INDIAN OCEAN COMMISSION



REVIEW OF CORAL REEF MONITORING ACTIVITIES IN THE SOUTHWEST INDIAN OCEAN

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ISLANDS
Nos îles. Nos vies. Notre devenir.
Our lands. Our life. Our future.

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Abbrevations

AFRC	Albion Fisheries Research Centre
AID	Association d'Intervention pour le Développement et l'Environnement (Comore)
AMP	Aldabra Marine Programme
ARVAM	Agence pour la Recherche et la Valorisation Marines
BV	Blue Ventures
CEAGI	Coastal East Africa Global Initiative
CHICOP	Chumbe island Coral Park
CI	Conservation International
CORDIO	Coastal Oceans Research and Development in the Indian Ocean (formerly Coral Reef Degradation in the Indian Ocean)
COREMO	Coral Reef Monitoring database (ARVAM)
COUT	Cellule des Océanographes de l'Université de Toliara
CRIS	Coral Reef Information System
CRTF	Coral Reef Task Force
DOC	Dissolved Organic Carbon
DRC	D'Arros Research Centre
EAME	East Africa Marine Ecoregion
EIA	Environmental Impact Assessments
FFEM	Fonds Français pour l'Environnement Mondial
GCRMN	Global Coral Reef Monitoring Network
GEF	Global Environment Facility
GVI	Global Vision International
ICM/ICZM	Integracted Coastal (Zone) Management
ICS	Island Conservation Society
ICT	Information Communication Technology
IHSM	Institut Halieutique et des Sciences Marines (Tulear)
IMS	Institute of marine Science
IOC	Indian Ocean Commission

IOGOOS	Indian Ocean – Global Ocean Observing System
IRD	Institute for Research for Development
IUCN	International Union for the Conservation of Nature
LIT	Line Intercept Transects
LPT	Line Point Transects
MACEMP	Marine And Coastal Environment Management Project
MBCA	Menai Bay Conservation Area
MIMCA	Misali Island Marine Conservation Area
MMCS	Mauritius Marine Conservation Society
MNP	Madagascar National Parks (formerly ANGAP)
MOI	Mauritius Oceanography Institute
MOU	Memorandum of Understanding
MPAs	Marine Protected Area
MWIOPO	Madagascar and Western Indian Ocean Programme Office (WWF)
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
PIT	Point Intercept Transects
PMM	Parque Nationale de Moheli
PRECOI	Programme Régionale de l'Environment du Commission de l'Ocean Indien),
ReCoMaP (ProGeCo)	Regional Coastal Management Programme (RECOMAP)
SCMRT-MPA	Seychelles Center for Marine Research and Technology-Marine Park Authority
SEMPA	Southeast MPA
SEYMEMP	Seychelles Marine Ecosystem Management Programme
Sida/SAREC	Swedish International Development Agency, Department for Research Cooperation.
SIF	Seychelles Islands Foundation
SNCRN	Seychelles National Coral Reef Network
SNPA	Seychelles National Parks Authority
SST	Sea surface temperature
SWIO	South West Indian Ocean
SWOT	Strengths Weaknesses Opportunities Threats analysis
UNDP	United Nations Development Programme
WCS	Wildlife Conservation Society
WIO	Western Indian Ocean
WWF	World Wide Fund for Nature/World Wildlife Fund

The ISLANDS region

The focal region for the ISLANDS project comprises the South West Indian Ocean (SWIO) islands, under the umbrella of the Indian Ocean Commission, with the inclusion of Zanzibar (fig. 1). The Global Coral Reef Monitoring Network (GCRMN) established itself as a global network in 1998 with the publication of the first global status report in 1998 (Wilkinson 1998). This coincided with the first global mass coral bleaching event associated with climate change, providing massive impetus for the continuation and growth of the GCRMN. The first GCRMN report from this region covered the whole of the Western Indian Ocean (Salm et al. 1998), but subsequently the islands and mainland subregions were separated from one another, matching the mandates of the Indian Ocean Commission for the islands, and of the East African Community and Southern African Development Community focussing on mainland East Africa. The next global GCRMN report (Wilkinson et al. 2000) had separate chapters for the WIO islands (Bigot et al. 2000) and mainland (Obura et al. 2000) states, both focusing on the impact of the mass coral bleaching event in 1998.

Figure 1. Map of the South West Indian Ocean (SWIO) islands region, including Zanzibar, in the context of the broader Western Indian Ocean countries of the Nairobi Convention region.

The islands subregion of GCRMN was operationalized through support from the IOC in the PRECOI project (Programme Régionale de l'Environment du Commission de l'Ocean Indien), funded initially by the GEF from April 1998. It brought together representatives from the island states (Madagascar, Mauritius, Seychelles, Comoros and France) in a subregional node for the GCRMN, with multiple members and relationships from national to international levels (see Table 1). Over its lifetime, PRECOI received funding for coral reef monitoring from the GEF, the French GEF (FFEM), ReCoMaP, CORDIO and national funding. The PRECOI programme supported capacity building, national and regional workshops for integration, and funding for monitoring activities in each of the countries, continuing until the programme terminated. Among other outputs (Box 1), PRECOI supported the publication of a methods guide on coral reef monitoring for the south-west Indian Ocean (in French and English), which provided consistency of methods across all countries of the region. Within each country, a process was followed to establish a national network of monitoring sites.

Box 1. Outputs of the SWIO GCRMN nodes

- Coral reef Monitoring guidelines
- Guidelines for vulnerability shallow coral reef mapping
- Atlas of Vulnerability of shallow coral reefs
- COREMO DATA BASE
- Training and Equipment
- Annual and regional reports
- Contribution the GCRMN status report

Table 1. Institutional arrangements in the SWIO GCRMN node.

Level	Host institutions and focal points
National	MPAs, Ministries of Environment, Universities, NGOs, CBOs
Regional	COI, Nairobi Convention Coral Reef Task Force, CORDIO, WCS, CI, ARVAM, IOC MPA Managers Network
International	GCRMN, International Coral Reef Initiative (ICRI), Reef Check

At the same time, broader regional support for monitoring the impact of the 1997/98 bleaching event was obtained through Sida/SAREC funding to the CORDIO programme, which replicated the mainland/islands split with an islands node based initially in Reunion and from 2002 onwards in the Seychelles. To provide a governance context for GCRMN in the region, a Coral Reef Task Force (CRTF) was established by the Nairobi Convention Conference of Parties from as early as 1998, but becoming operationalized around 2005. The purpose of the CRTF was to take on the role of mainstreaming coral reef monitoring and management into national and regional processes. Other regional programmes that supported coral reef monitoring and research that developed during from about 2000 to 2010 included the regional programmes of WWF – the Madagascar and Western Indian Ocean Programme Office (MWIOPO) for the islands, the East Africa Marine Ecoregion (EAME, now part of the Coastal East Africa Global Initiative, CEANI), and research activities of the Wildlife Conservation Society (WCS). The regional marine programme if the IUCN, covering the entire WIO region and working closely through the Nairobi Convention and its role in the Convention on Biological Diversity, was active through the 1990s, but ended in 2005.

With the ending of the PRECOI programme, consistent funding for coral reef monitoring in the SWIO islands region was terminated, as did direct support to the GCRMN network node. As a result, monitoring has been less consistent since then, and dependent on institutional and project funding, and few of the partners involved in the node previously have been able to maintain consistent participation in it.

Status of coral reef monitoring and capacity in the countries

This section summarizes the main points from the national status reports commissioned by the ISLANDS project, focusing on the main backbone of monitoring in each country, and additional smaller contributions and opportunities.

Comoros

Coral reef monitoring in the Comoros was established through the PRECOI project, in which the NGO AIDE Comore was identified as best foundation for continued monitoring in the country. It worked closely with the Ministry of Environment. On Moheli, the marine park (Parque Nationale de Moheli, PMM) was established with UNDP assistance in 2002, providing key sites in the monitoring network for the country. Anjouan island, with the least capacity and resources for monitoring has not benefited as much from long term monitoring as the other two islands. However, neither AIDE nor the PMM have had internal resources to maintain monitoring capacity after 2007 when PRECOI and related funding sources ended – since then, monitoring has been irregular.

Assessment studies have been conducted in Comores recently, in 2009 through research projects from Portland University (USA), and in 2010 under CORDIO's reef resilience assessment programme.

Madagascar

Madagascar is the largest of the island countries, and similar to the Seychelles, faces the challenges of logistics and communication across a large area. Consequently, it also has a varied institutional setup, with different NGOs working with government institutions in a sub-regional structure. As with the other countries, the main backbone of monitoring was established through the PRECOI project, then taken on by different groups in different regions. The main regions are:

- The northeast, where the Masoala Marine Park was the first and main marine protected area (nationally), run by Madagascar National Parks (MNP, formerly ANGAP) with assistance and co-funding from the Wildlife Conservation Society (WCS). Monitoring started with an assessment in the last months of the 1998 bleaching event (McClanahan and Obura 1998) and has continued to the present by WCS and MNP. The last of Conservation International's (CI's) rapid assessment surveys were in the northeast (Maharavo et al. 2011, Obura et al. 2011), and further assessments will form the basis for monitoring in locally protected areas;
- The northwest, led by historical research at the Centre Nationale de Recherche Oceanographique (CNRO) on Nosy Be, but with little work that sustained into the 1980s. Following rapid assessment surveys led by CI in 2005, 2009 and 2011, a protected area was set up at Nosy Hara, run by MNP with assistance by WWF. WCS has invested in marine protected areas but with low coral reef development, so with little focus on reef monitoring. More recently, interest in establishing more stable bases for monitoring is happening in the Mitsio islands and Nosy Be;
- The southwest, is a large stretch of reef coastlines from south of Tulear (about 25^{o}S) to the Barren Islands (17^{o}S). Interest in coral reef monitoring has been initiated through historical work at IHSM in Tulear and French scientists in the 1980s, but in the last decades, monitoring has been supported through NGO-led initiatives working with communities, including WWF (Itampolo), Blue Ventures (Andavadoaka – Velondriake, Belo sur Mer, Barren Islands), Reef Doctor (Ranobe) and others.

