Marine conservation in the British Indian Ocean Territory (BIOT): science issues and opportunities

Report of workshop held 5-6 August 2009 at National Oceanography Centre Southampton, supported by the NERC Strategic Ocean Funding Initiative (SOFI)

1. Executive summary

i) There is sufficient scientific information to make a very convincing case for designating all the potential Exclusive Economic Zone of the British Indian Ocean Territory (BIOT, Chagos Archipelago) as a Marine Protected Area (MPA), to include strengthened conservation of its land area.

ii) The justification for MPA designation is primarily based on the size, location, biodiversity, near-pristine nature and health of the Chagos coral reefs, likely to make a significant contribution to the wider biological productivity of the Indian Ocean. The potential BIOT MPA would also include a wide diversity of unstudied deepwater habitats.

iii) There is also very high value in having a minimally perturbed scientific reference site, both for Earth system science studies and for regional conservation management.

iv) Whilst recognising that there is already relatively strong *de facto* environmental protection, MPA designation would greatly increase the coherence and overall value of existing BIOT conservation policies, providing a very cost-effective demonstration of UK government's commitment to environmental stewardship and halting biodiversity loss.

v) MPA designation for the BIOT area would safeguard around half the high quality coral reefs in the Indian Ocean whilst substantially increasing the total global coverage of MPAs. If all the BIOT area were a no-take MPA it would be the world's largest site with that status, more than doubling the global coverage with full protection. If multi-use internal zoning were applied, a BIOT MPA could still be the world's second largest single site.

vi) Phasing-out of the current commercial tuna fisheries would be expected. Nevertheless, this issue would benefit from additional research attention to avoid unintended consequences.

vii) Climate change, ocean acidification and sea-level rise jeopardise the longterm sustainability of the proposed MPA. They also increase its value, since coral reef areas elsewhere (that are mostly reduced in diversity and productivity) seem likely to be more vulnerable to such impacts.

viii) To safeguard and improve the current condition of the coral reefs, human activities need to continue to be very carefully regulated. Novel approaches to wider sharing of the benefits and beauty of the MPA would need to be developed, primarily through 'virtual tourism'.

ix) Many important scientific knowledge gaps and opportunities have been identified, with implications both for BIOT MPA management and for advancing our wider understanding of ecosystem functioning, connectivity, and the sustained delivery of environmental goods and services.

x) Further consideration of the practicalities of MPA designation would require increased attention to *inter alia* site boundary issues, possible zoning, and socio-economic considerations, with wider engagement and consultations expected to involve other UK government departments (e.g. Defra/JNCC, DECC and DfID); neighbouring nations (e.g. Mauritius, Seychelles and Maldives); NGOs with interests; and other stakeholder groups (including Chagossian representatives).

2. Background

The 55 islands of the British Indian Ocean Territory (Chagos Archipelago; Fig 1) have a combined land area of less than 60 sq km – around 15% of the size of the Isle of Wight. However, they are surrounded by several thousand sq km of coral reefs[1], and the potential BIOT Exclusive Economic Zone for management of marine resources is at least 544,000 sq km – more than twice the total UK land area. This marine space includes mid-ocean ridges, trenches and abyssal plains, as well as coral reefs, atolls and banks. Whilst the UK government is already committed to strong environmental protection[2-5] of the Territory and its surrounding marine resources "as if it were a World Heritage site"[2], the case for formal, additional safeguards with international recognition has recently been made[6] by the Chagos Conservation Trust, as discussed at a meeting at the Royal Society on 9 March 2009.

To assess the scientific justification for such action, the UK Foreign and Commonwealth Office (FCO) sought independent advice from the National Oceanography Centre Southampton (NOCS) on environmental considerations relevant to the possible designation of a BIOT Marine Protected Area (MPA, see below). In response, NOCS, in partnership with university co-convenors, obtained NERC SOFI support for a workshop held on 5-6 August in order to i) widen the informal evidence base for such scientific advice, through involvement of relevant experts in the UK research community and elsewhere, and ii) identify knowledge gaps and associated marine science opportunities[7].

Workshop participants were made aware of the unique historical and legal complexities relating to the Territory. It was recognised that many issues relating to MPA establishment and governance for this area could not be covered by a two-day meeting, arranged at relatively short notice and focused on environmental questions in the context of existing conditions. A comprehensive socio-economic assessment would anyway be beyond NERC interests and competence, requiring wider stakeholder engagement and attention to human dimension issues (including ethical, jurisdictional and defence considerations) at both national and international levels. The workshop noted that a formal FCO consultation exercise is intended on the potential BIOT MPA, and the UK and Mauritian governments have had preliminary discussions on this issue[8].

Annex 1 of this report provides the workshop programme; Annex 2, the participants list; and Annex 3, references and notes.

3. MPA definition and global context

The workshop adopted the International Union for Conservation of Nature (IUCN) definition of a Protected Area, whether terrestrial or marine, as "A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"[9]. This definition is also used by the Convention on Biological Diversity (CBD).

Protected Area designation regulates, but does not necessarily exclude, human use. As detailed in Table 1 (below), six categories are recognised by IUCN, depending on the naturalness of what is being conserved, and the objectives and strictness of protection. Most existing large MPAs are zoned, to allow for multiple uses; e.g. 0.3% of the area of the Great Barrier Reef Marine Park is IUCN category I, fully protected; 33% category II; 4% category IV; and 62% category VI. MPA zoning can also be vertical, with different levels of protection for the water column and seafloor. For all categories, protection needs to be a deliberate goal, involving a long-term commitment and addressing both generic and site-specific conservation objectives, rather than as an incidental outcome of other management policies (e.g. defence), that may change according to external circumstances.

The global total MPA coverage (of all categories) has recently been estimated[10] as 2.35 million sq km, 0.65% of the world ocean. This value compares with the internationally-agreed CBD target of 10% (by 2012), and a 30% target by the World Commission on Protected Areas. Only 0.08% of the world's ocean was estimated to be fully protected, i.e. 'no-take'. Although there have since been additional substantive MPA designations in the Pacific by the US (Marianas Trench, Pacific Remote Islands, and Rose Atoll Marine National Monuments) and Australia (Coral Sea Conservation Zone; interim status), representative

Indian Ocean ecosystems remain poorly protected or unprotected[11,] with many already badly damaged. As a result, the US-based Pew Environment Group has identified the Chagos Archipelago to be "top of the global list" as the marine area most worthy of MPA status, with full protection considered to be both highly desirable and achievable.

For the purposes of the workshop, the potential MPA was considered to include land-based ecosystems and the lower atmosphere, as well as reef systems, the deep sea-floor and the open ocean water column. All discussions were held without prejudice to the outcome of proceedings at the European Court of Human Rights, i.e. whilst noting the UK government position on Chagossian issues, the workshop made no assumptions with regard to the possibility of future re-settlement of any of the currently uninhabited BIOT islands.

Table 1. IUCN categories for protected areas in MPA context[9].

