared to other management applied separately or together.

The Chagos/BIOT MPA is unprecedented in terms of its size; therefore there are very limited data from which to draw on in terms of informing our understanding of how such large MPAs protect species over and above other potential management regimes. Nonetheless, at a global scale, it is clear that most MPAs are insufficiently large, and that bigger MPAs are required due to the scales of species dispersal and movement (e.g. Mora et al. 2006). Thus to address the question of performance it is necessary to gather data on both the home range and movement parameters of individual species relative to the size of the MPA, as this may affect the level of protection afforded. The group thus discussed candidate species for study (see Synthesis, below) whilst the relative size an MPA needed to be to be effective for species identified as being highly migratory is discussed in question 3c.

The group noted that questions 3b-d explicitly examine BIOT in the context of the wider Indian Ocean and the geographic range of highly migratory species but that question 3a was less explicit. Thus the group discussed whether the question of 'performance' should be considered as that within the BIOT conservation and management zone (with parallels to what Group 1 would discuss) or the performance of the Chagos/BIOT MPA in the wider context (with parallels to what Group 4 would discuss). Both were considered to be of interest although the emphasis of the group's discussions was on the latter.

Simulation modelling approaches were considered a useful way of examining this question but it was noted that in order to parameterise the simulation models new information on the life history parameters of selected study species may be required. Tagging data, fisheries data, and biometric monitoring of study species could also contribute. 'Performance' of a protected area relative to other management tools could be measured against defined indicators and reference points, either for individual species or for the ecosystem health as a whole. These parameters were not pre-defined by the group as they would be specific to the assessment models used.

3b. Establish how effective the Chagos/BIOT MPA is as a scientific reference site for highly migratory species that can be exploited throughout their range.

If Chagos/BIOT is to act as a reference site the issues are similar to 3a and relate to range and rate of movement of species relative to the MPA (or equivalently residency, the proportion of time spent within the no-take area). Where the rate of movement of a fish is substantial, and the time spent within the no take area is short, as inferred for some tuna from historical catch data in and around BIOT, then any function as a reference site will be reduced for these species. To address the question of residency the group proposed monitoring the study species through tagging, and genetic and chemical sampling. Biometric data could be recorded for fish captured for these studies and where possible life history parameters derived (see also 3c below).

3c. Identify the size of MPA/proportion of migratory population required to provide conservation benefits for highly migratory species.

Existing historical analyses of IOTC data between 1994 and 2005 made available in background material to the workshop (Annexes 1 and 2 of MRAG, 2010) describe the catches and indicate the distribution of tuna harvested throughout the Indian Ocean on a monthly basis. The same level of detail is not currently available for non target species such

as elasmobranchs. Purse seine catch data shows that high catches of tuna only occur inside the BIOT EPPZ during December and January, and that the catch is highly variable from year to year (Figure 9, MRAG 2010). Longline data reveal a low level of tuna catches in BIOT throughout the year. Whilst IOTC data describe the distribution and catch of tunas in the Indian Ocean little is known about residency times of tunas in a particular area or the proportion and demographics of the stock that may not follow 'typical' migration patterns[2]. Mark recapture results of the Regional Tuna Tagging Programme for the Indian Ocean (RTTP-IO) indicate movement of yellowfin, bigeye and skipjack tunas over great distances in the West Indian Ocean (e.g. Figures 2-4 of MRAG, 2010), but it is not yet known how this relates to residency time.

In this context questions on the size of the MPA relate to whether a discrete resident sub-population of candidate species selected for study exists within BIOT. If there is a resident sub-population in an area then protecting that area will prevent that population being exploited. If the populations (e.g. tuna or elasmobranchs) are fully mixed, however, and there is no sub-population within a discrete area, then the question relates to the proportion of time that individuals spend within the MPA (i.e. residency time) and which may have an effect on the level of protection. Thus further research must be conducted to assess the level of protection afforded to migratory species based on the period of residency in the MPA, mobility, the proportion of the home range that must be protected in order to provide conservation benefits, and other attributes. In particular, one must address the question of the level of protection for individual tunas for various increments of their home range sizes being within the MPA, spawning areas, seasonal movements etc.

To address this question the group proposed tagging, genetic and chemical studies to better understand residency, the mobility and site fidelity of individual species. For a defined population or sub-population within a particular range, simulation modelling approaches were proposed to explore the question of the size of area that would need to be protected to provide conservation benefits, noting potential data limitations for non-target species.

<u>3d. Establish the extent that the Chagos/BIOT MPA adds to the protection already in place or planned (through IOTC, through BIOT fisheries and environmental legislation) for target and non-target species.</u>

This question will be informed by 3a-c. Separating cause and effect was considered to be the main constraint to addressing this question. In addition to separating effects attributable to the Chagos/BIOT MPA from other management measures in place, the group discussed the fact that the introduction of an MPA that excludes fishing activity will modify the behaviour of the fishing fleet which would also need to be taken into account. Limited data to test the importance of this effect exist. Plenary discussions echoed this point suggesting that identifying the drivers of this change will be a complex process given other variables including IOTC management activities, Somali Piracy, economic and commercial drivers, and the MPA.

Simulation modelling was considered by the group to be a useful approach to predict what the effects of the Chagos/BIOT MPA would be relative to the protection already in place or planned. To address the question of the extent to which fleet behaviour is modified by the

[2] 'Typical' migration patterns of tuna have been inferred from movements of purse seine vessels around the western Indian Ocean that follow a cyclical pattern passing through BIOT in December-January (see MRAG 2010, Annex 2).

MPA there is a need to implement adequate monitoring programmes. It may then be possible to account for changing fleet dynamics within the simulation model.

Synthesis.

Priority species for study

The questions for group 3 related to highly migratory species (3b, c) and to target and non target species of the tuna fisheries (3d) and the relative effects of MPAs compared to other fisheries management tools on those species. There was some debate as to what species to prioritise research on, particularly in a budget limited situation.

- For tuna species targeted by the fisheries it is important to determine what effect an MPA the size of the Chagos/BIOT would have on the species considering period and proportion of residency, mobility and home range.

- For non target species the group debated whether the focus should be on species with a higher residency time in the Chagos/BIOT MPA, or the more mobile / lower residency time species. The main focus of the group was on the impacts of the MPA within the wider Indian Ocean and thus the priority should be on the more mobile species to be identified through initial desk based studies (e.g. Oceanic Whitetip shark). It was noted that like tunas, non-target elasmobranch species also have the potential to be highly mobile and wide ranging – a desk study should identify precisely what species to focus on. It was argued that those species most at risk of extinction should be prioritised. This particularly includes elasmobranch species that have less robust life history characteristics (i.e. low fecundity and rates of reproduction, low growth rates etc).

- For species that the tuna fisheries do not interact with it is unknown whether the MPA would have any impact. Whilst there was considered to be intrinsic value in understanding what species were in the zone and their period of residence this was of low priority for the questions posed to this group and would be considered by Group 1. Some in the group argued that there should be more focus on ecosystem-based metrics of health, rather than just on individual species.

As raised previously by Group 1, the question of prioritisation was also related to cost, and to availability of data. It was noted that apart from tuna the lack of any baseline information was a significant issue to be addressed in order to monitor change and describe impacts. The final recommendation of the group was that the focus of research should be on the more mobile species, and non-target species in danger of extinction (to be defined). Other species that fisheries do not interact with were considered a low priority for this group. It was suggested that future research should examine both tuna and highly mobile non target species to be defined by desk study.

Addressing the question of 'How' - proposed research approaches:

Research methods proposed were broadly described as (1) monitoring activities (e.g. tagging) to understand the behaviour and dynamics of study species, and (2) simulation modelling activities to describe the impacts of the MPA. These would be underpinned by desk based studies to collate available information. It was considered that the key to addressing this group of questions was to understand the proportion of residency (in the

Chagos/BIOT MPA) and movement of the study species – which would be addressed by methods described by Group 1.

Desk based studies

Desk based studies should be employed to

- Define the priority non target species to be studied, based on criteria including their danger of extinction, and availability of existing information (i.e. feasibility for study). Species with little existing information but considered to be at high risk would also then be identified as potential priorities for gathering further data. Highly migratory protected, endangered or threatened species should be considered first. This also links back to Group 1.
- To collate life history parameters, fishery information etc. on the selected non target species to inform questions 3a, 3b and 3d and to parameterise models exploring questions 3a, c and d.
- To explore catch rate data inside and outside the zone (see fisheries monitoring data, below).
- To review existing monitoring programmes and derive recommendations on enhanced data collection that could inform research questions related to pelagic MPAs for highly migratory species.

Monitoring:

As previously noted, a key to establishing the effectiveness of the Chagos/BIOT MPA for target and non-target species (3b) is to examine the question of residency, and this also relates to questions about the proportion of the migratory stock that would need to be protected in order to provide conservation benefits (3c). Approaches suggested by the group related to tagging, and genetic and chemical sampling.

Additionally fisheries monitoring data (catch/effort) and biometric monitoring (size frequency, age and reproductive information) would also be useful for addressing questions 3a and 3b. This led to a discussion on the need for experimental fishing or whether other non-extractive methods could provide similar information. There was a strong feeling from some participants that experimental fishing within the MPA would violate the ethos of having a 'no-take' area.

Tagging:

Three types of tagging approaches were discussed all of which are relevant but which address different questions. Archival and satellite tags were considered useful for recording movement and behaviour. This was also supported by Group 1 who felt these were the only two valuable methods of tagging for sharks and tuna. The group proposed that for archival/satellite tags a minimum of 20 tags for each of the eight study species should be deployed.

Transponder arrays were considered useful to monitor the frequency with which individual fish moved past a set number of points, but their detection range was considered limited. Typical mark-recapture tags have a much longer life and in addition to scale of movement, could provide information on mortality and growth rates. The large scale Regional Tuna Tagging Programme of the Indian Ocean (RTTP-IO) was briefly discussed. For mark-recapture techniques it was noted that for fish marked inside BIOT, recaptures outside the

BIOT zone would provide information on scale of movement, but would provide limited information on questions related to residency.