Other initiatives that have supported assessments, and monitoring where long term investments have been made, have focused on resources and environmental impacts for more development or commercial interests rather than science or conservation. The NGO/consulting firm COUT has conducted many of these, including some sites in the NW and SW supported by UNDP, and around a port/mining development area at Fort Dauphin (in the SE), starting in 2007 and continuing to date.

As in other countries, one-off assessments have been increasingly applied in the last decade, to provide information for further work. In many cases, these have led to identification of MPA sites:

- Three RAPs by CI – NW and NE (Mitsio, Nosy Hara, Ambodivahibe, Loky Bay, Vohemar), 2005-2011 (refs);
- WWF has led several assessments for resilience, in the NW (Nosy Hara) and SW (multiple sites) (refs);
- WCS assessments, in the south (Andavadoaka, Salary Nord) and in the north (Nosy-Be, Nosy Mitsio) (refs);
- Blue Ventures, with MNP – Barren Islands (ref);
- Tulear and southern Madagascar – biodiversity focus – IHSM and the Natural History Museum, Paris, and WCS (ref).

Mauritius

Coral reef monitoring in Mauritius is split operationally between activities on the main island and those on Rodrigues, which run independently from one another. No consistent monitoring happens on the more remote islands (e.g. St. Brandons island), though occasional studies and research projects to provide some data on reef status.

In Mauritius, the Albion Fisheries Research Centre (AFRC) is the technical arm of the Ministry of Fisheries that implements coral reef monitoring, starting in 1998, and operating a GCRMN-recommended method as part of the PRECOI project. As a government agency, it sustains long term monitoring of some of the 13 monitoring sites on an annual basis, through internal budgets. Coral reef monitoring has been implemented alongside a number of other reef-focused projects by AFRC as well as the University of Mauritius, Ministry of Environment and Mauritius Oceanography Institute, with the principal projects focusing around assessments and mapping to establish MPAs (in Blue Bay and Balaclava), and research projects on coral diversity and restoration. Non-government organizations have also been involved in reef assessments, both national (particularly the Mauritius Marine Conservation Society (MMCS) and ARVAM/PARETO from the Reunion as technical experts, also focused around establishment of protection, and also with sensitization and ecotourism support.

On Rodrigues, monitoring was initiated by the Shoals of Capricorn Programme/Rodrigues Underwater Group in 1999-2000, conducting some initial assessments using Reef Check methods. These transitioned in 2002 when the Shoals Rodrigues NGO was established and the GCRMN monitoring method was adapted for local use. In the last 2000s, the Southeast MPA (SEMPA) was established, adding further sites to the long term monitoring network. With the strong investment and involvement of Shoals Rodrigues and SEMPA in reef monitoring, the GCRMN methods have been progressively modified and added to, to make them more useful for management objectives, and to match local priorities (such as of fishing, different habitats, etc).

Seychelles

Monitoring in the Seychelles is undertaken by a wide range of institutions and partners, reflecting fragmentation of the country among multiple small islands. This results in many challenges in conducting regular monitoring, as transport and logistical costs are high. Nevertheless, the broad involvement reflects the strong interest in coral reef health, and recognition of its central role in sustaining the national economy, providing the foundation for an effective monitoring programme.

The main backbone of monitoring in the Seychelles was established through the Shoals of Capricorn programme (1998-2001). It transitioned into the Seychelles Center for Marine Research and Technology-Marine Park Authority (SCMRT-MPA) in 2002, which itself transformed into the Seychelles National Parks Authority (SNPA) in 2010. Given the difficulties of monitoring over dispersed islands systems, the main focus of this work has been on the central granitic islands, with occasional surveys or assessments being done on outer islands.

At the same time as the Shoals programme was ending, funding from the GEF was obtained to start the Seychelles Marine Ecosystem Management Programme (SEYMEMP), which ran from 2001-2005. It also

focused on the main granitic islands of Mahe and Praslin, contributing to the SCMRT/inner islands datasets. When the programme ended Global Vision International (GVI) started a volunteer monitoring programme that included maintaining sites on NW Mahe as part of the national monitoring programme, which continues today.

On the Outer islands, different institutions invested in different islands maintain coral reef monitoring programmes:

- Aldabra – the Aldabra Marine Programme, started in 1999, bringing together the Cambridge Coastal Research Unit (University of Cambridge) and the Seychelles Islands Foundation (SIF). It also covers some sites on Assumption, Astove and St Pierre, though monitoring is not conducted every year due to limited funds. In recent years, the Aldabra marine station has been conducting annual monitoring at some sites, and in 2013 is developing an institutional monitoring programme to internally support coral reef monitoring annually.
- The Island Conservation Society (ICS) has a mandate to run environmental programmes through an MOU with the Islands Development Corporation, thus on Aride, Desroches and Alphonse it conducts assessments and monitoring of coral reefs.
- The D'Arros Research Centre (DRC), owned privately, initiated reef monitoring programmes within the Amirantes group, notably around D'Arros and St Joseph atoll, with additional sites on Remire and African Banks to establish baselines on corals, reef fish, deep sea benthos seabirds and turtles (Engelhardt, 2005; Bijoux *et al.* 2008)

Zanzibar

Coral reef monitoring Zanzibar has a long history, as the presence of a major institutions such as the Institute of marine Science (IMS, an institute of the University of Dar es Salaam) has provided a locus for human and financial capacity combined with easy accessibility around a small island. Monitoring started in 1994 following some basic assessments on both Unguja and Pemba islands, and by 2000 there were six permanent sites on Unguja and one on Pemba, supported at that time by Sida/SAREC and CORDIO, and more recently through other research/collaborative initiatives such as the Coral Reef Targeted Research project from 2006-10.

Complementing the technical capacity present on Zanzibar was the privately operated high-end tourism attraction at Chumbe island, where consistent support for long term monitoring has been obtained through fee-paying tourists. Staff at CHICOP have collaborated with the Zanzibar national monitoring programme to maintain one of the permanent monitoring sites, in addition to implementing a needs-oriented survey programme to inform their management system.

GCRMN methods were used consistently in the Tanzania national monitoring programme, and a string of graduate students in marine science at IMS has ensured sufficient capacity to undertake the surveys. Chumbe island adapted Reef Check-style monitoring for its own needs.

Zanzibar has also had a number of assessment studies, some of which leading to further monitoring and support for management, including a situation analysis of Mnemba atoll (xxx, 2005), broader site assessments for the MACEMP national marine programme funded by the World Bank across Unguja and

Pemba (Mnemba, MBCA, MIMCA – 2005, 2010), and a reef resilience survey of west Pemba (Grimsditch et al. 2009).

Analysis of regional CRM metadata, 1994-2013

Though many challenges have been faced in monitoring coral reefs in the region, significant effort has been made, and coral reef monitoring has been active across all the countries. A total of 1404 records were compiled for the six countries of the ISLANDS project, Comoros, Madagascar, Mauritius, Seychelles, Reunion and Zanzibar. Of these 519 records were classified as repeat-survey sites corresponding to annual monitoring programmes (including some with more frequent and some with less frequent samples). The balance, 885 are considered as one-off assessment surveys for rapid or other site assessments, and potentially some sites intended for monitoring, but discontinued after the first sample (fig. 2).

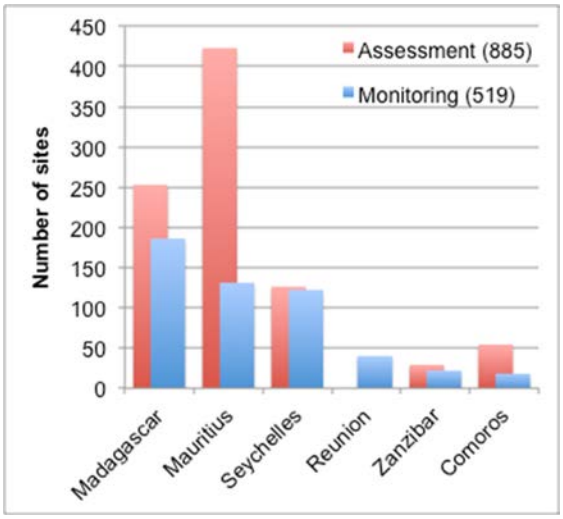

Figure 2. Number of assessment and monitoring sites reported for the SWIO islands.

Madagascar had the highest number of monitoring sites (180), following by Mauritius and Seychelles (≈ 150) then Reunion, Zanzibar and Comoros with 40-20 sites each. Mauritius had the highest number of assessment sites, reflecting rapid growth in environmental assessments required by law for development and commercial projects.