Category		Main characteristics
I	Strict nature reserve/wilderness area	Strictly protected, and as undisturbed as possible to preserve natural condition. Very limited visitor access. No commercial extraction of either living or non-living resources (no-take).
II	National park	Natural or near-natural areas; managed for ecosystem protection, with provision for visitor use. Resource extraction not generally considered compatible with this designation
III	Natural monument or feature	Aimed at specific natural feature (e.g. sea mount) or cultural site (flooded historical/archaeological area); visits and recreation may be encouraged
IV	Habitat/species management area	Aimed at particular habitats or target species (e.g. whale sanctuary); may require active management intervention or time-limited protection (e.g. during spawning/breeding season)
V	Protected landscape/seascape	Balanced interaction of nature and culture; human intervention is expected. Considered suitable designation for inhabited coastal areas of high aesthetic value
VI	Protected area with sustainable use of natural resources.	Explicit promotion of sustainable use of natural resources (including regulated fishing) to provide the means of achieving nature conservation

4. Scientific (and societal) importance of the BIOT area

Through national legislation (Marine and Coastal Access Bill), European directives (e.g. EU Marine Strategy Framework Directive, EU Habitats Directive, Natura 2000), international agreements (e.g. CBD, Ramsar Convention on Wetlands, UN Convention on Law of the Sea, and 2002 World Summit on Sustainable Development), and recent speeches[12], the UK government is committed to protecting marine biodiversity for direct and indirect human benefits. The wider scientific and societal rationale for MPAs is detailed elsewhere[13-16], although not without critics[17]. Discussions at the workshop focused on the environmental features of the BIOT area[18] that are either unique or particularly valuable in an MPA context. As follows, and in Tables 2 and 3 below:

- Large size. Many conservation-related benefits of Protected Areas increase non-linearly with size, since smaller areas are much less effective in maintaining viable habitats or populations of threatened species (particularly in the face of global warming, causing major spatial shifts in weather patterns and climatic regimes). Furthermore, the scale of a possible BIOT MPA would be global news, clearly delivering on UK political objectives for environmental protection and sustainability. Thus if all the potential EEZ is included, the BIOT MPA would be the world's second largest to date, only exceeded by Australia's Coral Sea Conservation Zone – and if all the MPA were a no-take zone, it would more than double the total world marine area with fully protected status.
- Habitat diversity. Whilst most conservation attention has to date focussed on shelf and coastal sea habitats (temperate and tropical), the BIOT area also includes an exceptional diversity of deepwater habitat types. Thus a very wide range of geomorphological and tectonic features are indicated from survey transects and satellite altimetry (sea surface height used as a proxy for bathymetry; Figs 2 & 3), with such features including plate separation, sea-floor spreading, sea-mounts and mid-ocean ridges (Chagos-Laccadive Ridge and Central Indian Ridge, the latter likely to support

chemosynthetic vent communities); deep trenches, to ~6000m (Chagos Trench and Vema Trench); and abyssal plains (mid-Indian Ocean Basin). Although the deepwater habitats of the BIOT area have not been mapped or investigated in any detail, work elsewhere has shown that: i) deepwater biodiversity is closely linked to physical diversity; ii) there may be marked temporal and spatial variability in community composition and abundances; and iii) species richness can be very high (particularly at the microbial scale; e.g. molecular analyses of deep sea sediment yielding >1000 species of a single class, Actinobacteria, per sample, with >90% being novel taxa)[19].

- Near-pristine conditions. Human impacts on the BIOT area are minimal, and less than any other tropical island groups in the Indian, Pacific or Atlantic Oceans. Fishing is limited and relatively well-regulated (see Section 6 below), and there are currently no significant economic activities on the islands other than those associated with the US military base on Diego Garcia. Direct anthropogenic impacts elsewhere in BIOT relate to the introduction of non-native terrestrial species (coconut palms and rats, not on all islands); illegal harvesting of sea cucumbers[20] and reef sharks, with occasional temporary encampments; mooring damage by visiting yachts; and some strandline marine litter, originating outside the BIOT area. Sea-water quality is exceptionally high (even in the Diego Garcia lagoon), with pollutant levels mostly below detection limits. The combination of these factors results in the BIOT area supporting around half the total area of 'good quality' coral reefs in the Indian Ocean, on the basis that 17% of that total is estimated to have been effectively lost, 22% is in a critical condition, 32% is threatened by a range of human activities, and only 29% (with BIOT providing 14%) remaining at low threat level[21]. The health of marine ecosystems in the BIOT area gives them crucial importance as the 'control' for research and management activities elsewhere, where human impacts are very much greater.

- High resilience of BIOT coral reefs. Since the late 1970s, coral reefs worldwide have increasingly suffered mass mortalities from temperature-induced bleaching, due to the breakdown of the symbiotic relationship between corals (animals) and algae (plants), the former relying on the latter for photosynthetically-derived energy. Whilst BIOT surface waters have warmed by ~1°C since the late 19th century, and many reefs there were badly affected by bleaching in 1998, they have recovered more, and faster, than any other known coral reef system[22]. This resilience has been ascribed to the lack of suspended sediment, pollution and other human impacts, providing beneficial consequences both for ecosystem integrity and water clarity. Thus grazing reef-fish limit prevent overgrowth by macro-algae, whilst high light penetration allows Chagos corals to grow to depths of >60m where they are less prone to thermal stress (cf lower limits of 20-40m elsewhere in the Indian Ocean). Chagos corals may also benefit from locally-favourable hydrodynamic conditions (intermittent inflows of cooler water, due to vertical movements of the thermocline), and/or genetic factors (prevalence of heat- and light-resistant dinoflagellate clades[23]). Whatever the basis for this resilience – currently subject to research attention, and meriting additional effort – it is of global conservation significance, in the context of recent dire prognoses for the future survival of coral reefs[24-26].

- Role as regional stepping-stone and re-seeding source. A key role for MPAs is their natural export of 'surplus' production and reproductive output, providing other areas with biomass and propagules (juveniles, larvae, seeds and spores) of species important either for commercial exploitation, conservation purposes or more general ecosystem functioning. This replenishment is hard to quantify, yet can be critical to the viability of heavily-harvested populations, particularly if they are also subject to regionally or temporarily variable breeding success. The BIOT area is exceptionally well-placed to serve this role (Fig 1), and preliminary studies of connectivity , based on species similarity coefficients and genetic markers[27], indicate potentially significant export (and hence scope for population replenishment) to the western Indian Ocean, consistent with ocean current data. In particular: corals and turtles are connected east-west, not north-south, whilst early fish genetics results indicate a high connectivity for species studied to date[28]. Other groups currently being tested (by US, German, Canadian and Taiwanese researchers) include terns and boobies, coconut crabs, and reef invertebrates. High-resolution biophysical modelling (combining life cycle features, dispersal behaviour and ocean hydrodynamics) could also advance our understanding of crucial connectivity issues; for example, as developed for zooplankton in the North Atlantic[29].

Table 2. Specific issues raised by the FCO to assist in assessing the conservation value of the BIOT area. Priority assessment: **XXXX**, very high global/regional importance; **XXX**, high global/regional importance; **XX**, moderate regional importance; **X**, low importance.