Genetic / chemical sampling

Genetic sampling was proposed as a means of exploring the question of residency of tuna within the Chagos/BIOT MPA and the extent of mixing of sub-populations. Some members of the group considered that such techniques would be unlikely to show significant variation. Instead it was proposed that chemical tissue analysis looking for heavy metals or polychlorinated biphenyls (PCBs) associated with pollutants in continental coastal areas may offer an alternative. Any populations that spent more of their time away from continental regions would be expected to have a lower level of these chemicals in their tissues.

It was noted that for genetic sampling non-lethal methods can be used, for example in conjunction with any tagging programme. Based on the experience of the group's members, it was indicated that for chemical tissue analysis the tissue sample size needed was greater than for genetic sampling and would therefore involve killing a number of individuals.

Fisheries monitoring data

This information is useful for target tuna, but there is inadequate data at present to monitor non-target species; limited information on the latter is compiled by the IOTC Working Party on Ecosystems and Bycatch. Historical data (e.g. Japanese longlining data) may also exist for both target and non-target species.

IOTC compile existing fisheries monitoring data on catch and effort which can be analysed within the envisaged desk based studies to examine the effect of the Chagos/BIOT MPA, for example on total catch, fishing location, fishing method and catch rates of tunas outside the EPPZ (Question 3a). It can be examined, with observer data if any, to see if fishing occurs 'close to the line' and whether the size of fish caught around BIOT changes over time. Some analysis has already been initiated by IOTC in relation to the area off Somalia closed due to piracy since 2007, and so far displacement of fishing vessels has occurred but without a major reduction in catch rates (IOTC-2009-SC-R(E)). Understanding the redistribution of effort outside the reserve will be important for modelling (see below), but it was noted that there is a high level of noise in the data already (poor data collection/submission, variable catches by location, especially in/around BIOT from year to year, vessel movements etc.) which would need to be accounted for in any study.

A more direct way of observing changes within BIOT would be to monitor changes occurring within BIOT over time since the implementation of the MPA, and also to compare them with the same observations made outside (the latter to address question 3a). Due to the natural variability in catch rates, which have been used as an index of abundance of fish within BIOT from year to year, again it was considered that separating the MPA effects from other effects would be challenging and that snapshot monitoring (once every few years) would be inadequate; data should be collected every year. Experimental fishing was discussed as one possible means of obtaining these data within BIOT but like Group 1, some members of the group were concerned at the commercial scale of fishing that would be required and whether this would be in the spirit of the MPA.

Alternatives to experimental fishing

Alternative methods the group discussed included:

- The collection of biometric data on fish caught during tagging programmes.
- Acoustic monitoring and / or underwater camera or video surveys.
- Making better use of the IOTC national observer programmes outside the Chagos/BIOT MPA to gather data on sightings of species that the fisheries do not interact with (whales, whale sharks etc), and to compare that with similar information that could be gathered inside the Chagos/BIOT MPA.
- Chumming and baiting to attract sharks that can be observed using SCUBA gear, and from which non lethal tissue samples could be collected.
- The use of fish aggregating devices (FADs) fitted with cameras and acoustic equipment. There was a mixed response to this suggestion. FADs are classed as a fishing gear in the BIOT legislation and their deployment is considered 'fishing'. FADs effectively modify the pelagic environment and thus the reliability of information gathered under them must be questioned. They could also not show changes from before and after the introduction of the MPA, although some discussion was held as to developing an appropriate correlate. The design of such sampling devices, their deployment and the interpretation of data collected from them would therefore need careful consideration. Instead the use of similar acoustic equipment and cameras on natural features such as the more shallow seamounts was proposed.
- Flyovers with aerial photography
- Use of hydrophones for monitoring cetaceans.

Modelling

Three types of model were discussed: Ecosystem models, examples of which are currently being developed through the AMPED project for migratory tunas; spatial models; and single or multi-species simulation models that could be age structured population dynamic models or biomass dynamic production models.

The group considered that modelling approaches should take into account the life history characteristics of the study species and spawning aggregations, where necessary. It was noted that for yellowfin and skipjack tuna information on spawning timing and location was available but less was known for big-eye tuna[3]. Discrete spawning aggregations do not occur, with spawning being widespread across the equatorial Indian Ocean, but for yellowfin tuna the peak purse seine fishing period in BIOT waters corresponded to part of the spawning period and so a proportion of the spawning stock would be protected by the MPA. Any modelling approach should include this information. The modelling approach applied by Steffanson and Rosenberg (2005; 2006) specifically for designing marine protected areas for migrating fish stocks was discussed. This model explicitly accounts for a spawning migration and dispersal during other months of the year, and could be applied to examine the impacts of the Chagos/BIOT MPA. Sensitivity analyses should be performed where parameters are unknown.

[3] Yellow fin tuna spawn widely across the equatorial Indian Ocean during the first quarter of the year (January to March); skipjack tuna spawn all year round without showing clear site fidelity; Bigeye tuna spawns June and December to January (summarised in IOTC-2009-SC-INF18).

For non target species that may be studied, it was noted that modelling would be difficult due to the paucity of fisheries (catch, effort) and life history (growth, fecundity, reproduction etc) data from the Indian Ocean with which to parameterise the models. It would be necessary to obtain as much information as possible from other sources such as the TOPP project.

For fisheries, simulation modelling approaches can be applied to examine the effect of (management) control rules on certain predefined (by management) indicators (e.g. fishing mortality, estimated abundance). Typically target or limit reference points may be set and the effect of applying a control rule can be examined in relation to these reference points (e.g. maximum sustainable yield (MSY) as a target, or 20% of the spawning stock biomass (SSB_{20}) as a limit reference point). Catch and effort controls can be examined, and the effect of an MPA can be examined also by modelling the way it affects catch and effort outside of the MPA. A limitation of this approach is that it focuses on results for external fisheries, which is not the intended purpose of the MPA. It would likely be more appropriate to develop a model in which the outputs are more closely aligned with the stated aims of the MPA (conservation benefits within the protected area and to the region as a whole), rather than external fisheries interests. Displacement effects could be examined based on assumptions about the size distribution of fish taken outside BIOT. Thus modelling approaches can be applied to address both:

- the impacts of the MPA: 3a if performance is defined; and, 3c, benefits, looking at the size of MPA required, or the relative residency times for individual species, or the proportion of the population that would need to be resident, in order to provide defined conservation benefits; and,
- the performance of the MPA relative to other management controls (3a), and the extent to which an MPA the size of Chagos adds to the benefits provided by existing management controls (3d).

Simulation modelling was not considered suitable for question 3b. Other modelling approaches can also be applied to examine spatial catch rate data and to model the redistribution of effort outside the MPA since its implementation. This requires analysis of catch and effort data before and after the MPA.

Members of the group suggested that the movements of different highly migratory species were not necessarily independent of each other, and that different species may move together, for example in pursuit of food. It was suggested that modelling could also be used to explore such a hypothesis, e.g. that elasmobranch species move with the tuna and will thus be impacted proportionally to the level of relevant fishing effort in different parts of the ocean (longline and purse seine with FADs). This can also be explored through tagging.

Costs

Desk based studies and modelling approaches are relatively cheap. Monitoring approaches using novel techniques are of intermediate and variable costs. Existing monitoring programs and data from all available sources (e.g. IOTC, scientific surveys, historical data) should also be utilised. Experimental fishing costs are likely to be high. Chemical and genetic analysis is of intermediate cost and can be implemented in conjunction with other monitoring activities in which fish are captured. Tagging operations can be expensive, depending on the scale of study, type of tag etc, though the rapid advances in technology mean that the prices are declining

Data gaps

IOTC holds a reasonable data set for tunas indicating baseline catch and effort, and catch rate data (as an index of abundance). Biometric data are also available to parameterise simulation models for target species. There is no stock recruitment relationship available however for any study species.

Baseline catch and effort data for non target species is inadequate although some exists in bycatch reports within BIOT. Data outside BIOT may not be equivalent. Biometric data and knowledge of life history parameters (spawning locations, times, hotspots of abundance etc) on non target species with which to parameterise simulation models is limited, though may be available from other sources.

Groups such as TOPP hold substantial data stores on movement patterns for many species of large predators, which may be useful for example as baseline data for parameterising movement models. Although gathered primarily from the Pacific Ocean, this project is looking to expand globally through the GTOPP program ('Global tagging of Pelagic Predators'). This may prove to be a valuable resource both for modelling, and for sharing logistic efforts and planned field-programs. Links between these projects should be investigated further.

3.1.4 Group 4: The contribution of a Chagos/BIOT MPA to a wider regional pelagic MPA network

Introduction

The subject of 'The contribution of a Chagos/BIOT MPA to a wider regional pelagic MPA network' was divided into sub-sections (see Box 4). Group 4 considered similar issues to those in Group 1, but in the context of the wider Indian Ocean and the contribution that Chagos/BIOT makes to the region. While the discussions certainly focused on Chagos/BIOT, these should be considered in the wider geographic context.

Box 4 The questions addressed by breakout group 4

Break Out Group 4: The contribution of a Chagos/BIOT MPA to a wider regional pelagic MPA network	
4a	Establish the relative importance of Chagos/BIOT compared to other locations in the Indian Ocean, and identify key areas within the Indian Ocean for protection e.g. areas considered biodiversity hotspots or valuable climate change reference point.
4b	Establish the location and geographic range of spawning nursery areas of target/non-target across the West Indian Ocean.
4c	Establish the size, location and connectivity of a network of protected areas necessary to effectively conserve key pelagic migratory species.
4d	Establish the importance of Chagos/BIOT as a source of increased biomass for other parts of the IO.

4a. Establish the relative importance of Chagos/BIOT compared to other locations in the Indian Ocean, and identify key areas within the Indian Ocean for protection e.g. areas considered biodiversity hotspots or valuable climate change reference point.