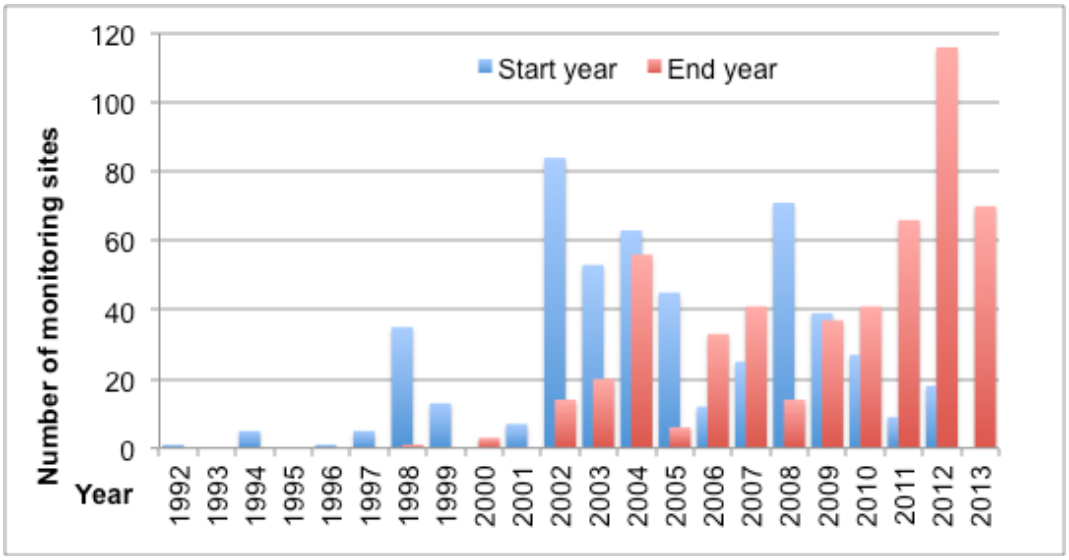

Figure 3. Years recorded as the earliest and most recent years for monitoring in the SWIO islands.

The first long term monitoring site in the region was started in 1992 (fig. 3), comprising a single site in the Seychelles, followed by 5 sites started in Zanzibar in 1994, and 5 in Madagascar in 1997. The coral

bleaching event in early 1998 initiated the first significant pulse of monitoring in the region, with 35 new sites started, mainly in Madagascar, Reunion and the Seychelles. The largest bout of new sites was started in 2002, 84 sites in all, predominantly in the Seychelles (GEF-funded projects) as well as in Mauritius and Madagascar. In subsequent years, large numbers of new sites were started in all the countries. Starting in 2002, some monitoring sites were discontinued, presumably to rationalize effort and focus on key sites with the greatest relevance for monitoring.

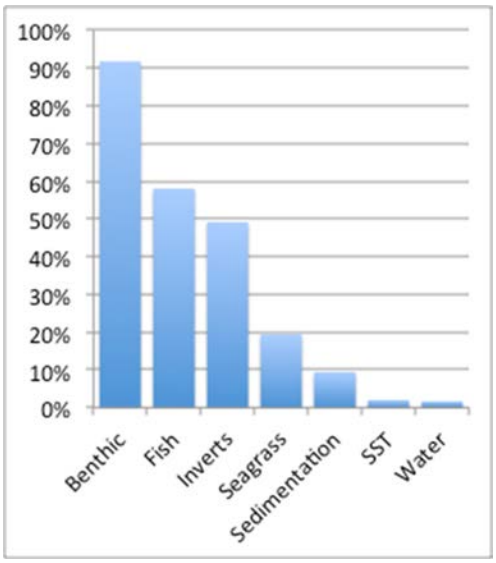

Figure 4. Proportion of sites at which monitoring was conducted on each of the components listed in the x axis, across the SWIO islands.

The priority in monitoring in the region has been overwhelmingly on benthic cover (fig. 4), with over 90% of all sites including monitoring of benthic cover, with lower proportions for fish (58%) and mobile invertebrates (49%). Monitoring for seagrasses has been reasonably common, at 20% of sites, but attention to physical parameters – sedimentation, water temperature and water quality, has been low. Greater detail on how these areas were split among countries is shown in Appendix 1.

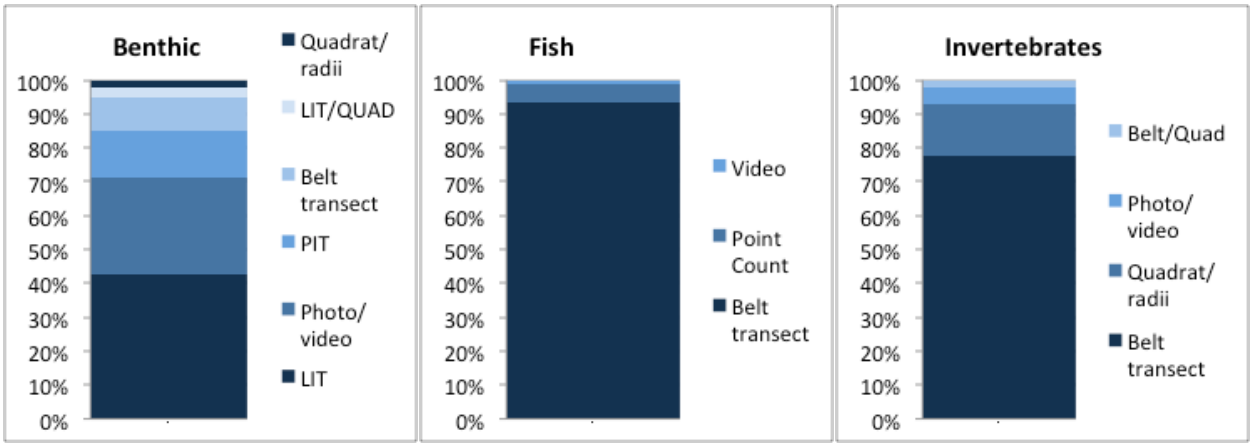

Figure 5. Methods used for monitoring of mobile invertebrates (left overall, right, by island) in the SWIO islands. LIT- Line Intercept Transect, PIT- Point Intercept Transect, QAUD-Quadrat.

The range of methods applied in each of the main monitoring areas – benthic, fish and mobile invertebrates was very high for benthic monitoring, and lower for fish and invertebrates (Fig. 5). This likely reflects the greater popularity of benthic status for reporting of coral reef health, the relative ease of benthic monitoring and diversity of methods available (e.g. English et al. 1997, Conand et al. 1999, 2000). By contrast, fish monitoring is technically more challenging and therefore is applied in fewer locations, and as a result there is greater consistency in methods used. Mobile invertebrate monitoring falls between these two, partly as it is easier than fish monitoring, but also the selection of target

invertebrates varies greatly due to management interests, and their densities can also be more variable, resulting in greater diversity of methods used. In addition to this variation in the methods used for monitoring, there is very high variation in the depths of monitoring sites across the region (Fig. A4, appendix 1). These high levels of variation in methods and depths reduce the comparability of monitoring data across the region.

Habitat selection for monitoring sites was relatively well split over 3 main classes of reef types (Table A1), with even numbers for fore reef/fringing reef/outer sites versus lagoon/patch reef habitats (144 and 135 sites, respectively), lower numbers of reef flat (very shallow) sites (84), and even fewer offshore/bank sites (25) . Differences in classification, among countries and programmes is high, resulting in a large number of sites being grouped in the category 'Other' (110), and this element requires some standardization across the region.

Capacity for monitoring

Across all island countries, broad-based national monitoring was initiated and then supported through externally funded programmes – the PRECOI programme for the SWIO islands, and Sida/SAREC support for Zanzibar. In some individual locations, monitoring has been sustained where partnerships have formed that either continue a flow of support from external sources (e.g. NGO-supported sites in Madagascar, Aldabra in the Seychelles), or generate funding from commercial (but basically foreign) sources (e.g. Chumbe island).

The importance of a key partner to sustain both human and financial resources is shown in all cases:

- an academic or technical institution in the vicinity of monitoring activities is shown for Zanzibar (IMS), SW Madagascar (IHSM), Reunion (U. of Reunion and the Institute for Research for Development IRD);
- an international NGO able to bring in financial and human resources to fund activities and build capacity of local/national staff and experts, such as in Madagascar and the Seychelles (multiple NGOs).
- Academic or research partners to foster work, bring in some funds, etc is also key, such as in Aldabra (Aldabra Marine Programme), and ot participate in the local monitoring efforts, seen in all countries.

Vulnerability of monitoring activities to isolation is shown for the Comoros, where neither government, the focal NGO, nor the protected area had resources to sustain monitoring, or in Pemba island (Zanzibar), more isolated from the center of resources than the main island Unguja.

Finally, the reliance of long term monitoring on experienced personnel makes it very vulnerable to limited and shifting opportunities for trained staff. This is clear in Zanzibar, where despite the large numbers of experienced students trained at IMS few remain involved in monitoring following their studies due to employment constraints and few opportunities on Zanzibar, or in the Comoros, Rodrigues and Madagascar, where key leaders in the establishment of long term monitoring become less accessible for fieldwork by moving up the promotion ladder to more bureaucratic positions and larger responsibilities.

Organization of monitoring

In each country a different framework for monitoring has been established, reflecting the opportunities and challenges for the country. Nevertheless two basic models have emerged, from which more efficient and sustainable models can be developed for the future:

National networks

National networks for coordinating coral reef monitoring developed in the Seychelles and Madagascar (Table 3). In the former, the small population size, small concentration of main partners on Mahe and high capacity and resources, resulted in a network that was negotiated very formally through an MOU from the beginning. However, coordination dissipated over the years as the interests of different partners diverged, and the identity of key agencies shifted with reorganization within government. Also, with different international collaborators and partners, methodologies being applied by each of the local partners diverged to meet their specific objectives. Thus, while a good idea, the structure was not sustainable, presumably as it did not sufficiently meet and anticipate the changing priorities and needs of the partners.

Madagascar started with a plethora of different projects and partners, though they collaborated under the PRECOI programme for capacity building. Over time, and with a strong national interest in conservation, setting national targets and needing to meet international obligations rationally, coral reef monitoring efforts became organized under a national ICM committee. This more organic growth of the coordination network has meant that it likely meets the interests of the main partners more closely, as well as being framed within national institutions and priorities. Methodologically, the partners have maintained greater coherence enabling them to report on their work jointly, and providing sufficient 'glue' to maintain the open collaborative structure.