FCO question	Priority	Summary response
Are there areas kept inviolate from human interference so that future comparisons may be possible with localities that have been affected by human activities?	**XXXX**	Nowhere on Earth is inviolate from human impacts, but the BIOT area is amongst the least affected (with many pollutants lower than in polar regions). Land access is highly controlled and limited to military personnel and support workers, the BIOT Administration, and authorised scientists. Most of Diego Garcia is a designated Ramsar site[30]; the Chagos Bank is a proposed Ramsar site; and five reef/island areas are managed as Strict Nature Reserves (all or part of Peros Banhos Atoll, Nelsons Island, Three Brothers and Resurgent Islands, Cow Island and Danger Island). Non-native terrestrial species are problematic on some islands; a recent attempt at eradicating rats from Eagle Island was unsuccessful. All the BIOT area is a Fisheries Conservation Management Zone, with commercial catches regulated by licence and limited to 'surplus production'. However, some illegal fishing (for sea cucumbers, sharks and reef fish) does occur, and the BIOT area is affected by over-fishing elsewhere (e.g. ~90% depletion of sharks throughout the Indian Ocean since 1970s).
Are there represent-ative examples of major marine ecosystems or processes? What is the level of heterogeneity?	**XXXX**	Very wide range of (tropical) marine habitats and ecosystems. Shallow water and land areas are all reef-based, including the world's largest atoll (Chagos Bank). Reef heterogeneity is high, depending on wave-exposure, shelter and water depth, with different coral assemblages. Some island ecosystems affected by historical use. Deep seafloor ecosystems expected to be highly diverse, based on large-scale geomorphological variety, but have not been surveyed or studied in detail. Water column (planktonic) ecosystems inherently less heterogeneous.
Are there areas with important or unusual assemblages of species, including major colonies of breeding native birds or mammals? Is there type locality or is the planning region the only known habitat of any species?	**XXXX**	The BIOT area is host to ~60 endangered species on the IUCN Red List[31] (including the world's largest arthropod, the coconut crab); 10 Important Bird Areas recognised by Birdlife International[32], at least 784 species of fish, 280 land plants, 220 corals, 105 macroalgae, 96 insects and 90 birds (24 breeding); and undisturbed and recovering populations of Hawksbill and Green Turtle. Bird breeding populations are amongst the densest in the Indian Ocean (e.g. 22,000 nests on Nelsons Island, that has a total area of only 80 ha). Vegetation includes remnants of Indian Ocean island hardwoods. Marine endemics and type localities include the Chagos Brain Coral *Ctenella chagius* and the Chagos Clownfish *Amphiprion chagosensis* However, there are relatively few other endemics, supporting the case for high connectivity between BIOT and other areas.
Are there areas of particular interest to ongoing or planned scientific research?	**XXX**	All areas are of scientific interest. Over 200 publications to date from research visits limited in number, duration and platform capabilities. Current work includes reef resilience and palaeo-climate studies (on 300 yr old corals). Scope for globally-significant advances in knowledge of i) ocean acidification, using BIOT as a 'clean' reference site for observations on atmospheric composition and ocean carbon chemistry; ii) climate change, by developing and testing climate prediction models; iii) spatial scaling of population connectivity, from field-based and theoretical approaches; and iv) deep sea biology, geochemistry and geology. [Also see Section 7]
Are there examples of outstanding geological or geomorphological features?	**XXX**	Unique or near-unique reef features include: i) Chagos Bank is the world's largest atoll; ii) archipelago has a very high number of drowned and awash atolls yet with good coral growth; iii) Diego Garcia is possibly the most completely enclosed atoll with a sea connection; iv) the calcareous algal ridges are the most developed of the Indian Ocean (these stop atolls from eroding); only long-swell Pacific atolls show the development seen in Chagos; v) there are lagoonal spur and groove systems (only site where this is reported; vi) most lagoon floors are carpeted with corals instead of sand and mud; vii) light penetration to >60 m in deep lagoons and seaward slopes, linked to exceptionally deep peak coral diversity (20 m); viii) earlier Holocene still-stand cuts and caves clearly visible at 30-45 m depth; ix) location is seismically active, resulting in examples of recent uplifted limestone (raised reef islands) and some down-jolted, now submerged reefs. As noted above, deepwater geology and geomorphology in the BIOT area is also potentially of great interest, but has yet to be subject to detailed scientific study.
Are there areas of outstanding aesthetic and wilderness value?	**XXX**	Nearly all of it. Most small islands and lagoons are extremely picturesque and idyllic, with several smaller islands in near-pristine condition. The 'bird islands' are exceptionally rich. Reef quality and health is at a level that has not been seen at most other global locations for > 50 years, with water clarity for seaward reefs near its theoretical maximum.

Are there any sites or monuments of recognised historic value?	**XX**[33]	Known historic sites include the restored old settlement on eastern Diego Garcia. Settlements on other atolls have mostly disintegrated, especially those on Egmont and Eagle which were abandoned in 1950s. Graveyards on Diego Garcia, Peros Banhos and Salomon, with some recent restoration. Some pre-settlement wrecks deduced from collections of artefacts, such as Ming pottery, copper and brass naval items from various times over last 400 years. An Australian expedition in November 2009 will look for even older remains or evidence of settlement from very early ocean-faring societies.
What is the general state of Indian Ocean fisheries and reef fish, and is the status of blue water and reef fish in Chagos different?	**XXXX**	Indian Ocean reef fisheries are mostly grossly over-exploited, with low catch per unit effort. Catch per unit effort of reef fish in the mostly un-exploited BIOT area are ~20 times higher than in East Africa and elsewhere (although that does not mean 20-fold higher harvests could be sustained). Licensed blue water fisheries in BIOT focus on migratory tuna (in BIOT waters for only 10-20% of their lives), with some bycatch. [Also see Section 5]

Table 3. Preliminary assessment of relative economic values (use and non-use) for the environmental goods and services[34,35] provided by the BIOT area, excluding mineral resources [from Slide 4 of presentation prepared for the workshop by Pippa Gravestock]. Darker shading = higher value.

	USE VALUES		**NON-USE VALUES**		
	Direct use	**Indirect use**	**Option value**	**Bequest value**	**Existence value**
Tourism					
Fisheries					
Shoreline protection					
Research					
Scientific baseline					
Aesthetic land/seascapes					
Support for Indian Ocean fisheries					
Cornerstone of Indian Ocean reef recovery					
Model for Indian Ocean reef restoration					
Spiritual and cultural values					
Iconic					
Pristine					
Biodiverse(ity)					
Unique					

The analyses given in Tables 2 and 3 indicate that non-use values of BIOT natural resources are generally higher than use values. Preliminary monetary values were also included in Gravestock's presentation. Global studies done on the economic benefits of coral reefs estimate their value to range between $100,000 - $600,000 per sq km per year. That range compares with current BIOT protection costs of ~$5 per sq km per year. There was not, however, the opportunity at the workshop for detailed discussions of economic issues.

5. Fishery issues

The expectation for MPAs is that they are partly, if not fully, no-take zones for fishing, either immediately or phased-in, on the basis that the protected area thereby assists in achieving stock recovery, and/or maximising longterm yields over a larger area. No-take zones should also eliminate any non-targeted bycatch, that might threaten endangered species.

As already noted, fisheries in the BIOT area are both protected and exploited to some degree. MRAG Ltd is currently contracted to the BIOT Administration for the provision of relevant services and advice, primarily relating to fishery management within the 200 nm BIOT Fisheries Conservation Management Zone (FCMZ) declared in 1991 and revised in 1998[3].

Indian Ocean tuna fisheries are regulated by the Indian Ocean Tuna Commission (IOTC), of which UK-BIOT is a member. Yellowfin, bigeyeand skipjack are the main species commercially-targeted in the BIOT FCMZ, through both longline and purse seine fisheries (Table 4)[36]. The latter generally has higher catches, although both are very variable due to tuna's migratory behaviour (with maximum abundance in

BIOT waters in December and January). Longline bycatches of sharks have been recorded by weight since 2005, averaging ~50 tonnes per year. Bird bycatch is not considered a significant problem.

Table 4. Summary of commercial tuna fisheries in BIOT FCMZ. Data based on fishing vessels' logbooks, as provided in 2008 UK national report to the IOTC Scientific Committee[36]

	Longline		**Purse seine**	
	2007/08	***range 2003/04-2007/08***	***2007/08***	***range 2003/04-2007/08***
Total catch (tonnes)	1366	590 - 1366	23418	95 - 23418
Catch per unit effort (tonnes per vessel per fishing day)	0.91	0.52 – 1.10	18.1	3.5 – 36.2

There are two other BIOT fisheries: i) a small recreational fishing in Diego Garcia and from visiting yachts; and ii) Mauritian inshore fishing, through historical rights regulated through free licences, with the number of licences based on assessments of surplus allowable catch. Licence uptake and inshore catches have been very low in recent years, with no Mauritanian-flagged vessels fishing since 2006.