In reviewing this question, the group felt that the component relating to climate change was too speculative to consider at present and this would be adding an additional uncertainty on top of many other uncertainties. CLIOTOP is also looking into IO climate change so more information should be established on their initiative before launching into something new and separate in Chagos/BIOT. Climate change was therefore dismissed from further discussions.

The group then broke the initial questions down into two components. First, identification of Indian Ocean hotspots for biodiversity is required which can be carried out by a) compiling and reviewing existing datasets (desk-based study); b) ecological niche modelling (as described by John Turner in the plenary session (appendix 4), and c) targeted sampling. Second, is to evaluate how Chagos/BIOT ranks as a hotspot. Biodiversity assessments are underway in the IO already (Tittensor *et al.*, 2010) and the group agreed that the most effective approach would be to develop collaborations with Derek Tittensor and others working in this area to establish where data from Chagos/BIOT could be collected in order to be added into regional and global databases and analyses. There are also datasets available that can be tapped into to address this question e.g. seasonal changes in chlorophyll from satellite data. Information for the Chagos/BIOT region should be available from satellites that will record this from the end of this year.

Group 4 participants did not have the expertise to develop the methodology to answer some of the questions relating to understanding the importance of the connectivity between deepwater and benthic environments to productivity and biodiversity, therefore, consulted Alex Rogers to develop these responses. We determined that pelagic and benthic cruises would be a key way of obtaining biodiversity data within Chagos/BIOT. These will complement ongoing surveys elsewhere in the IO. The priority would be to survey between SCUBA depth (25-50m) to 500-1,000m. These surveys can be done off most boats e.g. the Fisheries Patrol Vessel off yachts like the Golden Shadow that are potentially available for research projects of this kind. Such surveys can be conducted using standard ROVs which can be hired e.g. from the University of Plymouth for £1K per day. Baited cameras, drop cameras and other standard sampling methodologies could be applied. Deeper surveys require the specialised NERC (or equivalent) research vessels. Although this is expensive, the methodology is well established.

A preliminary desk-based study could readily correlate maps of seamount data from Chagos/BIOT with fisheries data (catches, amount, composition) to see if there are any areas that emerge as hotspots. Bathymetric data are available from the Chagos/BIOT Patrol Vessel (BPV), but no surveys have been carried out below SCUBA diver depths. On a broader geographic scale, the Great Chagos Bank may function as one seamount and it would be of interest to study the effects of the Great Chagos Bank on productivity (island mass effect) and biodiversity versus seamounts in the region.

Biodiversity mapping will identify regional biodiversity hotspots, but identifying key areas within the Indian Ocean for protection will require the development of a range of other criteria that will determine the feasibility of protection. Criteria are likely to be based on factors such as governance (national boundaries or High Seas), socioeconomic and political frameworks. CI have done work in this area so this should be collated as part of a preliminary desk-based study.

Establishing the true benefits of the MPA in a 'classic' study that looks at changes in biodiversity, biometrics and biomass over time within and outside the Chagos/BIOT MPA was discussed at length but will be hard to carry out. The starting point would be to review what might be possible from existing data. This is discussed further under question 4d.

4b. Establish the location and geographic range of spawning and nursery areas of target/non-target species across the West Indian Ocean.

The group agreed that some preliminary analysis could be carried out to determine what could be established from existing data to describe the location and geographic range of spawning and nursery areas of target/non-target species across the West Indian Ocean. Information on tuna spawning and nursery areas is available in IOTC reports and statistics, and Chagos/BIOT is recognised as a location for spawning tuna. However, much less information is available for species not targeted by the tuna fishery. The target species for these studies were thus also discussed and it was agreed that while tuna were important and some research should be done on them, the focus should be on enhancing information on other species, particularly those where there are some other data available/ongoing studies the region. Group 4 identified priority species as silky, blue and oceanic whitetip sharks, swordfish (all billfish), and sea turtles.

Spawning studies would need to collate a range of environmental parameters e.g. temperature, food (phytoplankton and zooplankton), salinity and thermocline to determine the environmental conditions within Chagos/BIOT and how these compare to those available for the WIO. The second stage would be to relate those with information available on spawning. There are some data available for all these parameters, though incomplete or limited in most cases. There are temperature data at 25m for a four year period, satellite data for phytoplankton, IRD has 20 years of biometric data on fished tuna and there is limited biometric information from about three years for tuna in Chagos/BIOT from the fishery. Some work has been done on Reunion on billfish and these should be further researched to evaluate the potential for a comparative study with Chagos/BIOT and other areas of the WIO. For sea turtles, mapping the nesting sites for turtles would be the simplest approach and some of this has already been done in Chagos/BIOT. Methods are well established and data from Chagos/BIOT should aim to feed into larger global sea turtle studies e.g. those of Brendan Godley's group at the University of Exeter.

As so much data from tuna are from fisheries, discussions identified the lack of knowledge about juvenile tuna. Below 35-40cm in size (the first six months of life) nothing is known about tuna in the WIO, therefore Chagos/BIOT could provide a useful study site to gain important data to understand what happens from spawning to six months old. Pelagic/inshore surveys would be the methodology to catch juveniles of the focal species using a combination of ROV (operated off any boat as described above), SCUBA and trawls/plankton tows. SCUBA observations from reef-based studies in Chagos/BIOT are worth exploring as Charles Sheppard and John Turner reported anecdotal sightings of juvenile sharks and tuna in the inshore areas. Where possible, a tagging programme should be established, using pop-up satellite tags. Opportunistic tagging can also take place if the recreational fishery continues out of Diego Garcia and this will also provide a source of data on the biometrics of focal species. Recognising the limitations of time of the BPV and its primary purpose for patrols, the group agreed that a research vessel would be required, designed for easy use for fish tagging. These surveys would help build maps of the location of juveniles of focal species.

As survey data increase e.g. benthic mapping, there may be opportunities to understand the habitat requirements for spawning, in addition to the environmental conditions, by overlaying datasets.

4c. Establish the size, location and connectivity of a network of protected areas necessary to effectively conserve key pelagic migratory species.

The group again started by reviewing what work is ongoing in this area to explore what research might be achieved or enhanced through collaboration. AMPED and MADE are both working on MPA networks and discussions should be held to determine how data collected from Chagos/BIOT could best contribute to these.

30-40% of all tuna in the Indian Ocean are caught every year – the fisheries/fisheries management organisations reported this was sustainable, but the conservation and science members of the group were surprised and concerned at this figure, particularly considering the levels of uncertainty with IO tuna fisheries data. Another related issue is the effect this has on non-target species, particularly those that are long-lived, slow growing with low fecundity e.g. sharks.

To determine the size and location of potential MPAs in the IO, the group discussed at which point a species can benefit from spatial and temporal closures, or a combination of the two. The group agreed addressing this question would be best achieved through a modelling approach that looked at the combination of protected areas (spatial closure) and other fisheries regulations (temporal closures, gear closures e.g. FAD reduction) to determine what would be required to conserve pelagic species in the IO.

Connectivity would be best established through a combination of genetic analyses and tagging studies. Genetic analyses of the population structure of the focal species would either be sample collection to fill data gaps for other studies (e.g. for sea turtles) of doing a novel focal study where there are no existing genetic population data. A combination of a literature search and discussions with genetic research groups would determine how best to proceed with these approaches for each focal species. As discussed for question 4b, population connectivity of focal species could be best achieved by tagging. This would involve satellite pop-up tags for the focal species selected by Group 4 to look at movement within the IO. Data should be exchanged and combined with other IO projects.

4d. Establish the importance of Chagos/BIOT as a source of increased biomass for other parts of the IO.

Discussions were held on how to determine whether there is spillover from Chagos/BIOT and how much and how meaningful this is in the context of the IO. It was agreed that measuring biomass would be very difficult, particularly in the absence of any baseline data from Chagos/BIOT (and much of the IO), however a feasibility study should be explored. Such a study would aim to establish the biodiversity of the system, the biometrics of the species within it and the biomass. Potential for comparison with the Seychelles/Maldives or other potential control sites needs to be explored.

The group then specifically discussed what might be possible in terms of looking at the effect on tuna. An interesting research idea that emerged and was adopted by the group was to test the effect of the MPA as a means of protecting spawning tuna. This is a different strategy from the current approach taken by IOTC which is to try to protect juveniles until they reach

breeding age. Establishing the effect of the closure on spawners could be modelled using existing data, including IRD spawning data and Chagos/BIOT data. The model would investigate the spawning stock biomass and effect of removing Chagos/BIOT. It would also be interesting to determine whether there is an additive/any effect of other closures e.g. that resulting from Somali pirates. This could be achieved through a desk-based modelling exercise to look at the spawning stock biomass in the IO, then apply models to determine the effect of 'removing Chagos/BIOT' and other locations. Displacement would need to be built in but there would be challenges of incorporating other factors.

A key area identified for research on this question was to gain a better understanding of the interaction between the benthic and pelagic zones. Connectivity between depths <1,500m with the mesopelagic and pelagic zones will determine food availability and productivity. Studies would use benthic coupling experiments with stable isotopes which would be achieved as part of an oceanographic sampling cruise.

The research cruises (pelagic, benthic (>1,000m), inshore (25 – 1,000m)) – as described in question 4a – will also help inform this question.

Synthesis

The vast majority of the discussion was based around tuna, partly because there are so few data available for other species. For example, caution needs to be observed when considering the quality and quantity of data available for modelling for other species; Chagos/BIOT bycatch (especially shark) data are considered the best available, yet is highly limited recording only presence/absence and is restricted to only a few years. There are virtually no shark studies of pelagic species in the Indian Ocean. The MADE project is doing detailed behavioural observations on a small number of sharks (n=25). The group decided that the focal species for pelagic studies in Chagos/BIOT and the wider WIO should be silky, blue and oceanic whitetip sharks, swordfish (all billfish) and sea turtles. Some specific tuna studies were also defined.