Table 3. Description of countries following a network approach in coordination of coral reef monitoring.

Country	Type	Strengths	Weaknesses
Seychelles	A network of involved organizations, initially joined by a formal MOU – Seychelles National Coral Reef Network (SNCRN)	One of the only ways to knit together disparate partners and locations. Takes advantage of different cost/funding opportunities among partners	Coordination and standardization among partners can be very difficult. Communication and logistics challenging.
Madagascar	A loose network of NGOs joined through collaboration with an agency (ANGAP/MNP). Recently, establishment of a ICM committee, with MPA planning at national levels	Necessary for coordination in a large national system with many locations and interest groups. In Madagascar, long experience and cooperation has led to this organically. Can take advantage of both national and site-associated funding to mix and match both, if available. Sharing of expertise across multiple sites, partners, etc.	Difficult to initiate where there are not clear joint objectives and priorities, or a weak overarching governance structure. Vulnerable to top-heavy bureaucracy and control

Institutional or 'project approach'

The small size of the other islands has contributed to a more 'project approach' in how national monitoring has developed (Table 4). In all cases, a single institution (or two very similar institutions) had sufficient capacity to initiate monitoring, be a part of almost all collaborations to implement/continue monitoring and could lead the entire programme over multiple years. In early years and with a regional network and sharing of expertise among countries, this was sufficient to maintain regular monitoring activities. But over the years, where funding became less secure and additional partners emerged (such as tourism ventures and community groups with strong local interests), the lack of a collaborative structure can stunt the growth and continuation of activities. In particular cases, such as Rodrigues where cultural and institutional commonalities are high, good collaboration and development of a formal MOU was possible. But in more diverse contexts, some level of competition and turf-ownership emerges, hampering full evolution of the coral reef monitoring framework.

Table 4. Description of countries following an institutional or 'project' approach in coordination of coral reef monitoring.

Country	Type	Strengths	Weaknesses
Comoros	Project structure from PRECOI, overseen by AIDE w. MOU with Env. Dept and UNDP, and increasing role of PMM	With very low capacity in government offices for a 'low priority' subject, leadership vested in an NGO enables more flexible raising of funds/collaboration with local and international partners.	No financial sustainably from national or local resources. Low sustainability and security for staff and expertise.
Mauritius	A government-run monitoring programme run by the AFRC	High internal consistency in methods, and basic funding to ensure a minimum set of sites monitored on a regular basis.	Cannot be expanded at scale without large investments in personnel and equipment. Stakeholders disenfranchised from undertaking monitoring at their sites and contributing to national system
Rodrigues – Shoals and SEMPA	Projects with focused needs. An MOU (2012) with Rodrigues Regional Assembly, for Shoals to lead monitoring throughout the island	Very focused, and limited variance among different interest groups. The best option for small islands and locations, where one or two clear leaders can support the entire system.	Cannot be expanded at scale across multiple more disparate locations. Limited resources and capacity within key organizations forces them to focus in a smaller area.
Zanzibar	Part of Tanzania's national system, with Zanzibar as one 'site', lead by IMS, with a few key partners, e.g. CHICOP.	The small size of Zanzibar is amenable to lead by a single organization. Access through national/aid funding in support of monitoring, when available.	With a medium number of potential partners, inefficient coordination and merging of multiple needs and capabilities.

Methods

The SWIO GRCMN network laid a strong foundation on the standard GCRMN methods, due to the coordinated support from PRECOI in its first 5-8 years of existence. The monitoring manuals, published

in English and French (Conand et al. 1999, 2000) documented these methods, giving guidance for application of standardized global methods, for the region.

Even so, as time has progressed a number of different methods, or adaptations to the existing methods have been added. In many cases this has occurred to address issues of:

1. Management needs
   - MPAs and projects needing specific data to support their decision-making or organizational processes,
   - MPAs and projects needing specific data to reflect principal habitats and resources within their sphere of influence.
2. Research questions
   - Expanding impacts and recognition of coral bleaching and other threats, leading to impact-oriented monitoring (coral bleaching, crown of thorns, diseases and pathogens, invasive species, etc.)
3. Opportunity
   - Fundraising models, such as through volunteer-based programmes, requiring simpler methods that need less time to train and gain competence.
   - Circumstance, such as in adapting monitoring to community competencies and priorities/ perceptions at site levels

Several types of methods are being applied in the countries, that can be integrated amongst one another in a next stage of the coral reef monitoring node. To facilitate this, they are summarized here in the following groups:

Intermediate – quantitative, GCRMN-recommended methods from English et al. 1994 (and see Conand et al. 1999, 2000).

Basic – quantitative, volunteer/diver oriented methods exemplified by Reef Check.

Focal issue – a number of focused surveys, such as of coral bleaching

Assessments – characterized by being done once, such as of biodiversity, or reef resilience

Mapping – focused on groundtruthing of satellite and other images, classifying bottom cover for image interpretation.

This summary does not cover more advanced scientific monitoring approaches, principally undertaken by researchers for specific questions they address, but that also generate information that can contribute to monitoring datasets, usually at the intermediate (GCRMN) level.

Intermediate / long term monitoring - GCRMN method

English et al. 1997 is the reference underpinning all applications of GCRMN teams around the world, providing strong guidance on survey tools (lines, belts, quadrats), resolution of identification, and replication. This guidance was simplified for application in the southwest Indian Ocean islands node for GCRMN in both English and French (Conand et al. 1999, 2000) in the form of manuals to be used in training during the PRECOI programme. Further details on monitoring methods relevant to GCRMN are contained in Wilkinson and Hill (2004), though this has not been applied extensively in this region.

The following sections summarize the intermediate/GCRMN-related coral reef monitoring methods reported in national reports to the ISLANDS project from Comoros, Madagascar, Mauritius, Seychelles and Zanzibar, from 1994 to 2012. The focus here is to identify commonalities among the countries that can help guide standardization and capacity building in the future, emphasizing continuity with past methods to ensure time series comparisons are strengthened, not weakened.

Benthic

Benthic monitoring is the simplest and easiest to train of the main classes, among the most important for understanding reef health, and the most routinely reported. In particular, the percent cover of hard corals is the most widely reported variable both in the region and globally.

Methods:

Transects - Line Point Transects (LPT), Point Intercept Transects (PIT), and Line Intercept Transects (LIT) have been used, of 10, 20 and 50 m lengths.

Imagery - still and video images have been used. Though analysis procedures (number of points and how placed) and how individual frames are aggregated to site totals not clearly stated. Since 2005, the software Coral Point Count (CPCe, http://www.nova.edu/ocean/cpce/) has been used extensively for analysis (Kohler and Gill 2006).

Random/fixed - random placement of transects/images is the norm, though permanent transects used in Rodrigues, where there is clear management relevance and scale allows.

Classification - Level of classification/identification varies among countries, in general using broad cover categories; many identify corals to genera, some identify algae to genera.

Replication – in general is relatively low, down to 2 transects in some sites.

Comments:

Percent cover – of benthic categories is the most common output variable.

Comparability among methods is relatively high, and can be to within 5 or 10% if methods are unbiased.

Low replication and biased/ non-random/subjective sampling of units are the most significant problems affecting comparability within programmes between sites and over time, and between programmes. Variation in depths also compounds the low replication problem.

Expertise and its consistency over time is another major barrier to comparisons over time and space.

Recommendation: standardization of methods is a priority, with greatest reliability being of LIT or still image methods; random placement will likely be more generally applicable in the region but where there are high level management interests to trigger responses, the use of fixed locations gives more precise results; identification at broader levels will continue to be done, but enhancing skills to enable genus identification of corals is desirable; improved replication is essential.

Fish

Fish community and population monitoring is challenging, due to their high mobility and diversity, though are often the feature of greatest interest (for fisheries), as well as being second only to coral and

benthic cover in understanding coral reef health. In many cases, transects for fish, benthos and invertebrates use the same line and start at the same point, but have different lengths.

Methods:

Belt transects – 25 or 50 m in length, generally 5 m wide though in some cases 2 m for smaller fish and greater precisions. Point counts are used on transects by GVI (Seychelles).

Random/fixed - random placement of transects/images is the norm, though permanent transects used in Rodrigues.

Classification – in most cases, select families are monitored, not all, and level of classification varies greatly, from family to key/indicator species.

Length/biomass – in general not collected.

Replication – in general is relatively low, down to 2 transects in some sites.

Indicator species – targeted species that may be counted in transects or general swims, sometimes including length estimation.

Comments:

Abundance of families or focal species is the most common output variable, per unit area.

Biomass is rarely calculated due to lack of length data.

Comparability among methods is relatively low due to inherent biases, differences in targeted taxa and already-high variability in fish communities in space and time.

Replication, bias and expertise problems are more significant than for benthic methods.

Indicator species approaches less variable, due to taxonomic focus.

Recommendation: use of 25 or 50 m belt transects should be continued as standard, likely with 5-6 replicates and random placement; identification is the most significant source of variation among programmes, and a standard list of focal families and target/indicator species will assist in capacity building and improving data quality; estimating length is necessary to provide the most useful indicator (biomass, or weight of fish), but this will need significant investementin capacity building.

Invertebrates/ threats

From the perspective of coral reef management, invertebrates of greatest interest are those classified as threats to reef corals, such as bioeroding sea urchins, or crown of thorns starfish. In some cases, sea cucumbers are important for their fishery value. However reporting their numbers reliably is challenging, as they may range in densities from very low (requiring large belt transects) to very high (requiring small $1m^2$ quadrats). Accordingly, there is great diversity in what different programmes have done, and variability/reliability in numbers reported.