MRAG representatives at the workshop questioned whether full closure of all BIOT fisheries would achieve the desired conservation outcomes, providing a paper[37] that argued that:

- Inshore and offshore fishing areas need to be considered separately. Whilst a full no-take MPA would undoubtedly benefit resident reef fish, its benefits were less certain for highly migratory species such as tuna.
- The most likely outcome of tuna fishery closure would be a displacement of the fishing fleets to the edge of the BIOT area; total fishing effort (and tuna catches) might therefore remain much the same, the only difference being that the BIOT Administration would no longer receive licence income.
- True conservation benefit for tuna may best be achieved by maintaining an IOTC catch quota allocation as a coastal state and subsequently managing that quota to meet conservation aims, as a sunset option. This could help reduce the total Indian Ocean tuna catch in contrast to merely closing the FCMZ and displacing fishing elsewhere.
- If all the BIOT area were a no-take zone, that action might reduce the conservation influence of UK-BIOT within the IOTC
- Furthermore, illegal fishing in the BIOT area might increase, since licensed fishing vessels currently assist in the policing (and exclusion from the FCMZ) of unlicensed ones. Such an increase would have cost implications for management and surveillance, no longer covered by licence fees.
- The above factors make it preferable to fully or partly continue the commercial fishery, by internally zoning the BIOT MPA, or by limiting its size to less than the current FCMZ.

Whilst acknowledging the complexities of the above issues, other workshop participants were not all fully persuaded by these arguments. Coupled modelling of fishing fleet behaviour and tuna population dynamics under different zoning scenarios was suggested as an approach that might assist in quantifying key interactions, together with an analysis of the effects of the current 'closure' of Somali waters (due to risk of piracy). An interim measure for the BIOT area could include a more comprehensive research and observer programme for the licensed tuna fisheries, to increase the database on tuna spawning, juvenile catches and bycatches, and sensitivity of individual and population movements to climate change[38] and other environmental variables. If the tuna fishery in the BIOT area were to continue, on the basis of MPA-zoning, then such research activities could, in MRAG's view, contribute to longterm population conservation whilst also identifying any areas of aggregation of protected, endangered or threatened species that might benefit from targeted time-area closures.

Ultimately the decision on the extent of the open ocean no-take zone within a potential BIOT MPA will be a political one. There is undoubted attractiveness in the simplicity – and greater presentational impact – of a large, no-take MPA. For either a scaled-down version or an internally zoned one, more subtle justifications would be needed, with the risk that such options might appear to be no different from business-as-usual.

The issue of Mauritian fishing rights was also considered to be a political one, that could only be resolved by negotiation and international agreement. Full protection of the BIOT area as a no-take MPA would also need to apply to recreational fishing by visiting yachtsmen and on Diego Garcia.

6. Threats, risks and uncertainties

The workshop discussion groups identified a number of events, activities and possible developments that, depending on their location, timescale, severity and combination, might either strengthen the case for MPA establishment or jeopardise its future success. These issues could be grouped under three general headings – environmental changes, human activities, and science-policy interactions – as below. This list does not claim to be comprehensive; for additional details on several of these topics, see the Chagos Conservation Management Plan (2003)[5].

Environmental changes

- Direct climate change impacts. In addition to a likely increase of ~ 2°C in sea surface temperatures over the next 20-30 years (with serious implications for the frequency of coral bleaching[24,25]), significant changes in storm activity, rainfall, and ocean circulation are now near-inevitable[39]. All these aspects of climate change will impact the integrity and ecosystem functioning of coral reef ecosystems not just in the Indian Ocean but globally, increasing the societal and scientific value of near-pristine reefs that have shown greatest resilience to date, and that are therefore most likely to survive in future.

- Ocean acidification. Closely linked to climate change, increases in dissolved CO_2 cause decreases in pH and aragonite saturation – with potentially serious implications for coral calcification[40]. Thus ~50% reduction in coral growth rates are predicted[41] if atmospheric CO_2 levels reach 450 ppm (optimistically considered the 'safe' target in international climate negotiations; levels are currently ~385 ppm). Ocean acidification may already be affecting the rate of post-bleaching recovery, and is highly likely to hasten the demise of coral reefs subject to other stressors.

- Sea level rise. Closely linked to climate change (but also affected by local vertical land/seafloor movements), relative sea level at Diego Garcia increased by 4.4 mm per year over the period 1988-2001[42], nearly twice the global average for absolute sea level change. If future increases are not fully matched by the upward growth of reef flats – considered unlikely on the basis of historical evidence – the consequence will be increased shoreline wave energy, erosion of island rims and much greater flooding risk, particularly during extreme weather events. Since the maximum elevation of most northern BIOT islands is only 1 - 2 m, these are at risk of becoming submerged or 'drowned' atolls within a century on the basis of business-as-usual climate change scenarios.

- Introduced species. Current (land-based) problems for invasive non-native animals and plants are relatively well known, and the need for control measures recognised. No marine introductions were found when surveyed by IUCN in 2006, but continued care, e.g. re ballast water discharge in Diego Garcia lagoon, is necessary.

Human activities

- Illegal fishing. Illegal near-shore and reef fishing (e.g. for holothurians – sea cucumbers[20]) is a concern, and any increases could require a step-wise increase in protection and enforcement effort, in the form of an additional fishery protection vessel (that could also be available for research and monitoring activities). Underlying factors include the increase in the small-vessel fishing fleets of Sri Lanka and other nearby nations, in part due to post-tsunami aid; the rapid growth of populations all around the Indian Ocean; and the declining condition of coral reefs elsewhere, with severe over-exploitation of their fisheries.

- Visitors. Anchor-damage from yachts was identified as a significant visitor impact in the 2003 Management Plan[5], and remedial action has since been taken. The workshop considered that the development of commercial tourism would risk ecological damage and disturbance, and was pragmatically unlikely because of current defence activities; the very limited land available for

infrastructure (~16 sq km, excluding Diego Garcia); and constraints on freshwater supply and waste disposal. Nevertheless, it would be important goal for a BIOT MPA to provide virtual visits online (e.g. using Google Earth, and via the websites of conservation bodies[43]). Such access should involve underwater and land-based webcams and opportunities for 'citizen science' engagement in research and educational projects.

- Research activities. Scientists are also occasional visitors (~50 over the past 25 years, not connected with defence issues). Whilst considerable care has been taken to ensure that researchers do not themselves cause environmental damage, high standards need to be maintained for any future expansion of scientific activities – that could be expected following MPA designation.

- Sound pollution. Underwater seismic surveys and defence-related underwater acoustic operations are potentially damaging to marine mammals such as whales and dolphins, and were identified as a concern at a recent Indian Ocean Cetacean Symposium[44]. Any such activities would need to be carefully regulated to minimise or exclude impacts within a BIOT MPA.

- Oil pollution, marine litter. No marine oil-spill incidents to date. Most UK legal measures to minimise the incidence of oil pollution and assign liability for clean-up costs already apply to BIOT. Marine litter (flotsam, mostly plastic debris originating outside the BIOT area) is a shoreline problem on northern islands; its periodic removal is underway to maintain beach quality for nesting turtles.

- Seabed mineral extraction. Although not currently of economic importance, deep sea mineral exploitation may occur in future as land-based ore reserves become depleted and metal prices rise. The Central Indian Ocean abyssal plain (Figs 1-3; to the east of the BIOT area) is rich in ferromanganese nodules[45], and deposits of polymetalic sulphides and cobalt-rich ferromanganese crusts may occur at the actively-spreading Indian Ridge system[46] (Figs 1-3; to the west of the BIOT area). An ISA licence for polymetallic nodule exploration[47] was issued to India in 2002 for an area of 150,000 sq km outside national jurisdiction to the south-east of the Chagos Archipelago. The environmental impacts of commercial-scale seabed mineral extraction have yet to be determined.