As with other groups, there was discussion about whether scientific fishing would be appropriate within the MPA. Some alternative ideas were discussed, such as aligning acoustic and fisheries data. Aerial surveys have been tried for bluefin tuna which form shallow schools, but certainly would not work for all species and appears to have limited application. The development of novel methodologies would, in itself, be a valuable research opportunity in Chagos/BIOT.

Group 4 recognised the importance of linking in with other programmes where collecting targeted data in Chagos/BIOT could help to fill research gaps and complement existing studies.

The structure of the research programme for this section was suggested as follows:

- Short term (Low cost)
  - Desk based studies e.g. collating existing data from Chagos/BIOT and feeding that into other regional and global databases and to inform proposed models.
  - Collaboration development with other IO projects working on focal species.
  - Mapping turtle nesting sites.

- Establish feasibility of a comparative study of Chagos/BIOT and other IO sites (Maldives, Seychelles?) in terms of biodiversity, biometrics and biomass.
- Modelling the effects of Chagos/BIOT MPA fishing closure on spawning tuna.

- Medium term (Medium cost)
  - Genetic analyses of population structure of focal species (mix of filling data gaps for larger projects and focal studies).
  - Pelagic and inshore surveys to map juveniles of focal species.
  - Tagging study, of juveniles and adults of focal species, including purchase of a tagging boat.

- Long term (High cost)
  - Pelagic and benthic research cruises for biodiversity assessments.
  - Establishing interactions between the benthos and pelagic zones.

4. Outputs

Strategy Development

The consultation document (FCO, 2009) does not explicitly define the objectives of the MPA but it describes anticipated benefits related to conservation, climate change science and development. Workshop participants recognised that Chagos/BIOT MPA offers benefits in terms of biodiversity conservation for the rich shallow water and reef environments. Due to the relatively low anthropogenic pressures, it also offers value as a reference site. At present, however, there is insufficient information to determine whether this MPA will benefit tuna and other species affected by fisheries. This is the first pelagic MPA of this size so it is important that the relevant research is carried out to determine how effective they are in conserving pelagic species and how Chagos/BIOT specifically can provide these data. It is therefore essential that basic monitoring to meet and understand the needs of the region should start as soon as possible. The MPA in Chagos/BIOT will predominantly prevent decline of biodiversity and habitat degradation rather than recovery of species and habitats which are the usual scenario where other MPAs have been established; only a few species were exploited (legally and illegally) prior to closure.

One of the key questions highlighted during this workshop was how to approach a ‘classic’ MPA study that determined the changes in established indices of ocean health e.g. abundance of species, over time. In the absence of comprehensive monitoring programmes prior to the MPA establishment, proxies may well be required to determine the effects of protection. Chagos/BIOT provides a potential test site for fisheries independent research methods that would have global application. This has been carried out elsewhere using alternative indicators of fish abundance. For example, abundance of penguins around an MPA in South Africa has been used to look at recovery of prey fish as indicators (Pichegru *et al.*, 2010). Seabirds could be used in a similar manner in Chagos/BIOT - higher seabird occupancy is associated with higher fish abundance - and tagging methods are well established. Equivalent sampling will be required inside and outside the MPA to detect relative abundance and changes over time. Tagging offers huge potential for understanding

the movement of large pelagic predators in relation to MPAs and their boundaries, and this addresses a key knowledge gap regarding residency of these species in the Chagos/BIOT region. However, it is essential that the purpose of each tagging study is clearly defined with appropriate methodology. Further, it was felt on reflection that period of residence was considered more relevant than residency for certain migratory species as their use of the MPA as a refuge could still offer important protection.

Mathematical modelling was seen as the solution to a number of the research questions, however, the point was made that these are only as good as the data that is used and in some cases, for example, elasmobranch bycatch, this is clearly inadequate.

Not surprisingly, much of the discussion was focused on tuna because of the commercial interest and that the data available is the most comprehensive for the region. However, there was general agreement that more attention is needed for other, threatened pelagic species, notably sharks, particularly considering the dearth of studies on pelagic sharks generally, and specifically, in the Indian Ocean.

Multi-stakeholder workshops are valuable; they ensure that all views are represented. The discussions were very constructive; however, some points could not be resolved. These include:

a) Definition of a sustainable fishery. While the fisheries representatives felt that 30-40% removal of tuna from the Indian Ocean was sustainable, this figure caused great concern amongst the conservation community present
b) Different perceptions on the quality of fisheries data
c) Assumptions on species' migration patterns based on fisheries data alone
d) Whether Chagos/BIOT is big or small as an MPA

A specific concern from the fishing industry was that the Chagos/BIOT MPA has been declared following an inappropriate interpretation of the precautionary approach, (i.e. before cost/benefit knowledge is available), and that the declaration has the potential to significantly impact fishing operations even though the conservation benefits for tuna may be negligible. Given the significant knowledge gaps surrounding the impacts of large scale, pelagic area closures, they proposed that in future, and in other locations, designation of large scale no-take MPAs should only occur after the research has been conducted and not before, at least until we have a better understanding of the possible risks associated with such area closures.

An additional concern was raised in relation to the objectives of the Chagos/BIOT MPA. The consultation document (FCO, 2009) does not explicitly define the objectives of the MPA but it describes anticipated benefits related to conservation, climate change science and development. The question that was raised was whether such broad objectives can in fact result in measurable benefits, and whether the presence of fisheries on pelagic resources would undermine these objectives, given that a no-take policy would have negative operational consequences for fisheries and therefore remove a substantial source of income for the MPA.

Appendix 7 gives the outline strategy as developed by the workshop attendees. There was agreement that short-term desk based studies were required as a first phase to compile information and data, and to assess the feasibility of different projects discussed during the workshop. The key steps emerging from this workshop are as follows:

1. Initiation of the desk-based studies which have now been articulated more clearly (Appendix 8).
2. Review the need for, and design of, a central database of all information on Chagos/BIOT. The purpose of such a database needs to be defined and this could be part of the desk-based studies. It was generally felt that it may be more appropriate to link to other databases e.g. IOTC, FAO database on LMEs, through metadata within the Chagos/BIOT database rather than establish an entirely new one.
3. Consider the potential for a scientific paper to document the workshop and its outcomes.
4. Build linkages and collaborations with related projects and organisations.
5. Develop a comprehensive and fully costed research strategy.
6. Submit funding applications through partnerships with relevant collaborators and in agreement with the FCO.

Some of the research areas are progressing already. For example, Alex Rogers plans to conduct the benthic deepwater surveys in the context of other work he is doing in the Indian Ocean. However, there is at least a three year lead in time for this work, not only because of the time required to access funding but also to schedule the NERC research vessel required for such work.

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Appendices

Appendix 1a: Delphi Questionnaire Round 1

Exploring the issues relevant to strengthening management of the British Indian Ocean Territory (BIOT) marine area

Delphi Questions Round One

Instructions

In this first round of this Delphi study we would like each expert panellist to respond to three important questions representing separate thematic areas related to the management of the pelagic marine area around BIOT. **In addition to being confined to the pelagic ecosystem and pelagic marine protected areas[4], the scope of the questions is also defined by the objectives of the Darwin Initiative** i.e. to enable the BIOT Administration to meet their objectives under one or more of the three major biodiversity Conventions: the Convention on Biological Diversity (CBD); the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); and the Convention on the Conservation of Migratory Species of Wild Animals (CMS). Of these, the following are relevant:

CBD Objective

a) *The conservation of biological diversity (and sustainable use of its components);*

Specifically signatories commit to:

- *rehabilitate degraded ecosystems (Theme 1, the local context)*
- *establish a global network of protected areas (Theme 2: The regional context)*

CMS Objective

b) *[The parties] should promote, co-operate in and support research relating to migratory species; (Theme 3, the management context)*

The UK Foreign and Commonwealth Office (FCO) consultation on whether to establish a marine protected area (MPA) in the British Indian Ocean Territory captured knowledge from a wide range of experts (http://www.fco.gov.uk/resources/en/pdf/3052790/2010/marine-life-apr-2010). The consultation document and expert submissions responses have been assessed to draw out the key issues, uncertainties and researchable constraints relevant to management of the pelagic area. As an outcome of this process, the issues have been compiled into lists of statements related to the three themed questions.

The first round of the Delphi process seeks to have members of the experts panel establish the importance of the issues identified from the consultation. The attached questionnaire presents the themes with the statements not listed in any particular order. Please read each statement carefully. There are two boxes, one related to importance, the other to the extent of existing information related to the statement to be completed as follows:

- **Importance**: Please indicate the level of importance you would assign to the particular statement in relation to the contribution to answering the question (not the extent to which you agree with the statement). Each statement should be scored independently.

[4] i.e. we are NOT looking at reef systems and coastal MPAs

- **Existing information**: Please indicate using the scoring system the extent of information that exists that is related to the statement

Statements can be scored as important even if there is existing information, this will indicate only that it is not such a high priority for new research.
The questionnaire should take about 30 minutes to complete. Additional space is provided in case you feel that you need to expand on any points.
In the following questions we refer to species that are:
a) Target species. These are on the IOTC (Indian Ocean Tuna Commission) list of species i.e. pelagic species targeted by the fishery in IOTC. Important fishery target species relevant to BIOT are yellowfin tuna, skipjack tuna and big-eye tuna.
b) Non-target species. These are NOT on the IOTC list of species but are pelagic fish and other animals that may be directly impacted by fishing (i.e. non-target species for the IOTC fishery)
c) Other species. Species that are present in the open ocean areas but that are not necessarily directly affected by fishing.
Please complete the questionnaire by **Monday 7th June** and return it (saved file) to r.arthur@mrag.co.uk

Question 1. The local context: The BIOT Environmental Preservation and Protection Zone (i.e. to 200nm).

In your opinion, which of the following might be the key issues and effects <u>within</u> BIOT of the pelagic MPA that will be important in demonstrating if rehabilitation of the pelagic ecosystem has occurred?

Critical issues related to the local effects of the pelagic MPA identified from the FCO consultation are listed below. Please indicate in the first box the <u>importance</u> you would assign to each of the core components and in the second box your assessment of the extent of <u>available information</u> using the following Likert scale.