Methods:

Belt transects – most common, generally 20, 25 or 50 m in length, 2 or 5 m wide;

Quadrats – $1m^2$ quadrats used in some locations, for some invertebrate taxa;

Random/fixed - random placement of transects/images is the norm, though permanent transects used in Rodrigues;

Classification – in most cases, key/indicator species are selected based on their threat/impact to corals (e.g. urchins, crown of thorns);

Replication – in general is relatively low.

Comments:

Abundance of focal species is the most common output variable, per unit area.

Comparability among methods is low due to inherent biases, differences in targeted taxa and already-high variability in invertebrate communities in space and time.

Replication and bias problems are equivalent to fish methods.

Expertise is less of a problem than for benthic and fish methods due to focus on key taxa and low number of classes generally used.

Recommendation: judicious use of 25 * 1 or 2 m belt transects with 1m2 quadrats where necessary should be continued as standard, with adequate replicates and random placement; selection of target invertebrates and level of identification is a significant source of variation among programmes, and a standard list of focal families and target/indicator species should be done.

Physical

Measurement of physical seawater parameters requires very diverse techniques and sampling regimes. Traditionally, seawater temperature and visibility were measured using hand-held devices (e.g. thermometer, secchi disk) during field visits of monitoring teams, but with increased automation and sensor development, the value of such in situ measurements is diminishing. Even so, there has been little investment in physical measurements by monitoring teams, and because this has only developed in the last few years, once monitoring funds became more limiting after 2005 or so, little has been implemented.

Methods:

Sea surface temperature (SST) – the most common variable measured, using automatic loggers deployed on the bottom or in the water column for some time.

Visibility – rarely measured, either with a secchi disk (vertically or horizontally), or just estimated visibiliity.

Salinity – rarely measured consistently on reefs, is done using a CTD in Rodrigues.

Nutrients (nitrates, nitrites and phosphates) – rarely measured as part of reef monitoring programmes, though may be done nearby for other purposes (in Rodrigues, use the Palintest (photometer) system.

Dissolved Organic Carbon (DOC) – monitored in Mauritius.

Comments:

Temperature is often reported as mean, min/max, standard deviation and climatologies (e.g. maximum monthly mean) due to interests in coral bleaching.

Very little consistency in reporting of other physical variables.

Recommendation: a standard list of priority simple physical measures for measurement, external sources from which remote sensing proxies can be obtained (e.g. sea surface temperature) and guidance to low—cost but reliable sensors/loggers should be prepared.

Summary

Though there has been high stated consistency in the region on the use of GCRMN-recommended methods, there is clearly high variability in the details of methods used and why. In practise groups have departed from recommended methods for expediency. With sufficient expertise and replication, most methods give comparable basic results (e.g. in percent cover, biomass and abundance), but variation in expertise between programmes and countries, staff turnover and low levels of replication conspire to make all but the most basic comparisons tenuous.

Across the different components of the monitoring programmes, the two most consistent limitations are:

a) low replication and biased or non-random/subjective sampling of units, such that variation is inappropriately sampled, and it is difficult to make strict or statistical comparisons across years and programmes.
b) The availability of sufficient expertise and its consistency over time results in higher variation in the quality and sampling practices of monitoring from year to year, and across projects.

Basic monitoring – volunteer / community

The use of methods more accessible to the public is the driving force in the development of methods such as Reef Check. Though commonly mentioned in the region, these are not, however, widely utilized except in a localized context. Three main contexts define the use of these methods in the region:

1. for localized management areas and needs.
2. in volunteer programmes that attract inexperienced visitors who can be trained in these basic techniques in a short time, and collect usable data in the remainder of their voluntary programmes.
3. As preliminary surveys prior to establishment of more quantitative methods for regular monitoring – e.g. Reef Check was used in Rodrigues in 1999/2000.

The programmes in which these have been applied are described below.

Chumbe Island, Zanzibar (Chumbe Island Coral Park)

CHICOP has a small 0.3 km^2 high-value reef slope that supports non-consumptive tourism, with high accessibility, and uses manpower from local communities as the rangers and primary tourism guides on the island. To generate sustainable data collection over the long term by community rangers, CHICOP developed a monitoring programme based on fixed transects for fish and invertebrates and on which point counts (circles) are made for visually estimating coverage of broad benthic categories. This system is integrated with annual monitoring done in conjunction with scientists from IMS, but provides data over a broader spatial extent for use in management.

Andavadoaka, Madagascar (Blue Ventures)

Blue Ventures combines a volunteer-based programme (university students from the UK) with community conservation in Andavadoaka, and adopted Reef Check as a foundation method for training both sets of people. Monitoring is conducted over an extensive area of patch reefs. The methods have been adapted over time to support conservation initiatives focused on community fisheries for octopus,

establishing and monitoring reef condition and key resources (octopus) under a regime of temporary reserves.

Global Vision International (GVI) and Earthwatch Institute, Seychelles

Working on different islands and locations in the Seychelles, both GVI and Earthwatch have developed customized monitoring methods that can be taught to short-term volunteers while they collect usable data over a period of a few weeks. In both cases, data collection is under a contract with the Seychelles authorities to feed into national systems for coral reef assessment and monitoring. While not comparable quantitatively with the basic methods, these do enable written comparisons with other sites. In both cases, as with Chumbe Island, a selected number of key sites are surveyed more quantitatively, to contribute to a national monitoring database.

Biological inventories and assessments

Assessments are useful as early-stage surveys of new areas to provide information to decide on further investment in an area. The term is generic, and there can be very large differences in methods used, and principal purpose of the assessments, such as for biodiversity, for aspects of coral reef condition or ecological resilience, or to identify sites for Marine Protected Areas or other actions. This approach has been followed in multiple cases throughout the region:

Resilience-based assessments

A specialized assessment for ecological resilience of coral reefs was developed by the IUCN (Obura and Grimsditch 2009, www.iucn.org/cccr), that has been conducted in 15 island locations in the SWIO islands: 2 in Comoros, 5 in the Seychelles, 4 in Madagascar, 1 in Mauritius and 3 in France (Mayotte, Glorieuse/Iles Eparses, Reunion). In general, the resilience assessments have been applied as part of broader programmes, e.g. for reef management in the Seychelles, biodiversity planning in Madagascar, and exploration in Mauritius and the French Isles Éparses. The method developed in 2009 is being revised and streamlined in 2013-14 for further use, and in particular for repeat surveys to assess changes in resilience over time.

Coral bleaching

Coral bleaching is the principle driver of coral reef degradation in the region, so is the focus of attention at all levels. As a rapidly developing event (over 1-5 months), monitoring a bleaching event requires a customized method, and repetitive sampling over the space of a few months. Monitoring of coral bleaching is increasingly being done at local levels by managers, with some examples of methods being done in the region (see below). Forecasting of coral bleaching events is relatively reliable, and being done by NOAA globally (http:// http://coralreefwatch.noaa.gov/satellite/) and CORDIO for the WIO region (www.cordioea.net/bleachingalert), enabling monitoring and response programmes to be established and put on call when bleaching risk is high.

Bleaching monitoring methods include:

- In Mauritius in 1999, bleaching impacts surveys were undertaken by the Universities of Mauritius and Bangor (Wales).

- In Rodrigues from 2002-7, 30 minute survey intervals were used by a team of 3-4 people, recording benthic composition on a 6-point scale, hard and soft corals identified to genus or species and abundance estimated using a 6-point scale.
- The Wildlife Conservation Society presents a method for counting all corals in estimated 2*2 m quadrats, identifying them by genus, and recording bleaching and mortality on a 7-point scale. The method has been widely applied and published on (McClanahan et al. 2007).
- As part of the IUCN resilience assessment method, CORDIO presents a method using a fixed area (25*1 m belt, with individual 1 m^2 quadrats for corals < 10 cm) in which corals are identified to genus, their size class recorded, and bleaching reported as the proportion of a colony that is pale, bleached and/or dead.

Coral disease

Interest in coral diseases has grown globally, and with ongoing monitoring in Reunion. Nevertheless, disase monitoring is not widespread in the WIO, though capacity building in coral disease monitoring has been conducted with a workshop at IMS, Zanzibar, in 2008, run by the World Bank-funded Coral Reef Targeted Research Project, with resources available at http://coraldisease.org/diseases. Some monitoring groups have incorporated some disease observations into their protocols, but with low consistency in reporting among years.

Other

Mapping

Mapping of coral reefs requires large numbers of points with very specific though relatively coarse data on benthic cover and community composition, determined through preliminary analysis of both imagery available and reefs in the study domain. Three major efforts involving ground-truthing have been conducted, at different levels of resolution:

- The Shoals of Capricorn Programme produced a biotope map of Rodrigues reefs based on Landsat 7ETM+ in 2000. This was improved with high resolution (0.6m) pan-sharpened Quickbird imagery in 2008 and a new biotope map was produced for SEMPA by ground-truthing a new QuickBird satellite image acquired in 2008 (Klaus et al., 2008).
- In the Comoros, the NGO AIDE, with regional technical assistance, conducted coastal and reef vulnerability mapping in 2003, with LandSat images taken in 1998.
- In the Seychelles, the SCMRT-MPA, with the Khaled bin Sultan Living Oceans Foundation and the Cambridge Coastal Research Unit (University of Cambridge), conducted detailed mapping using airborne multi-spectral images (from CASI) in 2005, of the Amirantes islands Marie-Louise, Boudeuse, Poivre and Alphonse (Hagan et al. 2008).

The Millenium Reef mapping project has undertaken image analysis for all locations in the SWIO region, but ground-truthing of the images has only been done in Mayotte (France). Thus this dataset is not uniformly usable without significant investment in further analysis.