- Bioprospecting. The high genetic diversity of coral reef ecosystems makes them attractive targets for biotechnological and pharmacological applications[48]. However, bulk harvesting is generally not required; instead small samples are used for initial screening, with subsequent laboratory-based molecular characterisation and production scale-up of any novel bioactives. The high cost of drug safety testing, together with patenting problems for natural products, has limited commercial development to date.

Science-policy interactions

- Political uncertainties. The head of the FCO delegation at the workshop stated the UK government position with regard to Chagossian re-settlement, US military use of Diego Garcia, and Mauritian sovereignty claims for the Chagos Archipelago: on all of these issues, no changes to existing arrangements were envisaged in the near future. Whilst some workshop attendees considered that more detailed planning for an MPA should not preclude re-settlement, and/or the possible return of all or some of the islands to Mauritian jurisdiction, these scenarios were not discussed in detail. The FCO emphasised that any proposal for the establishment of a BIOT MPA was without prejudice to the outcome of proceedings at the European Court of Human Rights.

- Financial commitment. MPA designation, establishment and maintenance are not cost-free activities: a longterm financial commitment is needed for their success[49]. Protection costs for the BIOT area are currently modest (estimated by Gravestock to be ~$5 per sq km per year), at the low end of a global analysis[50] of MPA costs that had a median of $775 per sq km per year. Whilst larger areas can be expected to have lower costs when expressed on a per area basis, other site-specific factors would continue to keep costs low for a BIOT MPA; in particular, the very low visitor numbers (reducing infrastructure and maintenance costs), and the negligible opportunity costs (income that might otherwise be available from alternative uses).

- Stakeholder support. As already noted, wide stakeholder support would be needed for the success of a BIOT MPA, where stakeholders are defined as all groups involved in achieving project objectives – not just in terms of permission or financial support, but also those who are directly or indirectly affected, and with the ability to influence public opinion.

7. Science needs and opportunities

A recent online review[51] identifies a very wide range of environmental science topics (mostly coral-reef related) considered to be of high importance for the Chagos Archipelago, grouped under 16 headings: Stepping stone in the Indian Ocean; ocean warming effects; coral mortality from warming; coral recovery and trajectories; fore- and hindcasting of coral population trajectories; lagoon responses; fish responses to climate change; acclimation by zooanthellae clades; water, exchange, clarity and sand budgets; reef geomorphology from remote sensing; estimates of fish diversity from remote sensing; pollution and water quality; invasive and introduced species; bird life; exploitation and poaching; and geochemistry and climate teleconnections.

The workshop had neither the time nor the expertise to consider all of these in detail. Nevertheless, it did re-group some key knowledge gaps and environmental science opportunities, in the context of both wider understanding (hypothesis-testing research opportunities, that might be of interest to NERC, the Royal Society or NSF) and MPA management (more operationally-focussed requirements, for support by BIOT Administration/FCO, DfID, Defra or NGOs), as summarised in Table 5 below.

NERC support could either be through individual, responsive-mode research grant proposals; consortium bids, assessed on scientific merit and involving a multi-institute research team; or a large-scale Research Programme, addressing NERC strategic priorities and initiated through theme leaders' Theme Action Plans. The workshop noted that responsive-mode grant bids were highly competitive, and that it was difficult to achieve the critical mass needed for interdisciplinary work. Whilst Research Programme development and approval was likely to be a lengthy and uncertain process, multi-sector linkages (involving marine, terrestrial, geological and atmospheric research communities) could enhance the likelihood of success. Co-support arrangements could also be potentially advantageous, e.g. research proposal development via the multi-agency Living with Environmental Change (LWEC) programme[52].

Table 5. Summary of some environmental science needs and opportunities for the BIOT area

	Knowledge gap	Context of wider understanding	Context of MPA management
1. Survey-based research and mapping	Deep sea bathymetry in BIOT area	Geomorphological evolution of West Indian Ocean basin; plate tectonics and other seafloor processes	Basic mapping and knowledge of habitat diversity; requirement for EEZ recognition under UNCLOS, and MPA boundary definition
	Deep sea biodiversity in BIOT area	Development of biodiversity rules re ubiquity/endemism, trophic structuring, and upper ocean - lower ocean connectivities; potential for novel discoveries	Inventories of species' presence and abundances within the MPA; reference for future changes
	Shallow sea (50-200m) habitats and biodiversity in BIOT area [below diving range]	Key ecosystem component linking islands/reefs with open ocean; maximum planktonic production likely to be at base of thermocline	Inventories of species' presence and abundances within the MPA; importance for fish feeding and spawning; reference for future changes
	Detailed mapping of island vegetation and soil structure	Comparison of natural and human-influenced tropical island eco-systems; improved calibration/ validation of satellite-based data	Baseline information for monitoring and stability/ erosion assessments
2. Monitoring environmental change	Atmospheric and marine biogeochemistry observations	Role as 'clean' control site, including dynamics of air-sea exchange processes; testing and development of global models of climate change and Earth system biogeochemistry (including ocean acidification)	Basic parameters for detecting site pollution and anthropogenic impacts

Monitoring environmental change cont	Measurements of key coral reef parameters (for corals, reef fish invertebrates, turtles and birds) as indicators of ecosystem health	Distinguishing responses to local, regional and global environmental change; quantifying factors determining ecosystem resilience; reference data for studies elsewhere	Information on MPA status and management effectiveness (protection, restoration or remedial action)
	Open ocean plankton studies and abundance estimates for top predators (blue water fish and sea mammals)	Regional studies of ocean productivity, linkage to ocean circulation changes; development of ecosystem approach to marine resource management	Information on MPA status and management effectiveness
	Physical oceanography measurements over range of spatial scales, including sea-level changes	Improved models of reef and lagoon currents and circulations within wider context; impacts of extreme events and future climate change	Identification of coastal erosion risks
3. Large-scale or generic science questions	Palaeo-climate studies using coral cores (century-scale)	Understanding responses of reef system to past changes	Quantifying natural variability and referencing future changes
	Biological connectivity of BIOT area to wider region (via genetics, tagging and modelling, and including open-ocean fisheries)	Theoretical basis for ecosystem scaling and delivery of goods and services; optimising design and effectiveness of protected areas; management of migratory fish populations	Quantifying benefits of MPA for food security in wider Indian Ocean; engagement with Indian Ocean Tuna Commission and wider conservation activities
	Factors determining recovery from coral bleaching and wider ecosystem resilience	Improved understanding of species interactions, non-linear ecosystem changes, emergent properties of intact systems and functional redundancy	Information on MPA status and management effectiveness; 'best practice' approaches for application elsewhere

Annex 1. Workshop programme

Wednesday 5 August

10.30 *Coffee and registration*

10.45 Welcome, scene setting and current progress

- Context of meeting, broad outline (Lindsay Parson)
- UK government perspective of Chagos/BIOT MPA (Joanne Yeadon)[53]
- Chagos protection as of now (Charles Sheppard)
- Chagos – shallow water ecosystems and issues (John Turner)
- Chagos – mid- and deepwater ecosystems and issues (David Billett)

12.00 Discussion

12.30 *Lunch*

13.30 Short presentations/contributions with discussion, including:

- Fisheries management in the Chagos FCMZ (Chris Mees)
- Marine conservation: the Pew perspective (Jay Nelson)
- The economic value of the British Indian Ocean Territory (Pippa Gravestock; presentation given by Charles Sheppard)
- Marine conservation: the IUCN perspective (Dan Laffoley)
- Issues relating to MPA development and design (Francesca Marubini)
- Marine conservation in SE Asia (Heather Koldewey)
- MPA development in Southern Ocean (Susie Grant)
- Shallow marine benthic biodiversity: tropical-temperate comparisons (Andrew Mackie)