1 2 3 4 5 6 7 Least Most [in contributing to answering the question (not the extent to which you agree with the statement)]		
Critical effects related to recording the status of the BIOT pelagic area:	**Importance** **(in contributing to answering the question)**	**Existing Knowledge** **(extent of available knowledge)**
1. With legal and illegal fishing outlined during the FCO consultation as being the main anthropogenic stressor impacting on populations of target and non-target pelagic species within BIOT, assessing the rehabilitation of these populations would include establishing the current baseline parameters and: a) observing changes in abundance and/or distribution of previously targeted species (e.g. tunas). b) observing changes in abundance and/or distribution of non-target species which were previously caught as by catch by long line and purse seine fishing vessels (e.g. pelagic sharks). c) observing changes in abundance and/or distribution of other species, including those not necessarily directly affected by previous fishing activity (e.g. seabirds).	a) b) c)	
2. Establishing the structure and function (including important species) of the BIOT pelagic ecosystem to derive indicators of ecosystem health.		

Comments:	

Question 2. The regional context – the wider Indian Ocean.

In your opinion, which of the following are the critical issues associated with a BIOT pelagic MPA that would demonstrate a contribution to the <u>wider Indian Ocean</u> pelagic ecosystem?

Critical issues related to the wider effects of the BIOT pelagic MPA identified from the FCO consultation are listed below. Please indicate in the first box the <u>importance</u> you would assign to each of the core components and in the second box your assessment of the extent of <u>available information</u> using the following Likert scale.

1	2	3	4	5	6	7
Least						Most

[in contributing to answering the question (not the extent to which you agree with the statement)]

Critical issues related to the contribution of the BIOT MPA to the wider Indian Ocean include:	**Importance** **(in contributing to answering the question)**	**Existing Knowledge** **(extent of available knowledge)**
1. With the consultation highlighting the role of BIOT as a reference point against which to measure changes in the marine environment elsewhere, establishing a sound baseline indicating the current status of biodiversity in the wider Indian Ocean pelagic ecosystem against which BIOT can be compared would include:		
a) Identifying the key features/criteria that establish an area as a biodiversity hotspot or valuable climate change reference point.	a)	
b) Establishing the relative importance of BIOT compared to other locations in the Indian Ocean and identify key locations for protection (is BIOT one of them, where are the biodiversity hotspots?).	b)	
c) Establishing the distribution, density (and catchability) of target, non-target and other species across the Indian Ocean, and establishing climate change impacts.	c)	
d) Mapping the Indian Ocean wide extent of open ocean ecosystem(s) degradation (fishing, pollution etc) and identifying how BIOT can act as a	d)	

reference site. e) Identifying, quantifying and mapping open ocean ecosystem services.	e)	
2. The consultation identified the conservation benefits and contribution of BIOT to a global network of MPAs. To determine the extent of these benefits and assist planning of an effective network there is a need to establish the location and geographical range of spawning and nursery areas in order to define where pelagic MPAs should be situated: a) for important species targeted by the Indian Ocean tuna fishery	a)	
b) for important non-fishery-target species	b)	
3. The following commitments from the World Summit on Sustainable Development are relevant: halting the decline of biodiversity by 2010, establishing global marine protection networks by 2012 and restoring depleted fish stocks by 2015. () To assess the contribution BIOT can make to these global environmental commitments there is a need to identify and map spatial and temporal patterns of human interaction with the open ocean ecosystem(s) in the Indian Ocean (transport routes, fishing, protected areas etc).		
4. The consultation identified a potential role of BIOT as a 'refuge' for species heavily exploited in other parts of the Indian Ocean. In this context there is a need to establish the extent and period of residence within BIOT of pelagic migratory species including: a) for important target species	a)	
b) for important non- target species	b)	
5. Establishing the distribution, movement and aggregation (e.g. feeding and spawning) of life-stages of important species and the vulnerability of life stages to direct and indirect human impacts in order: a) To clarify the value of pelagic MPAs as a refuge for migratory species.	a)	
b) To identify suitable locations for spatial or temporal closures outside of the BIOT no-take MPA.	b)	
6. Establishing the size of resident populations of pelagic migratory species in BIOT that would be necessary to provide any net conservation benefits to the Indian Ocean		

population (i.e. as a refuge and source site with spill over effects): a) for important target species b) for important non- target species	a) b)	
7. Establishing the size, location and connectivity of a network of protected areas necessary to effectively to manage and conserve key pelagic migratory species, and the role of BIOT in that: a) for important target species b) for important non-target species	a) b)	
8. Establishing the pelagic features and factors (bathymetry, hydrodynamic and oceanographic effects such as ENSO / El Niño) and the links to ecosystem behaviour that determine the abundance and dispersal of pelagic migratory species and their location in order to define where pelagic MPAs should be situated: a) for important target species b) for important non-target species	a) b)	
9. The consultation identified the closure of BIOT as having a potentially important role as a source of increased biomass for other parts of the Indian Ocean and as a contribution to restoring depleted fish stocks by 2015. There is a need to assess these contributions: a) for important target species b) for important non-target species	a) b)	
Comments:		

Question 3. The management context.

In your opinion, which of the following are the key challenges or constraints related to the management of pelagic migratory species and biodiversity that a research programme could contribute to addressing?

The key challenges or constraints confronting pelagic migratory species and biodiversity management in practice/application from the FCO consultations are listed below. **Note that this list is constrained by the objectives of the Darwin Initiative as described at the start of this document** and so do not include for example social, economic and political issues. Please indicate in the first box the importance you would assign to each of the core components and in the second box your assessment of the extent of available information using the following Likert scale.

1	2	3	4	5	6	7
Least Important						Most Important

[in contributing to answering the question (not the extent to which you agree with the statement)]

Key challenges/constraints for management of pelagic migratory species & biodiversity include:	Importance	
1. Basin-wide fishing was suggested as important in relation to overall catches and by-catch. There was uncertainty about the effect closing the BIOT pelagic fishery would have on catches and by-catch, particularly whether this would displace fishing to less well regulated areas or reduce fishing. Establishing the effect of the BIOT pelagic MPA on catch rates and yields will help identify the net conservation benefits of open ocean MPAs for: a) for important target species b) for important non-target species		
	a)	
	b)	
2. The FCO consultation document suggests that there is value in having a minimally perturbed scientific reference site. There is a need to establish how effective the BIOT MPA is as such a scientific reference site for highly migratory species that can be exploited throughout their range.		
3. During the consultation it was suggested that the closure of the entire BIOT EEZ would not provide sufficient area to completely protect highly migratory fish stocks of the Indian Ocean during their life cycles. However, MPAs are recognised as an important component of fisheries and ecosystem management. There is a need to establish the extent that the BIOT MPA adds to the protection already in place or planned (through IOTC, through BIOT fisheries and environmental legislation) a) for important target species	a)	

b) for important non-target	b)	
4. The consultation established that no-take MPAs can be part of the solution for the management of migratory pelagic species, along with other management measures. Establishing the performance of open ocean no-take areas compared to other forms of management applied separately or together (for example, spatio-temporal closures that target key life history stages or biodiversity hotspots) can help determine this role a) for important target species b) for important non- target species	a) b)	
5. The consultation identified the role in data collection and recording undertaken by the BIOT Authorities for vessels fishing in its waters and the contribution of that data to assessing fish stocks. Given that some of these data will no longer be available, it is necessary to establish the data now required from BIOT to enable IOTC to assess the status of important target species in the region and to establish the effect of the loss of data and analysis from BIOT on IOTC's assessments.		
6. During the consultation, there was uncertainty about the effect of closure of the fishery on illegal fishing and costs of enforcement. On the one hand it was suggested licensed fishing vessels have assisted in the policing (and excluding) of unlicensed vessels potentially deterring illegal, unregulated and unreported (IUU) activities, while on the other closure simplifies policing. Determining the efficiency of detecting and combating IUU fishing within the BIOT MPA can better inform and define the level of surveillance needed to effectively eliminate IUU activity and thus safeguard any conservation and biodiversity benefits of pelagic MPAs.		
7. Quantifying the risks from IUU fishing and their relative impact on biodiversity and conservation benefits of the BIOT pelagic MPA.		
8. MPAs have been identified as providing benefits to fish stocks within their boundaries (and beyond). During the consultation it was suggested that this might act as an incentive and lead to an increase in illegal, unregulated and unreported (IUU) fishing activities. Assessing the potential incentive value for IUU fishing created by the presence of an MPA could assist in determining additional management and enforcement measures required for open ocean MPAs.		
Comments:		

1b: Delphi Questionnaire Round 2

Question 1. The local context: The BIOT Environmental Preservation and Protection Zone (i.e. to 200nm).

In your opinion, which of the following might be the key issues and effects <u>within</u> BIOT of the pelagic MPA that will be important in demonstrating if rehabilitation of the pelagic ecosystem has occurred?

Critical effects related to recording the status of the BIOT pelagic area:	***Importance***		***Existing knowledge (mean)***	***Your Score (Round 1)***	***Your revised score***	***Your rank of immediacy***
	Mean score	***Standard Deviation***				
1. With legal and illegal fishing outlined during the FCO consultation as being the main anthropogenic stressor impacting on populations of target and non-target pelagic species within BIOT, assessing the rehabilitation of these populations would include						
a) observing changes in abundance and/or distribution of previously targeted species (e.g. tunas).	a)					
b) observing changes in abundance and/or distribution of non-target species which were previously caught as by catch by long line and purse seine fishing vessels (e.g. pelagic sharks).	b)					
c) observing changes in abundance and/or distribution of other species, including those not necessarily directly affected by previous fishing activity (e.g. seabirds).	c)					
2. Establishing the structure and function (including important species) of the BIOT pelagic ecosystem to derive indicators of ecosystem health.						

Comments:

Question 2. The regional context – the wider Indian Ocean.