Other habitats

Other habitats adjacent to coral reefs have received much less attention for long term monitoring. Mangrove systems have been the most heavily studied, with long term monitoring being initiated in some countries. There have been a number of initiatives proposed to integrate monitoring across ecosystems (e.g. in the IOGOOS programme), but to date none have been implemented. Rodrigues

conducted monitoring of a number of non-coral habitats from 2006-9, including lagoon sites using semi-quantitative benthic estimates (alge and seagrass beds) and belt transects for invertebrates. However these were discontinued as the data was found to be insufficientlyl reliable.

Data archiving, security and storage

The security and storage of data from past monitoring efforts has not been dealt with effectively in the region. CoReMo, supported through the GCRMN as well as the PRECOI project in the region has been the only full database system used in the region. Ongoing use of the database is shown in Table 5, showing 175 sites out of the total of 519 monitoring sites (fig. 3) being held in COREMO. This somewhat overestimates the active usage however, as at present ARVAM in Reunion and the Albion Fisheries Research Station (AFRC) in Mauritius currently update their datasets in COREMO.

Table 5. Institutions and countries using CoReMo to archive their coral reef monitoring data.

COUNTRY	Host	# sites
Comoros	AIDE	18
Madagascar	Not given	78
Mauritius	AFRC	1
	Reef Conservation	4
	SEMPA (Rodrigues)	45
	Shoals of Capricorn	2
	Shoals Rodrigues	13
Reunion	Not given	14
Total		175

The diversity of monitoring programmes in Madagascar and the Seychelles, run by NGOs and other non-technical organizations, including on Rodrigues, has resulted in broader use of Excel as the main spreadsheet package for storing and analysing data. In Zanzibar, the National Oceanographic Data Center at IMS hosts the coral reef monitoring database, but in Excel also.

Regional SWOT

A regional SWOT was compiled from the national SWOTs submitted by the countries, providing an extensive compilation of the various possibilities and obstructions for ongoing monitoring in the region. The ongoing activities of the ISLANDS project, in particular with reference to training, the Coral Reef Information System, monitoring manual and mapping will address multiple of these.

Strengths	***Weaknesses***
Spatial coverage and partners – in some countries there are several monitoring programmes covering diverse regions and sites, and this is replicated at the regional level among countries. This gives the opportunity for collaborations, to share expertise and assist one another in undertaking surveys. ***Standardized monitoring protocol*** – standardization in primary methods is essential, offering the chance for additional more specific protocols for different sites, partners, countries. ***Ownership of national monitoring programmes*** – ownership is strong in all countries, though sufficient partnership and collaboration in ownership is essential to maintain monitoring across all needed sites. Where government support is strong (financially or through	***Lack of sustainable financing for monitoring***: due to limited resources (financial, human and equipment) and dependence on short term or one-off financing, many programmes are unable to maintain monitoring consistently over time and across many sites. ***Limited reporting and lack of information sharing***: monitoring on some sites may be carried out by different organizations, with limited opportunities for information sharing and sharing lessons learned. With low capacity to undertake data analysis and report, this can also result in less sharing of information among sites and countries. ***Limited capacity – data collection, analysis and reporting***: Due to the limited workforce in coral reef management/monitoring, there is a shortage of skilled staff across all skills needed, and often the field teams

MOUs), this contributes greatly to success, as well as strong ownership and devolved responsibilities in NGOs and other implementing partners. ***Sensitization, education and awareness*** – all island countries are relatively aware of the need for coral reef conservation, so this should be used to strengthen the commitment to monitoring to inform government an stakeholders of the status of resources/assets. ***International assistance*** for coral reef monitoring has been strong in the region, but over-reliance weakens national and local commitment. It should be used strategically and to integrate among countries and programmes, but not supplant local/national support for monitoring. ***Experienced staff and continuity*** – some programmes have had long continuity of staff, maintaining standards. However this is always vulnerable to change, and this aspect must be further strengthened in the future. High qualifications and training are needed in monitoring methods, as well as dive training and water/boat safety. ***Design of monitoring to suit management needs*** (MPAs particularly) motivates continuity and investment in monitoring. ***Ownership of equipment*** by the institutions conducting the monitoring is a strength, including of compressors. However, investment in maintenance and replacement is essential. ***Collaboration with research and tertiary academic institutions*** in multiple countries is a key factor in maintaining monitoring effort, standards and retraining. ***Community support for monitoring*** can be a key factor, usually motivated by an understanding of the value of monitoring, and ownership/stewardship of the sites in the monitoring network.	that collect data don't have the skills to conduct data analysis and reporting. ***Central databases for data archiving and storage***: Even where a national or central database has been put in place in the past, monitoring data are scattered among various organizations and in various forms, or the central databases don't conduct regular outreach and reporting to valorize the information they contain. ***Permanent site marking***: Some programs use permanent sites for monitoring, and marking techniques have proven problematic. Metal pegs hammered into the substrate to mark the locations may become dislodged by wave action or on occasion are actively removed by fishers. ***Limited capacity - proposal writing and fund raising****:* the shortage of sustainable financing is worsened by the lack of skills in most MPAs and project sites to prepare proposals and raise funds. ***Loss of key staff***: most monitoring programmes contain a small number of key staff, who do move to other organizations, or get promoted through their systems, over time. Without established capacity building processes, this results in loss of expertise over time. ***Lack of centralized coordination (monitoring and/or management)*** in some countries can result in weaker monitoring programmes, as each site/institution may diverge along its own priorities, or with a change in programmes and funding, not prioritize long term monitoring any more. Similarly, where there is a lack of a national strategy for coral reef conservation, support for monitoring is weakened. ***Limited engagement of government and the scientific community*** can in some countries weaken monitoring systems. ***Lack of equipment,*** or its rapid ageing over time is a major threat to ongoing monitoring, particularly for scuba gear, a compressor and boats.
Opportunities	***Threats:***
Capacity building and enhanced knowledge can be built around new models of "training of trainers" as well as when new equipment and technology are introduced. ***Increasing the number of sites and replication levels*** – as interest in development expands, interest in new locations grows opening the door for expanding monitoring to new sites through EIAs and other processes. Also, as understanding of the limitation of current monitoring sites improves, strategic inclusion of additional sites in unrepresentative habitats should be done. ***International collaboration and participation***, such as through study and volunteer programmes. As global interest in reef health and recovery progresses, can expand these collaborations as a sustainable financing mechanism, as well as to expand the monitoring network. ***Adaptive management***: national commitments to strengthen the management and conservation or reefs and marine resources opens opportunities to increase monitoring levels to demonstrate progress, and to adapt existing management practices to suit emerging realities and	***Lack of funding at national and international levels*** for monitoring activities is a major threat to maintaining ongoing monitoring, as it is logistically expensive. ***Limited human resources and infrastructure***: The pool of existing staff and potential trainees varies considerably by site, organization and country, making the maintenance of sufficient knowledgeable people difficult. It is also difficult to retain key and dedicated staff, so turnover and throughput (and therefore ongoing training) must be assured. ***Piracy and security***: this has grown as a significant threat in recent years, and will continue for more. ***Political instability***: poses an ongoing threat in some countries, diverting attention and resources from basic activities such as monitoring. ***Growing threats from local and global factors*** threaten the long term health of reefs, though increasing sensitivity about impacts, and evidence for impacts, will support monitoring while it may not be good for reefs

needs. ***Participatory resource monitoring***: with increasing implementation of co-management programmes in LMMAs and engagement of communities and the private sector in the use and management of MPAs, engagement of different stakeholders in monitoring will greatly reduce the pressure on managers to do it, and benefit from in-kind support from the stakeholders.	

Next steps / recommendations

The findings of this regional report identify a number of key next steps that should be undertaken to consolidate and expand coral reef monitoring activities in the region, and re-energize the Islands network of the Global Coral Reef Monitoring Network. The points below reflect some degree of prioritization in making this happen, but most are needed for a truly effective regional monitoring programme. As this report is part of the ISLANDS project and intended to motivate investments/funding in subsequent project phases, the recommendations are also framed to facilitate immediate action and response within the project framework. At the same time, all of the actions require ownership and responsibility and commitment from the partners and people in the coral reef monitoring community, in particular to ensure sustainability after the end of the ISLANDS project in 2014.

Partners network approach

Building on learning from Madagascar and the Seychelles, and using ICT tools that enable linking among remote locations and across the smaller islands in a regional network, pursue a partner-network structure that combines some aspects of national structure, but also key partners with relevance across countries in field-expertise, analysis skills, writing/reporting and stakeholder/partner relationships. New partners from the NGO sector, involvement of key community/stakeholder groups and academic/research partners are all needed.

Fundamentally, the national networks must be grounded in and supported by national mechanisms, for example working/technical groups for Integrated Coastal Management. At the regional level, continuation of the IOC-supported Global Coral Reef Monitoring Network node for the Southwest Indian Ocean islands is desirable, strongly linked with the Nairobi Convention Coral Reef Task Force to ensure full engagement with the mainland countries.

Methods

The methods and metadata sections of this report show a wide diversity of methods being applied in the region, and future improvements will require refocusing on essential core methods for all teams to be trained in and apply. The GCRMN-recommended methods at 'intermediate' levels (more basic than those applied by researchers, but more advanced than those accessible to citizen/civil society groups) have been most consistently applied across the region for almost 18 years, providing a long time series of great value if maintained into the future. This level is also adequate for decision-making in the context of Marine Protected Areas and aspects of coral reef fisheries management. Improvements in replication and standardization are, however, essential, and these will form the focus of technical advice

(a manual) in the next steps of the ISLANDS project, linked to capacity building needs (see next point). Additionally, standardization in the terminology on reef habitats and depths of sampling are recommended. Specific recommendations from the methods section are reproduced here:

Benthic: use of 25 or 50 m belt transects should be continued as standard, likely with 5-6 replicates and random placement; identification is the most significant source of variation among programmes, and a standard list of focal families and target/indicator species will assist in capacity building and improving data quality; estimating length is necessary to provide the most useful indicator (biomass, or weight of fish), but this will need significant investement in capacity building.