16.30 Scientific review; key issues

17.30 *Close*

19.30 *Workshop dinner: The Olive Tree*

Thursday 6 August

09.00 Short presentations/contributions with discussion, continued

- Deepwater bathymetry and habitat mapping (Colin Jacobs)

09.15 Working Groups on science justification for BIOT MPA : benefits, threats and research issues

12.00 Reports from Working Groups (Rapporteurs: David Billett, Phil Williamson)

12.30 *Lunch*

13.30 Concluding discussions

15.30 *Close of meeting.*

Annex 2. Workshop participants

The following individuals attended:

David Billett	National Oceanography Centre Southampton
Alan Evans	National Oceanography Centre Southampton
Susie Grant	British Antarctic Survey
Simon Harding	Institute of Zoology
Peter Hunter	National Oceanography Centre Southampton
Colin Jacobs	National Oceanography Centre Southampton
Douglas Kerr	Foreign & Commonwealth Office
Heather Koldewey	Zoological Society of London/Institute of Zoology
Dan Laffoley	International Union for Conservation of Nature / Natural England
Andrew Mackie	National Museum of Wales
Francesca Marubini	Joint Nature Conservation Committee
Chris Mees	MRAG Ltd
Jay Nelson	Pew Environment Group: Ocean Legacy Program
Iain Orr	Independent observer
Scott Parnell	Foreign & Commonwealth Office
Lindsay Parson	National Oceanography Centre Southampton
John Pearce	MRAG Ltd
Katharine Shepherd	Foreign & Commonwealth Office
Charles Sheppard	University of Warwick / Chagos Conservation Trust
John Turner	University of Bangor
Keith Wiggs	BIOT Administration
Phil Williamson	University of East Anglia / NERC
Ian Wright	National Oceanography Centre Southampton
Joanne Yeadon	Foreign & Commonwealth Office

Others invited to attend but unable to do so included NERC Theme Leaders (Biodiversity and SUNR) and representatives from Plymouth Marine Laboratory, Scottish Association for Marine Science, University of Exeter, University of Newcastle, Defra, Royal Society, Linnean Society and UNEP Coral Reef Unit. Lynda Rodwell (University of Plymouth) and Mark Spalding (The Nature Conservancy) declined to participate on the basis of perceived deficiencies in stakeholder representation.

Comments and other written submissions were provided both before and after the workshop by Pippa Gravestock (University of York), Sidney Holt (ex FAO), Peter Sand (ex-UNEP lawyer, University of Munich), David Vine (American University) and David Snoxell (Coordinator of Chagos All Party Parliamentary Group), also on behalf of the Chagos Refugee Group (Olivier Bancoult) and the Mauritius Marine Conservation Society (Philippe la Hausse de Lalouvière and Jacqueline Sauzier). Most of these inputs were either circulated to all workshop participants or made available at the meeting.

Annex 3. References and notes

1. 3,400 sq km is a minimum estimate for the BIOT coral reef area. The total may be as much as 20,000 sq km if all water to 60m depth supports coral communities. BIOT land areas are from www.fco.gov.uk/en/about-the-fco/country-profiles/asia-oceania/british_indian_ocean_territory
2. BIOT Administration/FCO (1997) *The British Indian Ocean Territory Conservation Policy 1997*.
3. BIOT Administration/FCO (1998) *The Fisheries (Conservation and Management) Ordinance 1998.*
4. Huckle AE (2004) Proclamation No 1 of 17 September 2003 establishing the Environment (Protection and Preservation) Zone for the British Indian Ocean Territory. *Law of the Sea Bulletin* 54, 99.
5. Sheppard CRC & M Spalding (2003) *Chagos Conservation Management Plan.* Online at www.zianet.com/tedmorris/dg/chagos_conservation_management_plan2003.pdf. Includes references to other BIOT-relevant legal provisions.
6. Chagos Conservation Trust (2009) *The Chagos Archipelago: its nature and the future.*
7. Relevant research relates directly to priority challenges in two NERC themes (Biodiversity, and Sustainable Use of Natural Resources) and indirectly to all other five NERC themes and the inter-agency Living with Environmental Change (LWEC). NERC Strategy at www.nerc.ac.uk/about/strategy.
8. Meeting of delegations of the Mauritian and British Governments, Port Louis, Mauritius, 21 July 2009. The Mauritian side welcomed, in principle, the proposed establishment of a marine protected area. A further meeting to consider such issues is planned for October 2009. [Information from Joint Communiqué provided by FCO]
9. N Dudley (ed) (2009) *Guidelines for Applying Protected Area Management Categories,* IUCN. Online at http://data.iucn.org/dbtw-wpd/edocs/PAOPS-016.pdf
10 Wood LJ, L Fish, J Laughren & D Pauly (2008) Assessing progress towards global marine protection targets: shortfalls in information and action. *Oryx* 42, 340-51.
11. Kelleher G, C Bleakley & S Wells (1995) *A Global Representative System of Marine Protected Areas*, IUCN
12. Speech by Huw Irranca-Davies, Defra Minister, at UK Overseas Territories Conservation Forum conference "Making the Right Connections: A conference on conservation in UK OTs, Crown Dependencies and other small island communities", Grand Cayman, 4 June 2009. At www.ukotcf.org/pdf/2009Conf/FirstReport.pdf
13. National Research Council (US). Committee on the Evaluation, Design, and Monitoring Marine Reserves and Protected Areas in the United States. (2001) *Marine Protected Areas: Tools for Sustaining Ocean Ecosystems*. National Academies Press, 272 pp
14. Norse EA & LB Crowder (eds) (2005) *Marine Conservation Biology: the Science of Maintaining the Sea's Biodiversity.* Island Press, 496 pp
15. PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) (2007) *The Science of Marine Reserves*. Available via www.piscoweb.org/outreach/pubs/reserves
16. Durban Accord, arising from the 2003 World Parks Congress; http://cmsdata.iucn.org/downloads/durbanaccorden.pdf
17. Sand PD (2007) 'Green' enclosure of ocean space – *déjà vu? Marine Pollution Bulletin* 54, 374-6
18. The "BIOT area" is used in this document as the potential Marine Protected Area for the British Indian Ocean Territory, corresponding to the existing BIOT Fisheries Conservation Management Zone (1998), the BIOT Environment (Protection and Preservation) Zone (2003/2004) and the minimum potential Exclusive Economic Zone for the Territory, with their limits being 200 nautical miles from coastal baselines except where median lines apply. Such an area (of ~544,000 sq km) also includes all land areas, internal waters and the territorial sea currently defined on the basis of 3 nm limits. It is possible that a UK claim will be made to extend the BIOT EEZ (by ~180,000 sq km) to include additional continental shelf areas under Article 76 of UNCLOS. No assumption is made here as to whether such an EEZ extension should also be part of the MPA.
19. Stach JEM, LA Maldonaldo, DG Masson, AC Ward, M Goodfellow & AT Bull (2003) Statistical approaches for estimating Actinobacterial diversity in marine sediments. *Applied & Environmental Microbiology*, 69, 6189-200.
20. Price ARG, A Harris, A Mcgowan, AJ Venkatachalam & CRC Sheppard (2009) Chagos feels the pinch: assessment of holothurian (sea cucumber) abundance, illegal harvesting and conservation prospects in British Indian Ocean Territory. *Aquatic Conservation: Marine & Freshwater Ecosystems* doi 10.1002/aqc.1054. Online at http://www3.interscience.wioley.com/journal/122461154/abstract?CRETRY=1&SRETRY=0
21. Analyses from data in Wilkinson C (2008) *Status of coral reefs of the world: 2008*. Global Coral Reef Monitoring Network.
22. Sheppard CRC, A Harris & ALS Sheppard (2008) Archipelago-wide coral recovery patterns since 1998 in the Chagos Archipelago, central Indian Ocean. *Marine Ecology Progress Series* 362,109-17.
23. Yang SY, D Obura, CRC Sheppard & CA Chen (2009) High incidence of phyloytype A and among-reef variation of *Symbiodinium* diversity in seven common scleratinian species at the Chagos Archipelago, Indian Ocean. *Marine Ecology Progress Series*, in press.
24. Sheppard CRC (2003) Predicted recurrences of mass coral mortality in the Indian Ocean. *Nature* 425, 294-7.
25. Carpenter KE & 38 others (2008) One-third of reef-building corals face extinction from climate change and local impacts. *Science*, 321, 560-3.