In your opinion, which of the following are the critical issues associated with a BIOT pelagic MPA that would demonstrate a contribution to the wider Indian Ocean pelagic ecosystem?

Critical issues related to the contribution of the BIOT MPA to the wider Indian Ocean include:		Importance Mean score	Importance Standard Deviation	Existing knowledge (mean)	Your Score (Round 1)	Your revised score	Your rank of immediacy
1. With the consultation highlighting the role of BIOT as a reference point against which to measure changes in the marine environment elsewhere, establishing a sound baseline indicating the current status of biodiversity in the wider Indian Ocean pelagic							
a) Identifying the key features/criteria that establish an area as a biodiversity hotspot or valuable climate change reference point.	a)						
b) Establishing the relative importance of BIOT compared to other locations in the Indian Ocean and identify key locations for protection (is BIOT one of them, where are the biodiversity hotspots?).	b)						
c) Establishing the distribution, density (and catchability) of target, non-target and other species across the Indian Ocean, and establishing climate change impacts.	c)						
d) Mapping the Indian Ocean wide extent of open ocean ecosystem(s) degradation (fishing, pollution etc) and identifying how BIOT can act as a reference site.	d)						
e) Identifying, quantifying and mapping open ocean ecosystem services.	e)						
2. The consultation identified the conservation benefits and contribution of BIOT to a global network of MPAs. To determine the extent of these benefits and assist planning of an effective network there is a need to establish the location and geographical							
a) for important species targeted by the Indian Ocean tuna fishery	a)						
b) for important non-fishery-target species	b)						
3. The following commitments from the World Summit on Sustainable Development are relevant: halting the decline of biodiversity by 2010, establishing global marine protection networks by 2012 and restoring depleted fish stocks by 2015. To assess the contr							
4. The consultation identified a potential role of BIOT as a 'refuge' for species heavily exploited in other parts of the Indian Ocean. In this context there is a need to establish the extent and period of residence within BIOT of pelagic migratory specie							
a) for important target species	a)						
b) for important non- target species	b)						
5. Establishing the distribution, movement and aggregation (e.g. feeding and spawning) of life-stages of important species and the vulnerability of life stages to direct and indirect human impacts in order:							
a) To clarify the value of pelagic MPAs as a refuge for migratory species.	a)						
b) To identify suitable locations for spatial or temporal closures outside of the BIOT no-take MPA.	b)						
6. Establishing the size of resident populations of pelagic migratory species in BIOT that would be necessary to provide any net conservation benefits to the Indian Ocean population (i.e. as a refuge and source site with spill over effects):							
a) for important target species	a)						
b) for important non- target species	b)						
7. Establishing the size, location and connectivity of a network of protected areas necessary to effectively to manage and conserve key pelagic migratory species, and the role of BIOT in that:							
a) for important target species	a)						
b) for important non-target species	b)						
8. Establishing the pelagic features and factors (bathymetry, hydrodynamic and oceanographic effects such as ENSO / El Niño) and the links to ecosystem behaviour that determine the abundance and dispersal of pelagic migratory species and their location in							
a) for important target species	a)						
b) for important non-target species	b)						
9. The consultation identified the closure of BIOT as having a potentially important role as a source of increased biomass for other parts of the Indian Ocean and as a contribution to restoring depleted fish stocks by 2015. There is a need to assess these							
a) for important target species	a)						
b) for important non-target species	b)						

Comments:

Question 3. The management context.

In your opinion, which of the following are the key challenges or constraints related to the management of pelagic migratory species and biodiversity that a research programme could contribute to addressing?

Key challenges/constraints for management of pelagic migratory species & biodiversity include:	Importance			Existing knowledge (mean)	Your Score (Round 1)	Your revised score	Your rank of immediacy
	Mean score		Standard Deviation				
1. Basin-wide fishing was suggested as important in relation to overall catches and by-catch. There was uncertainty about the effect closing the BIOT pelagic fishery would have on catches and by-catch, particularly whether this would displace fishing to l							
a) for important target species	a)						
b) for important non-target species	b)						
2. The FCO consultation document suggests that there is value in having a minimally perturbed scientific reference site. There is a need to establish how effective the BIOT MPA is as such a scientific reference site for highly migratory species that can b							
3. During the consultation it was suggested that the closure of the entire BIOT EEZ would not provide sufficient area to completely protect highly migratory fish stocks of the Indian Ocean during their life cycles. However, MPAs are recognised as an impo							
a) for important target species	a)						
b) for important non-target	b)						
4. The consultation established that no-take MPAs can be part of the solution for the management of migratory pelagic species, along with other management measures. Establishing the performance of open ocean no-take areas compared to other forms of manage							
a) for important target species	a)						
b) for important non- target species	b)						
5. The consultation identified the role in data collection and recording undertaken by the BIOT Authorities for vessels fishing in its waters and the contribution of that data to assessing fish stocks. Given that some of these data will no longer be avai							
6. During the consultation, there was uncertainty about the effect of closure of the fishery on illegal fishing and costs of enforcement. On the one hand it was suggested licensed fishing vessels have assisted in the policing (and excluding) of unlicensed							
7. Quantifying the risks from IUU fishing and their relative impact on biodiversity and conservation benefits of the BIOT pelagic MPA.							
8. MPAs have been identified as providing benefits to fish stocks within their boundaries (and beyond). During the consultation it was suggested that this might act as an incentive and lead to an increase in illegal, unregulated and unreported (IUU) fishi							

Comments:

Appendix 2: List of participants & working group nominations

Name	Affiliation	Nominal Working Group
Jonathan Baillie	ZSL	Workshop Chair
Matthew Gollock	ZSL	1(facilitator)
Nick Dulvy	Simon Fraser University, Canada & IUCN SSG	1
Lucy Harrison	Simon Fraser University, Canada & IUCN SSG	1
Vincent Lucas	Seychelles Fishing Authority	1
Michel Goujon	ORTHONGEL, France	1
Alex Rogers	ZSL	1
Yuh-chen Chern	Fisheries Agency, Council of Agriculture, Taiwan	1
James Moir Clark	MRAG	1
Robert Arthur	MRAG	1
Tim Davies	MRAG	2 (facilitator)
Joanne Yeadon	British Foreign & Commonwealth Office	2
David Agnew	MRAG	2
Julio Moron	OPAGAC, Spain	2
Lucy Harrison	Simon Fraser University, Canada & IUCN SSG	2
Simon Harding	ZSL	2
Chris Mees	MRAG	3 (Facilitator)
Hilario Murua	AZTI - Tecnalia / Unidad de Investigación Marina, Spain	3
Tom Blasdale	Joint Nature Conservation Committee, UK	3
Charles Edwards	MRAG	3
David Kaplan	AMPED, France	3
Derek Tittensor	Dalhousie University, Canada	3
Callum Roberts	University of York, UK	3
Alison Debney	ZSL	3
Heather Koldewey	ZSL	4 (facilitator)
Charles Sheppard	University of Warwick & Chagos Environment Network	4
John Pearce	MRAG	4
Laurent Dagorn	MADE, France	4
Alain Fonteneau	AMPED, France	4
James Jansen	British Foreign & Commonwealth Office	4
Alistair Gammell	Pew Environment Group	4

Allen Vincatassin	The Diego Garcian Society	4
Catherine Head	ZSL	Logistics

Working Groups

1. Monitoring Target & Non-target Species
2. Fishing, fisheries assessments and IUU fishing
3. Pelagic MPAs and highly migratory species
4. The contribution of a BIOT MPA to a wider regional pelagic MPA network

Appendix 3: Workshop Agenda

The British Indian Ocean Territory Marine Protected Area Research Strategy Workshop Agenda

12th-13th July 2010

Hosted by Zoological Society of London & MRAG Ltd.

Chaired By: Jonathan Baillie

Monday 12th July

9.15 am	**Tea & Coffee Reception**

Session 1: Research Questions

10am	**Welcome and Introduction** Jonathan Baillie (ZSL)
10.10am	**Present status of BIOT MPA** Presentation by Joanne Yeadon (British Foreign & Commonwealth Office)
10.20am	**Delphi Process Summary** Presentation by Matthew Gollock (ZSL)/Rob Arthur (MRAG Ltd)
10.35am	**Workshop Aims & Introduction** Heather Koldewey (ZSL) / Chris Mees (MRAG Ltd.) Rules of engagement Desired Outputs Opportunity for questions
10.45am	**Panel Discussion – State of Knowledge** 3-5 minute presentations from a diverse expert panel
11am	**Break**
11.15 am	**Plenary Discussion – State of Knowledge** Open discussion to compile list of datasets, projects and knowledge from all participants that will contribute to the workshop aims.
12.30 pm	**Lunch**
1.30 pm	**Focused Discussion in Working Groups (Round 1):** 1. Monitoring target and non-target species inside and outside of the BIOT MPA.