Fish: judicious use of 25 * 1 or 2 m belt transects with $1m^2$ quadrats where necessary should be continued as standard, with adequate replicates and random placement; selection of target invertebrates and level of identification is a significant source of variation among programmes, and a standard list of focal families and target/indicator species should be done.

Mobile invertebrates: a standard list of priority simple physical measures for measurement, external sources from which remote sensing proxies can be obtained (e.g. sea surface temperature) and guidance to low—cost but reliable sensors/loggers should be prepared.

A complementary role to long term monitoring is increasingly seen in the region, of volunteer-based efforts and one-off event or condition surveys and assessments. Examples of these include for coral bleaching/disease/predator outbreaks, for Environmental Impact Assessments (EIAs) and post-event surveys such as for reef resilience. Standard protocols should also be developed for these, to maximize their compatibility with long term monitoring data.

Capacity building

With a gap of 3-5 years in consistent funding, from about 2010 to the present, significant gaps in both datasets and human resource capacity have occurred throughout the region. All institutions undergo turnover in staff, so renewed and consistent capacity building is essential to maintaining and rebuilding the capability for coral reef monitoring in each of the countries. Based on the methods recommended in the manual (above), a 'training ramp' can be proposed to provide for regular recruitment of people into basic/volunteer monitoring programmes, and channeling the most dedicated of these into regular monitoring teams. Sharing of personnel among programmes and even countries will also help to mitigate the impacts of staff turnover, and can be a core objective of the network approach recommended above.

Enhancing the skills and capacity of existing personnel through progressive development should be a key priority, to retain skilled staff. Even when key personnel move to other jobs, they can assist as mentors/trainers. Priority topics for capacity building include in data analysis and reporting, fundraising and proposal writing.

Sites (representation and expansion)

At both local levels (where management interests expand to new sites or different issues) and national/regional levels (where representation of reef habitats and zones in the current network of sites

may be limited), expansion of monitoring to new sites is desirable. However, given the constraints of funding and sustainability that have affected monitoring to date, this expansion needs to be done strategically, and with a view to sustainable financing. Analysis of the monitoring metadata shows a large number of monitoring sites being started AND stopped, and more returns will be obtained from more strategic selection of new sites that can be committed to over the long term. Even if monitoring cannot be assured annually, returning to the same sites at longer time intervals is more efficient than stopping sites altogether.

By selecting new sites and according to focal issues, new resources may be made available to support monitoring, e.g. through supplying industries such as mining and tourism with baseline and trend data that they need to meet industry and/or national standards. The finance they are required to invest in monitoring, based on varying national legislation, could be used to strengthen the broader landscape of monitoring and assessment in a country.

Data archiving and integrity

Consistent use of an archival database has not been successful across the region, requiring new effort to make this happen. While the COREMO database has been introduced to teams, and training conducted during the PRECOI project, ongoing training was not sustained alongside periodic revisions of the software, and only some countries (Reunion and Mauritius) have maintained their use of the database.

In the last decade the digital revolution and ICT resources call for a novel and innovative way to facilitate this, and particularly to enable different partners in a programme – whether a national network or the regional network – to share and analyse their data. Accordingly, the ISLANDS project is spearheading the development of an online Coral Reef Information System (CRIS), in partnership with the GCRMN, to pilot its utility and application for national and local monitoring teams. As part and parcel of that development, training tools and a manual must be developed to ensure it is accessible to users, and is useful.

Leadership

New leadership is required from among the most experienced members of the national programmes and regional network to maintain momentum in coral reef monitoring. As summarized in the Nosy Be workshop report (April 2013), the first generation of leaders of the regional monitoring node have moved on, and a new generation must take its place. Fostering this leadership will need to be a priorit of regional entities such as the IOC, as well as national governments and regional NGOs.

Sustainable financing

As always, this is a critical area for improvement. Multiple approaches to sustainable financing must be attempted. However, closest to the circle of control/influence of the monitoring network(s), ensuring the quality and relevance of the data provided will be the surest way to justify demands for funding. Thus, not only the quality of data collection, but the needs for reporting for local management, industry and statutory requirements (e.g. environmental impacts), national reporting and regional assessmeents should be considered. If the monitoring network can meet these needs, then investment in monitoring will be more justifiable, and can likely be sustained from diverse sources.

Traditional sources of funding – from government, through donor or NGO-supported projects or for management entities such as MPAs need to be made the most of, as well as new ones. One novel opportunity could come from the burdgeoning coastal development sector, where the importance of national reference sites should be explored/promoted – these could serve as reference points for impact assessments and commercial/industrial growth, to obtain financing from the EIA sector to maintain long term monitoring at these sites.

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Appendix 1 – Coral reef monitoring metadata and analysis

Method

Metadata on coral reef monitoring in the SWIO islands region was compiled by National Consultants under the ISLANDS project, and compiled into a regional summary table. Due to variation in the metadata reported by each country, grouping and classification was conducted by the Regional consultant to the ISLANDS project, enabling analysis and summarization at regional levels.

The final metadata table, and details on classification for each variable are summarized in the results section below. The metadata table is presented for public access on the Coral Reef Information System, as well as on request from the Indian Ocean Commission.

Results

Table A1 – Metadata submitted by National Consultants was compiled using the column names in the left two columns. The right hand columns describe what the users input into the table, and processing needed for analysis.

English	French	User inputs	Processing
COUNTRY	COM	Text	Fixed list
Sector	Secteur	Text	None
Site	Site	Text	None
Station	Station	Text	None
Longitude	Longitude	Varied formats	Conversion to digital degrees
Latitude	Latitude	Varied formats	Conversion to digital degrees
Depth	Profondeur	Depth, single or range	Conversion to single number (center of range)
Geomorphology	Type_geomorphologique	Varied	Conversion to back/patch/lagoon reef; fore/fringing reef; reef flat; Barrier/bank/offshore; Other; Seagrass bed; (blank)
SURVEY_type	Type_suivi	Text	none
SURVEY_name	Nom_suivi	Text	none
SURVEY_start (year)	Date_debut_suivi	Numeric	Verified number
SURVEY_frequency	Frequence	Varied	Conversion to <annual; annual; annual w. gaps; >annual; Once
SURVEY_last year	Date_derniere_campagne	Numeric	Verified number
TARGET_fixed benthos	Cibles_Benthiques Sessiles	Descriptive text	Conversion to Benthic; Coral condition; Habitat mapping; ND; (Blank)
TARGET_mobile benthos	Cibles_Benthiques Vagiles	Descriptive text	Conversion to Yes/No
TARGET_fish	Cibles_Poissons	Descriptive text	Conversion to Yes/No
TARGET_Seagrass beds	Cibles_Herbiers	Descriptive text	Conversion to Yes/No
TARGET_water	Cibles_Eau	Descriptive text	Conversion to SST; water quality; No
TARGET_sediment	Cibles_Sed	Descriptive text	Conversion to Yes/No
METHOD_fixed benthos	Methode_Benthiques Sessiles	Descriptive text	Conversion to LIT; Photo/video; PIT; Belt transect; LIT/QUAD;

			Quadrat/radii
METHOD_mobile benthos	Methode_Benthiques Vagiles	Descriptive text	Conversion to Belt transect; Quadrat/radii; Photo/video; Belt/Quad;
METHOD_fish	Methode_Poissons	Descriptive text	Conversion to Belt transect; Point Count; Video
METHOD_Seagrass beds	Methode_Herbiers	Descriptive text	Not analyzed
METHOD_water	Methode_Eau	Descriptive text	Not analyzed
METHOD_sediment	Methode_Sed	Descriptive text	Not analyzed
DATA_CoReMo-compatibility	Donnees_CoReMo_compatibles	Descriptive text	Conversion to Yes/No
DATA_CoReMo-data entered	Donnees_Coremo_bancarisees	Institution name	Not analyzed
ID_station	ID_station	Descriptive text	none
Raw Data Accessibility		Descriptive text	none
Contracting Authority		Institution name	none
Services Provider	Maître d'Ouvrage	Institution name	none
SIRC_Reference	Maître d'Œuvre	Descriptive text	none
Remarks		Descriptive text	none

The primary analysis of the metadata submitted is contained in the main report. Additional details are summarized below, with particular focuse on between-country differences.

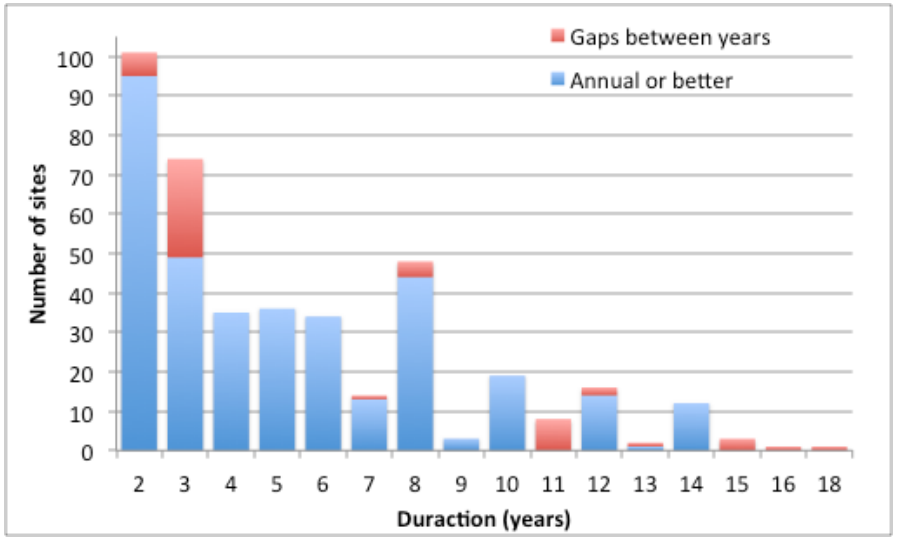

Fig. A1. Duration of monitoring at each site for the SWIO islands, for sites sampled at least 2 years apart. The legend shows sites with annual sampling, or more frequently, and those marked with missed years/gaps between sampling intervals.