26. Coral Reef Crisis meeting at Royal Society, 6 July 2009. Scientific publication in prep: A Rogers *et al* (2009) The coral reef crisis: scientific justification for critical CO_2 threshold levels of <350 ppm.

27. Sheppard CRC & MRD Seaward (eds) *Ecology of the Chagos Archipelago*. Linnean Society Occasional Publications, 2.

28. B Bowen (Univ of Hawaii), pers comm to CRC Sheppard.

29. Spiers DC, WSC Gurney, MR Heath & SN Wood (2005) Modelling the basin-scale demography of *Calanus finmarchicus* in the northeast Atlantic. *Fisheries Oceanography* 14, 333-58.

30. Ramsar Information Sheet (UK61002) at www.jnc.gov.uk/pdf/RIS/UK61002.pdf. Includes 170 scientific and technical references.

31. www.iucnredlist.org

32. www.birdlife.org/action/science/sites

33. Views of Chagossian representatives would be desirable on this issue, for their assessment of historical and cultural values.

34. Perman R, Y Ma, J McGilvray & M Common (2003) *Natural Resource and Environmental Economics*. Pearson Education Ltd.

35. Van Beukering PJH, L Brander, E Tompkins & E McKenzie (2007) *Valuing the environment in small islands - an environmental economics toolkit*. JNCC, Peterborough.

36. Mees C, J Pearce, J Clarke, O Wilson & A Carroll (2008). *UK National Report to IOTC Eleventh Session of the Scientific Committee, Mahé, Seychelles, 1-5 December 2008.*

37. *MRAG comments on the proposal to designate the British Indian Ocean Territory (BIOT) Fisheries Conservation Management Zone (FCMZ) as a marine reserve.*

38. Maury O & P Lehodey *(2005) Climate impacts on oceanic top predators*. GLOBEC Report 18. Online at www.globec.org/structure/regional/cliotop/cliotop_science_plan.pdf

39. IPCC (2007) Fourth Assessment Report of Intergovernmental Panel on Climate Change.

40. Gattuso J-P, M Frankignoulle, I Bourge, S Romaine & RW Buddemeier (1998) Effect of calcium carbonate saturation of seawater on coral calcification. *Global Planetary Change* 18, 37-47.

41. Silverman J, B Lazar, L Cao, K Caldeira & J Erez (2009) Coral reefs may start dissolving when atmospheric CO_2 doubles, *Geophysical Research Letters*, 36, L05606, doi:10.1029/2008GL036282.

42. Ragoonaden S (2006) Sea level activities and changes on the islands of the Western Indian Ocean. *Western Indian Ocean Journal of Marine Science* 5, 179-94.

43. NGOs and other bodies with relevant public communication interests (e.g. via online 'wildcams' and 'crittercams') include National Geographic, IUCN/WCPA (Protect Planet Ocean), Marine Education Trust, Zoological Society of London, Pew Environment Group, and the Royal Society for Protection of Birds.

44. Lankanfinolhu (Maldives) Declaration arising from Indian Ocean Cetacean Symposium in Maldives, 18-20 July 2009. Online via www.mrc.gov.mv/index.php/news_events/iocs_closing

45. Mukhopadhyay R, AK Ghosh & SD Iyer (2007) The Indian Ocean Nodule Field, Vol 10: *Geology and Resource Potential (Handbook of Exploration and Environmental Geochemistry)*, Elsevier.

46. Murton BJ, ET Baker, CM Sands & CR German (2006) Detection of an unusually large hydrothermal event plume above the slow-spreading Carlsberg Ridge: NW Indian Ocean. *Geophysical Research Letters*, 33, L10608, doi:10.1029/2006GL026048

47. For details of exploration licenses issued for the Indian Ocean and elsewhere by the International Seabed Authority, see www.isa.org.jm/en/scientific/exploration

48. For example, NRC Committee on Marine Biotechnology (2002) *Marine Biotechnology in the Twenty-First Century: Problems, Promise, and Products.* 132 pp, National Academies Press.

49. Emerton L (2003) Covering the economic costs of Marine Protected Areas: extending the concept of financial diversity and sustainability. *Vth World Parks Congress: Sustainable Finance Stream.* Online at www.conservationfinance.org/Workshops_Conferences/WPC/WPC_documents/Apps_01_Emerton_v1.pdf

50. Balmford A, P Gravestock, N Hockley, CJ Mclean & CM Roberts (2004) The worldwide costs of marine protected areas*, Proceedings National Academy of Science* 26, 9694-7. Online at www.pnas.org/content/101/26/9694.full

51. Sheppard CRC & 19 others (2009) *Science in Chagos. What we know and what we need to know*. Online at www.reefnewmedia.co.uk/cmt_chagos/uploads/pdf/science/science_in_chagos.pdf

52. The aims of the Living with Environmental Change (LWEC) programme include whole-system assessments and risk-based predictions of environmental change and its effects on ecosystem services, health (human, plant and animal), infrastructure and economies; also integrated analyses of potential social, economic and environmental costs, benefits and impacts of different mitigation and adaptation responses. LWEC partners include NERC, ESRC, Defra, DfID, DECC, Met Office, Natural England and around 15 others. Details at www.lwec.org.uk

53. Apart from this initial short presentation, stating the current UK government position, FCO participants had an observer role at the meeting.

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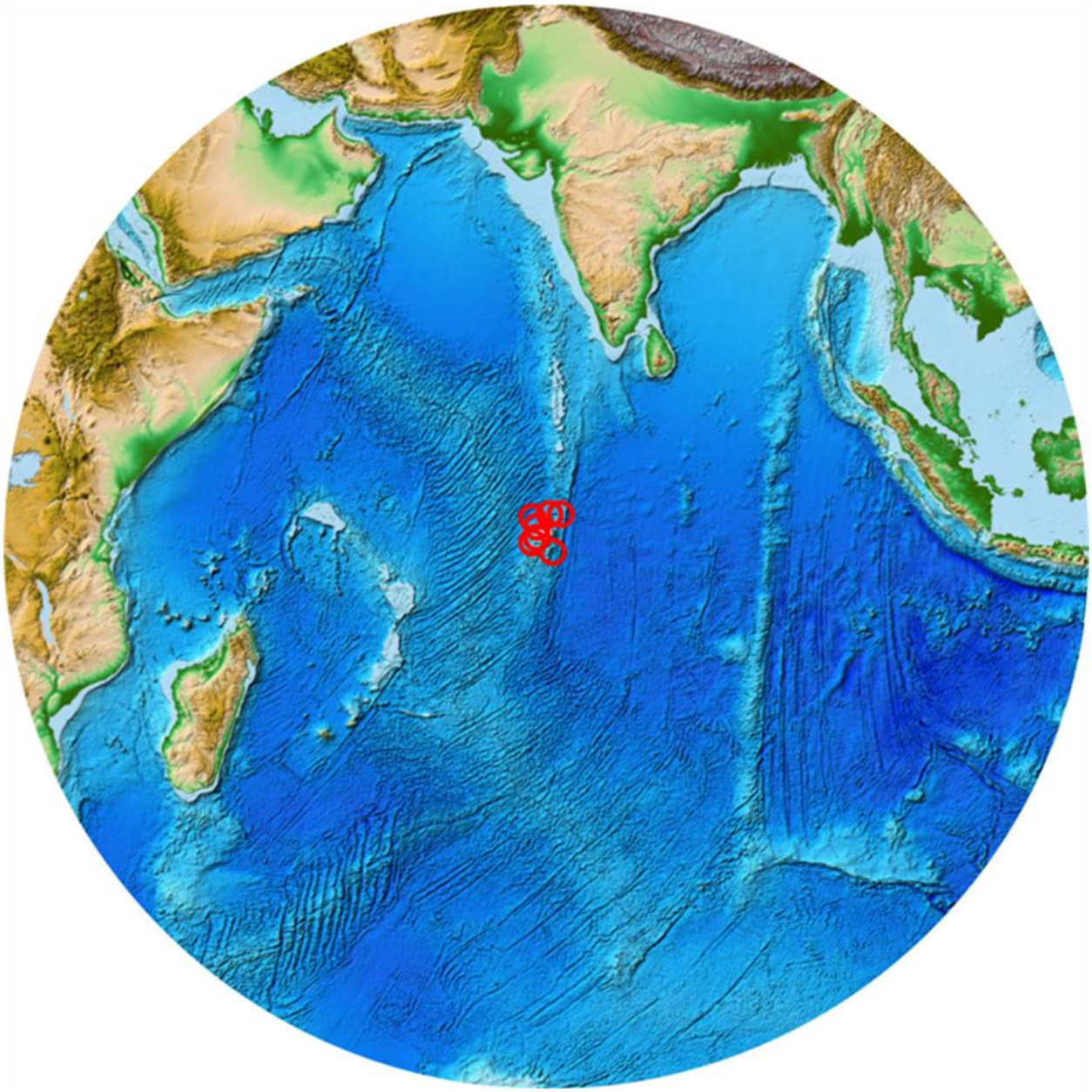