2. Fishing, fisheries assessments and IUU
3. Pelagic MPAs and highly migratory species
4. The contribution of a BIOT MPA to a wider regional pelagic MPA network

3.30 pm **Break**

3.45 pm **Plenary discussions**
10 minutes each with 20 minutes feedback

5.45 pm **Break for the day**

7.30pm **Optional Workshop dinner**

The British Indian Ocean Territory Marine Protected Area Research Strategy Workshop Agenda

12th-13th July 2010

Tuesday 13th July

Session 1 Continued: Research Questions

9am	**Focused Discussion in working groups (Round 2):** 1. Monitoring target and non-target species inside and outside of the BIOT MPA. 2. Fishing, fisheries assessments and IUU 3. Pelagic MPAs and highly migratory species 4. The contribution of a BIOT MPA to a wider regional pelagic MPA network
11.00am	**Break**
11.15am	**Present Working Group Discussions** 10 minutes each with 20 minutes feedback
1.15pm	**Lunch**

Session 2: Outline Research Strategy

2pm	**Summary Discussion:** Recommended Strategy Synthesised presentation – CM/HK to begin discussion
3.30pm	**Break**
3.45pm	**General Discussion:** Opportunity for research synergies
4.30pm	**Workshop Ends**

Appendix 4: Plenary presentations

Presentation by Dr John Turner: BIOT and climate change

Presentation by Dr Alex Rogers: Deepwater Ecosystems in the Indian Ocean

Presentation by Dr Hilario Murua: Status of IOTC databases for IOTC and non-IOTC species

Presentation by Dr. David Kaplan: The AMPED project

Presentation by Dr Chris Mees: The BIOT MPA: Identifying future research priorities to inform management

Appendix 5: Existing data sources

Data source	Availability
Relevant to group 1: Monitoring target/non-target species	
BIOT catch/effort database and logbooks (via MRAG)	Available
BIOT Observer data (via MRAG) - target spp. = available; - non-target spp. = poor; - other species = absent	Partially available
IOTC databases (catch/effort)	Available
Japanese longline data (1950-1999)	Partially available
Taiwanese longline data (1967-present)	Available
Observer data for IOTC members (as of 2010/11, 5% coverage for all fleets)	Partially available
IOTC member VMS data (inc. Chagos/BIOT data)	Unavailable
FAD data (subset with use restrictions)	Partially available
IOTC tuna tagging data (IO-RTTP)	Available
Birds/turtles - tagging programme data	Available
Pelagic shark tagging data (silky, blue, oceanic whitetip)	Partially available
Shark Specialist Group: expert knowledge, biological parameters	Available
BIOT cetacean observer data (presence/absence)	Available
Aquamaps (Freiberg): spatial cetacean data	Available
Matthieu Decorrier - seabird distribution/abundance (e-tagging)	Partially available
Satellite bathymetry	Available
Habitat suitability for deepwater spp.	Available
Pelagic features: SST, chlorophyll conc., etc (NERC programme)	Available
Oceanographic research surveys (1970s)	Available
Argos oceanographic data	Available
Relevant to group 2: Monitoring and surveillance	
BIOT patrol vessel: - IUU fishing - patrol data	Partially available
US Military surveillance data	Unavailable
Relevant to group 3: Migratory species	
CMS turtle group: expert information	Available
CMS shark group: expert information	Available
IUCN tuna group: expert information	Available

Regional tuna Tagging Programme-Indian Ocean (RTTP-IO)	Available
Tagging of Pacific Predators (TOPP)	Available
Climate Impacts on Oceanic Top Predators (CLIOTOP)	Available
Relevant to group 4: MPA networks	
WCMC marine protected area database	Available
Birdlife Important Bird Areas (IBAs) (note: High Seas IBAs not well developed in the IO)	Available
Global diversity patterns (via Derek Tittensor)	Available
Risk index for seamounts (via Derek Tittensor)	Available
IOTC temporary closures	Available
Benthic protected areas in IO	Available

Appendix 6: Draft strategy - presented by Dr Heather Koldewey & Dr Chris Mees

Outline BIOT Research Strategy

Short term

- Desk based studies
  - Overlay existing data sets (within BIOT; across IO) to understand:
    - Oceanographic/bathymetry effects
    - Biodiversity hotspot locations (and BIOT relative to those)
  - Analysis of history of IUU, drivers of risk and indicators of IUU e.g. markets
  - Explore feasibility of modelling non-tuna species based on data availability (data compilation exercise)
  - Identification of focal species for tagging projects and further research
  - Identification of focal sites outside BIOT for replicates/fished vs non-fished areas
  - Feasibility study on how to measure displacement or whether too much noise

Short term

- Modelling – tuna focus (other species as data permits)
  - Spatial model of tuna incorporating life history features to establish relative impact of BIOT MPA
  - Effects of protecting spawners (within BIOT) as an alternative strategy to protecting juvenile tuna
  - Impact of protecting whole spawning stock as an alternative strategy to protecting juvenile tuna
  - Modelling risk of IUU within BIOT and impact of different surveillance/deterrent strategies
  - Ecological niche modelling for cetaceans, sharks, turtles

Medium term

- Establish baseline (abundance, distribution) of non-target species within BIOT, ideally compared to other sites within IO.
- Develop non-invasive indices of abundance e.g. camera/acoustic methods and ways of deployment e.g. FAD/mooring study/seamounts

Tagging studies

- To determine residence, rate/scale of movement, relationship to oceanography/bathymetry, relationship between species.
- Satellite / Archival
  - Prioritise species by threat / ecology
    - Not so threatened we can't catch them
    - Choose a species that could be representative and/or contribute to wider datasets
- Mark/recapture
- Transponder arrays

Medium term

- Genetic studies to investigate population structuring of key pelagic species within IO.
- Chemical analysis to investigate population structuring on a shorter time frame
- Biometric data collection integrated into overall research plans
- Investigate feasibility of alternative fishery independent methods

Long term

Scientific cruises
- Benthic, pelagic and inshore (>60m – 1,000m)

- Ecosystem Health Approach
- Large scale baseline pelagic survey
  - Phyto- to Nekton trawls
  - CTD
  - Acoustics
  - Bathymetry

Synergies

- Avoid duplication of effort
- Key linkages
  - AMPED
  - MADE
  - IOTC
  - IUCN SSG
  - CLIOTOP
  - GOBI
  - SWIOFP
  - IUCN Global Marine Programme
  - ASCLME
  - Chagos scientist network (via Charles)
  - Sea Around Us

Funding

- GEF – funding for high seas

Logistics

- Tagging vessel
- Cruise vessels
  - NERC-type for big scale benthic/pelagic
  - BPV (?) or smaller survey vessels in short term for shallower (to 1000m) surveys
- Utilise recreational fishery
- Use of planes
- FADs

Appendix 7: Short term desk-based and modelling studies

Type	Title	Length	Who
Desk based 1	Collection and preparation of data required for the parameterisation of simulation models.	4 weeks	Tim's PhD
Desk based 2	Investigation of non extractive methods which could provide similar fisheries and biometric data to that currently gained through commercial or experimental fishing.	2-4 weeks	ZSL to lead
Desk-based 3	A review of historical illegal, unregulated and unreported (IUU) fishing within Chagos/BIOT: synthesis of knowledge of past and current IUU activities, including those involved and the key species affected, and the social, economic and institutional drivers behind IUU fishing.	4-8 weeks	Tim's PhD with MRAG
Desk based 4	A review of current MCS performance within Chagos/BIOT, including both active BPV operations and the surveillance effect of licensed vessels	4-8 weeks	Tim's PhD. MRAG surveillance strategy report (available by May 2011)
Desk-based 5	A feasibility study into "an investigation of displacement effects (fishing effort or gear shift) in response to the Chagos/BIOT MPA".	2-3 weeks	Tim's PhD
Desk based 6	Collating available data on target and non-target species in Chagos/BIOT and the Indian Ocean in order to understanding what direct monitoring is required.	2-3 weeks	Tim's PhD then subsequently ZSL/MRAG to consider understanding what direct monitoring is required.
Desk based 7	Identification of IO hotspots for biodiversity (to be supplemented by targeted sampling – non-desk based)	2-3 weeks	Links to Modelling 5 with John Turner's group Bangor, and to WCMC for chlorophyll / oceanographic databases. MRAG can provide input re use of IOTC database.
Desk based 8	Map seamount data from Chagos/BIOT with fisheries data (catches, amount, composition) to see if there is any areas that emerge as hotspots.	1-2 weeks	Alex Rogers (seamount) and MRAG re fisheries data
Modelling 1 (One	Build appropriate simulation model (e.g. spatial biomass or age	Medium term	Tim's Phd with MRAG particularly on

model would be built but a number of simulations could be run to explore different questions)	structured population dynamic model) that explicitly accounts for spawning migration and other spatial dispersal of the stocks; Parameterise versions of the model with information for the selected study species. Run simulations including inter-alia:		the Biological modelling
	a) Compare the performance of a no take MPA against other fisheries management applied separately or together (and specifically an MPA equivalent to Chagos/BIOT compared to existing or planned IOTC management)		
	b) Establish the proportion of the population to be protected to provide defined conservation benefits and hence the size of an MPA needed for highly migratory species taking into account protection of spawners.		
	c) Establish the effect of protection ofthe spawning stock biomass, specifically the protection of that part of the stock within Chagos/BIOT, compared to protection of nursery areas.		
Modelling 2	Determine how the Chagos/BIOT MPA affects catch and effort on part of the target and non-target stock.	2 months	On hold – pending other outputs / availability of data through IOTC (May build on work done by Charles Edwards)
Modelling 3	Modelling tuna fleet dynamics, distribution and behaviour to explore the risks of IUU to Chagos/BIOT as a result of displacement due to Somali piracy in the western Indian Ocean.	Medium term	Tim's PhD
Modelling 4	Identifying and quantifying the future risks of IUU within Chagos/BIOT following the implementation of fisheries closed area.	Longer term	Tim's PhD
Modelling 5	Ecological Niche Model	?	John Turner / Bangor – links to Desk based 7/8

Appendix 8: Synergies & Funding

Synergies

A short discussion identified that the work in Chagos/BIOT has a number of synergies that need further development, including:

- IOTC (fisheries and observer data).
- TOPP
- Projects on bird movement e.g. Birdlife, Pew
- Turtle tracking projects
- Pentagon
- NASA
- US NOAA
- AMPED – for ecosystem modelling
- MADE – shark tagging and bycatch
- Benthic/pelagic research cruises – Alex Rogers in the South West Indian Ocean in 2011/12; French cruise planned for the South East Indian Ocean in 2012.

David Kaplan reported that the AMPED programme runs until the end of 2012 and they will consider Chagos/BIOT more closely as a focal area in their analyses.

Funding

Participants put forward ideas for funding approaches for the short, medium and long-term components of the strategy, including FAO, GEF (High Seas Project - seems dependent on Chagos/BIOT being defined as an LME), EU (PRCD programme), OTEP, SOS (tagging apex predators), Living Oceans Foundation (for use of Golden Shadow), NERC (research vessel), Swire Foundation.

Appendix 9: Tim Davies PhD Outline

Area-based conservation in the open ocean: modelling the response of fishing fleets to large scale marine protected areas.

Tim Davies

24 November 2010

Supervised by Prof. E.J. Milner-Gulland (Imperial College) and Chris Mees (MRAG Ltd).

1 Introduction

Marine protected areas (MPAs) are routinely advocated by conservationists as a tool for safeguarding species, habitats and entire ecosystems and the services they provide (Botsford et al., 2003; Lester et al., 2009). Fisheries managers too have long recognised the benefits of spatial closures (Hilborn, 1985), which have been shown to allow stock recovery (Roberts et al., 2005), improve economic yield (White et al., 2008), and to buffer against scientific uncertainty and management implementation error (Stefansson and Rosenberg, 2005).

International commitments under the Convention on Biological Diversity are facilitating the creation of a global MPA network on the high seas; an area that currently has very little formal protection (Game et al., 2009). However, it may be a case that conservation policy is ahead of the science, as the ecological benefits associated with MPAs in open ocean systems are not as clear as they are for inshore and coastal areas (see Game at al., 2009 for a review). Consequently there remains some uncertainty as to how effective area-based conservation can be in protecting the highly migratory species (HMS) that are characteristic of the open oceans (see Kaplan et al., 2009; but also Koldewey et al., 2010).
A frequently voiced concern is that reallocation of fishing effort will diminish the intended conservation benefits of an MPA, with practical constraints on reserve size meaning migratory or highly mobile fish stocks are likely to be only partially protected throughout their range (Stefansson and Rosenberg, 2005, 2006; Kaplan et al., 2009). Another threat to any MPA, but especially those in the remote open ocean, is the persistence of illegal fishing - the risk of which may even worsen if fishers perceive an increase in fish stocks within a reserve (Ban et al., 2009).

If MPAs are to be used effectively as conservation tools these risks must be understood and managed through appropriate MPA design and implementation. A fundamental part of this is understanding how fishing fleets respond to restrictive management interventions. This is an interdisciplinary area of research that has only recently begun to emerge in fisheries science, and there are still relatively few empirical studies of fisher behaviour in the literature (Salas and Gaertner, 2004). A number of modelling approaches have been used to predict changes in fleet dynamics following the introduction of management controls (Rijnsdorp et al., 2001; Wilen et al., 2002; Powers and Abeare, 2009), although these generally make simplified assumptions regarding fisher behaviour based on economic or ecological theory (see Gillis et al., 1993). However, fisher behaviour is not motivated by maximising profit alone (Salas and

Gaertner, 2004) and in reality a range of social, cultural and institutional influences drive fisher decision making (Branch et al., 2006).

1.1 Research aims and objectives

This PhD will explore the utility of area-based management as a tool in the conservation of highly migratory pelagic species in the open ocean. Extensive data compilation and analysis will underpin the development of fleet behaviour models, and models of population dynamics for pelagic species. Using simulation these models will be used to explore the response of fleet behaviour to large-scale area closures, and in particular how changes in fleet behaviour impact upon populations of highly migratory pelagic species. These models and simulations will be based on the tuna fleets and pelagic species of the Western Indian Ocean.

Explicit objectives are as follows:

1. **Understand how tuna fishers in the Western Indian Ocean make harvesting decisions.**
    - Collate historical fisheries data on abundance, distribution and catch rate of tunas and other harvested species.
    - Interview tuna fishers to identify additional social, cultural, institutional and economic considerations in decision-making.
    - Explore the influence and extent of Somali piracy on fishing activity, which appears to be a growing and serious problem in the Western Indian Ocean (Kaplan et al., 2009).
    - Use multivariate analysis to examine how the identified covariates explain observed effort allocation, fleet distribution and management compliance in the Indian Ocean tuna fleets. Note on data collection:

    A note on data collection:
    - Licensed fleet: direct interviews will be sought with skippers of tuna vessels operating in the Western Indian Ocean. Possible ports for conducting interviews are in the Seychelles (for the purse seine fleet) and Japan or Mauritius (for the longline fleet).
    - Unlicensed fleet: information will be gathered from the surveillance logs and arrest reports of the BIOT fisheries patrol vessel[5].
    - Fisheries catch and effort data will be collected from the literature and from IOTC (publically available) and BIOT (via MRAG) databases.

[5] These data are collected and held by MRAG, with access subject to permission by the Foreign and Commonwealth Office.

2. **Parametise models of fleet dynamics.**
    - Select appropriate models (e.g. aggregate or agent-based) depending on the analysis in Objective 1;
    - Construct separate models for the different tuna fleets (including licensed and unlicensed fleets);
    - Validate models using observed fishing effort within the Western Indian Ocean.

3. **Collect biological data and construct biological models.**
    - Collect available biological data on Indian Ocean tuna stocks, including movement data from regional tagging studies. This data will supplement catch data collated during Objective 1.
    - Develop spatially explicit models of tuna population dynamics. Similar models will also be developed for important bycatch species, although these are likely to be less sophisticated given the paucity of detailed biological data available.

4. **Explore the performance and trade-offs of alternative management strategies using management strategy evaluation (MSE).**
    - Define (1) a number of alternative scenarios based around different management (including enforcement) strategies for a large-scale MPA, and (2) appropriate performance criteria, related to conservation objectives, with which the conservation benefits and trade-offs simulated under alternative scenarios can be compared.
    - Run the MSE using the alternative scenarios defined above.

2 Research tasks outline

2.1 Literature review

- A broad review of the conservation and fisheries management benefits of MPAs, including a more focused review of the recent debate surrounding pelagic MPAs;
- A review of the importance of including fisher behaviour in the management process. A summary of approaches used to model resource user decision-making, with focus on fishers and fleet dynamics;

- A more detailed review of agent-based modelling approaches, and the importance in capturing differences between individuals;
- A review of the research on the role of communication and social networks in decision-making;
- A review of interview-based techniques, including getting data on illegal harvesting.

2.2 Designing and building social models

The initial task in my methodology will be to collate the available data for the Western Indian Ocean tuna fisheries, in terms of which fleets are active in the region, when and where they distribute their effort, which species they target and historical information on catches (including bycatch species). Data will be collated, to the extent possible, for both the licenced and unlicenced fisheries.

A common assumption across existing studies of effort distribution is that fleet dynamics are driven by the economic motivation to maximise profit. However, there are many other additional social, cultural, institutional and political drivers that influence fisher behaviour (Branch et al., 2006), many of which are likely to be important in understanding how fishers respond to area closures. In order to understand which of these finer behavioural drivers are relevant in the Western Indian Ocean tuna fisheries I will:

1. Conduct interviews with skippers of licensed tuna vessels directly (purse seine and longline fleets).
2. Review existing interview data from the literature and from BIOT patrol vessel reports (the latter being particularly relevant for information regarding the unlicensed fleet).

This process will ultimately inform how models are parametised, and will also give an indication at which level to model fleet dynamics. For example, where variation between vessels appears superficial it may be sufficient to model the fleet at an aggregate level, whereas if variation between vessel behaviour is much greater, and has potential to produce significant divergence in the effort allocation, it might be necessary to adopt an agent-based approach.

Interviews will also be important in understanding the extent and method of communication between vessels regarding the location and abundance of the resource. It is then possible to explicitly model the flow of information between fishers, which is known to influence fleet dynamics (Little et al., 2004; Branch et al., 2006).

2.3 Biological models of highly migratory species (HMS)

Modelling the movement and population dynamics of HMS is necessary on two fronts. Firstly, the movement of stock biomass in space and time influences fleet dynamics and as such the two models should be dynamically linked. Secondly, understanding the impact of an MPA on

HMS requires the simulation of population dynamics over time, with model outputs generating appropriate performance metrics related to specific conservation objectives.

There are several spatially explicit modelling approaches available to simulate the movement and biomass of fish stocks through time (Pelletier and Mahévas, 2005), many of which are also broadly interchangeable with models of fleet dynamics (e.g. Stefansson and Rosenberg, 2005). In order to choose a modelling approach I will collate and review the available life history and movement data for a number of important HMS[6] in the Western Indian Ocean. Key sources will be published data used for fisheries management (e.g. growth, recruitment, mortality), and information from tagging or tracking studies on migration and movement. As with the models of fleet dynamics, an appropriate modelling approach will be chosen depending on the amount of available data. The quantity of data available for the two groups (target and bycatch species) is likely to vary substantially, and it may be necessary to employ different modelling approaches for each.

2.4 Evaluating management strategies

The various models of fleet and population dynamics described above will simulate an environment subject to a single management rule: a fixed no-take MPA based superficially on the Chagos MPA. However, there is scope to develop this evaluation process in two ways:

1. Illegal fishing can be explored in more detail. Different levels of illegal fishing, based on variation in fisher's perceptions of fishing opportunities and risk of capture, explored through model sensitivities. Furthermore, alternative scenarios can be used to explore how changes in an enforcement strategy influence illegal behaviour (e.g. greater investment for increased patrols, higher fine).
2. The performance of alternative MPA designs can be compared using a management strategy evaluation (MSE) approach. However, as an exhaustive MSE analysis is not the primary objective of this PhD, and so only a few illustrative alternative management approaches would be compared (e.g. targeted MPAs or MPAs used in conjunction with additional fishing effort controls).

In whichever scenarios are chosen, models can be constructed to include variation and error within particular elements of the model (e.g. harvesting costs, migration distances).

[6] Species of interest include the three major tuna species targeted by the tuna fleet (skipjack, yellowfin and bigeye) as well as non-target species taken as bycatch (sharks and billfish).

3 Work plan

The timeframe for the five objectives is expected to be as follows:

	Y1			Y2			Y3		
Objective/Task	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**
Literature review and extended proposal									
Pilot interviews (Seychelles)									
Collation of catch/effort data									
Review of historical IUU within BIOT									
Field trips (Seychelles + Japan?)									
Development of fleet models									
Collection of biological data and development of biological models									
Define management scenarios and run MSE									
Write up									

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