Figure 1. The British Indian Ocean Territory is centrally-located in the Indian Ocean (larger BIOT islands circled). This position increases its conservation significance as a 'stepping stone', re-population source and refuge for other localities.

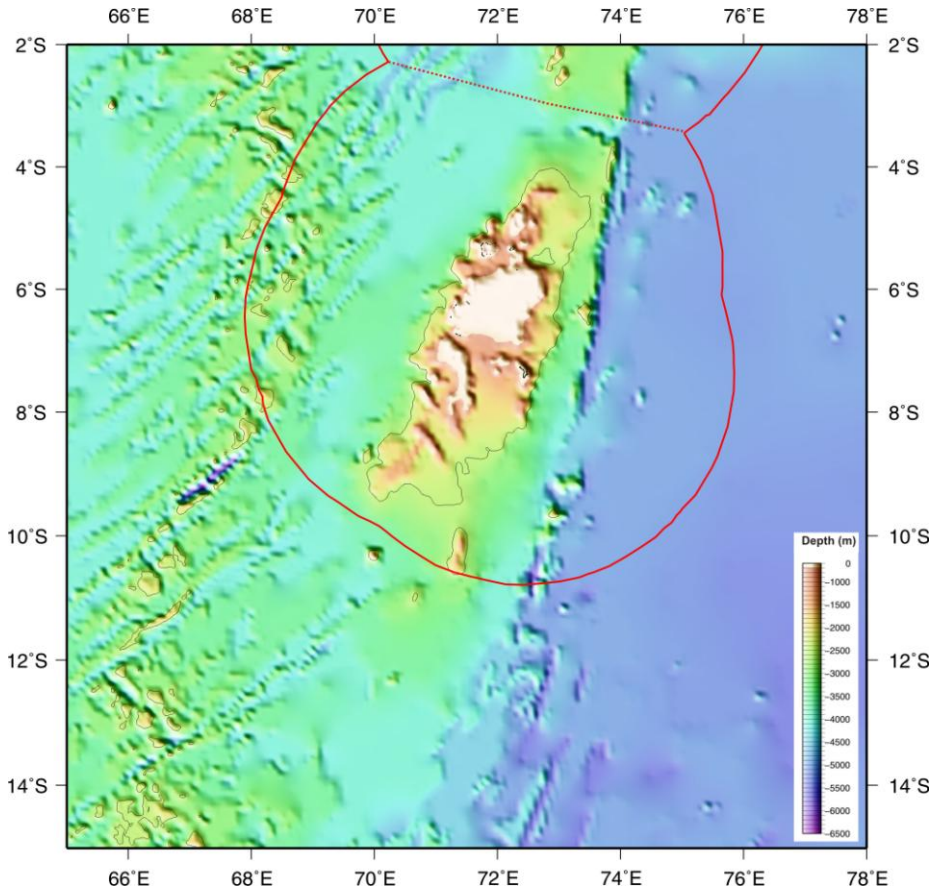

Figure 2. Bathymetry around the British Indian Ocean Territory, mostly indirectly determined from satellite-derived sea height data. The boundary of the current Fishereries Conservation Management Zone (minimum potential EEZ) is shown, based on 200 nm limits. (Image: NOCS/GEBCO)

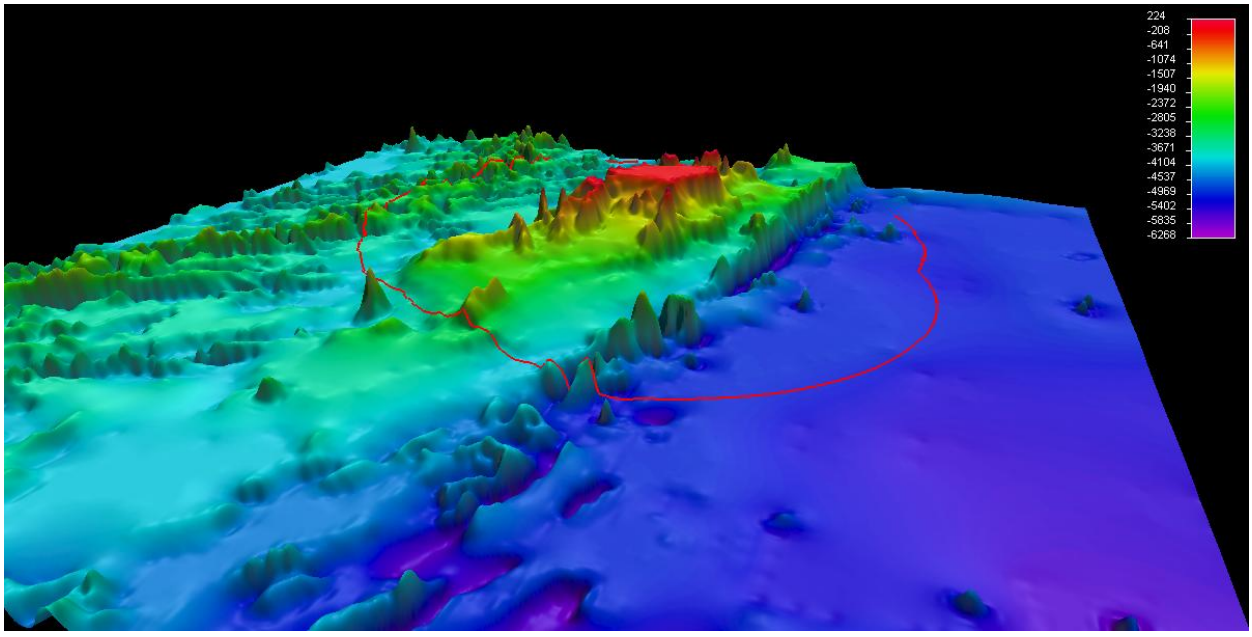

Figure 3. Bathymetry around the British Indian Ocean Territory, as above; 3D view from south-east. (Image: NOCS/GEBCO)