Figure 3 (in the main report) shows large numbers of new monitoring sites being started, and existing monitoring sites being discontinued, resulting in broad variation in the duration of monitoring at any individual site. Figure A1 shows the duration between the beginning and end years, differentiating those sites that were monitored annually or more frequently (e.g. monthly, or twice a year) and those sites with significant gaps in the years sampled (though note that it is likely not all gaps were scored reliably in the metadata table). A large number of sites were sampled for only 2-3 years (43%), and about the

same proportion for 4-8 years (41%). A total of 65 sites across all countries have been monitored for 9 - 18 years, though 16 (25%) of these have significant gaps, and mostly in the longer time series.

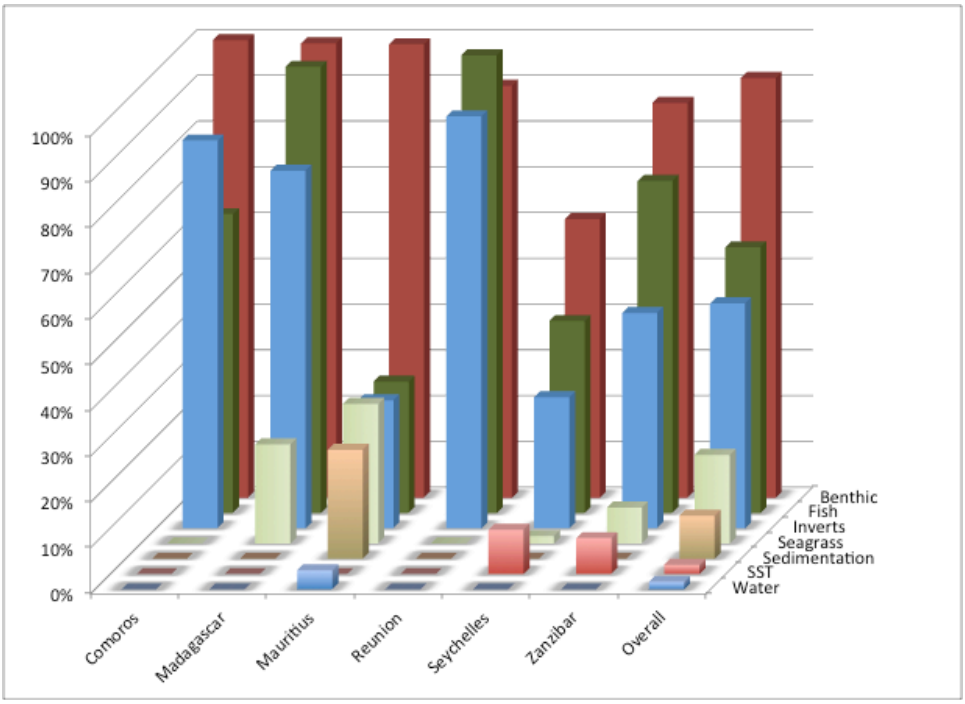

Fig. A2. Proportion of sites at which monitoring was conducted on each of the components listed in the x axis, for each of the SWIO islands.

The degree of focus on monitoring activities on a country basis (fig. A2) has been relatively consistent, with the exception of Mauritius, in which attention to benthic monitoring has been much more extreme than the others (with < 30% of sites including fish and invertebrate monitoring). Conversely, the influence of sedimentation in Mauritius has received greater attention than in the other countries. Both of these patterns are correlated with the greater use and application of environmental impacts surveys in Mauritius, in response to legal requirements for development. The Seychelles also differs slightly from the other countries, with a lesser focus on benthic monitoring, likely reflecting a greater diversity of monitoring programmes and less consistency among them.

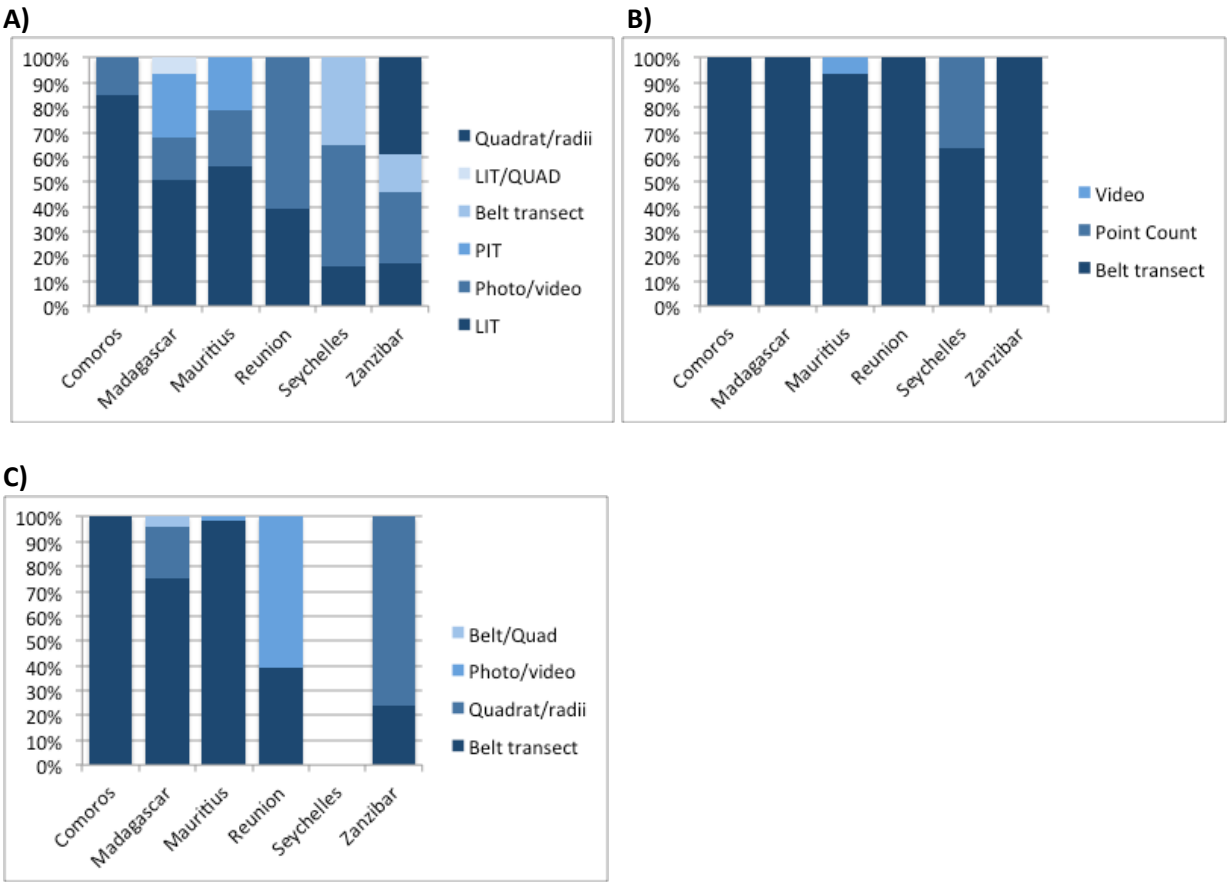

Fig. A3. Differences in methods used for monitoring among countries of the SWIO. A) benthic cover (left overall, right, by island) in the SWIO islands. LIT- Line Intercept Transect, PIT- Point Intercept Transect, QAUD-Quadrat. B) fish (left overall, right, by island) in the SWIO islands. LIT- Line Intercept Transect, PIT- Point Intercept Transect, QAUD-Quadrat. C) mobile invertebrates (left overall, right, by island) in the SWIO islands. LIT- Line Intercept Transect, PIT- Point Intercept Transect, QAUD-Quadrat.

The degree of consistency in monitoring methods for the three different classes of monitoring varied among the countries (fig A3). It should be expected that Madagascar, Mauritius and the Seychelles should have generally higher diversity of methods given the larger number of sites monitored in those countries (fig. 2).

Table A2. Habitats included in coral reef monitoring in the SWIO islands region.

Row Labels	Comoros	Madag.	Maurit.	Reunion	Seychell.	Zanzibar	Total
Back/patch/lagoon reef		64	75			5	144
Fore/fringing reef		85	13	23	14		135
Reef flat		20	26	17	1	17	81
Barrier/bank/offshore		22	3				25
Other		2	5		103		110
Seagrass bed			18				18
Blank	18				5		23
Total	**18**	**193**	**140**	**40**	**123**	**22**	**536**

Monitoring sites were relatively evenly spread among back reef/path/lagoon reef habitats and fore reef/fringing reef habitats (Table A1), with 135-145 sites each, followed by reef flats and barrier/bank/offshore sites. A number of programs used different methods of classification (in the Seychelles, the difference between granitic and carbonate reefs is important), and in some programmes, habitat was not indicated. Along with variation in habitats for monitoring, the depth of monitoring sites varied greatly across the region (fig. A4). The greatest consistency is of shallow (<2 m) sites in Mauritius, and mid-depths (8-10 m) in Mauritius and the Seychelles

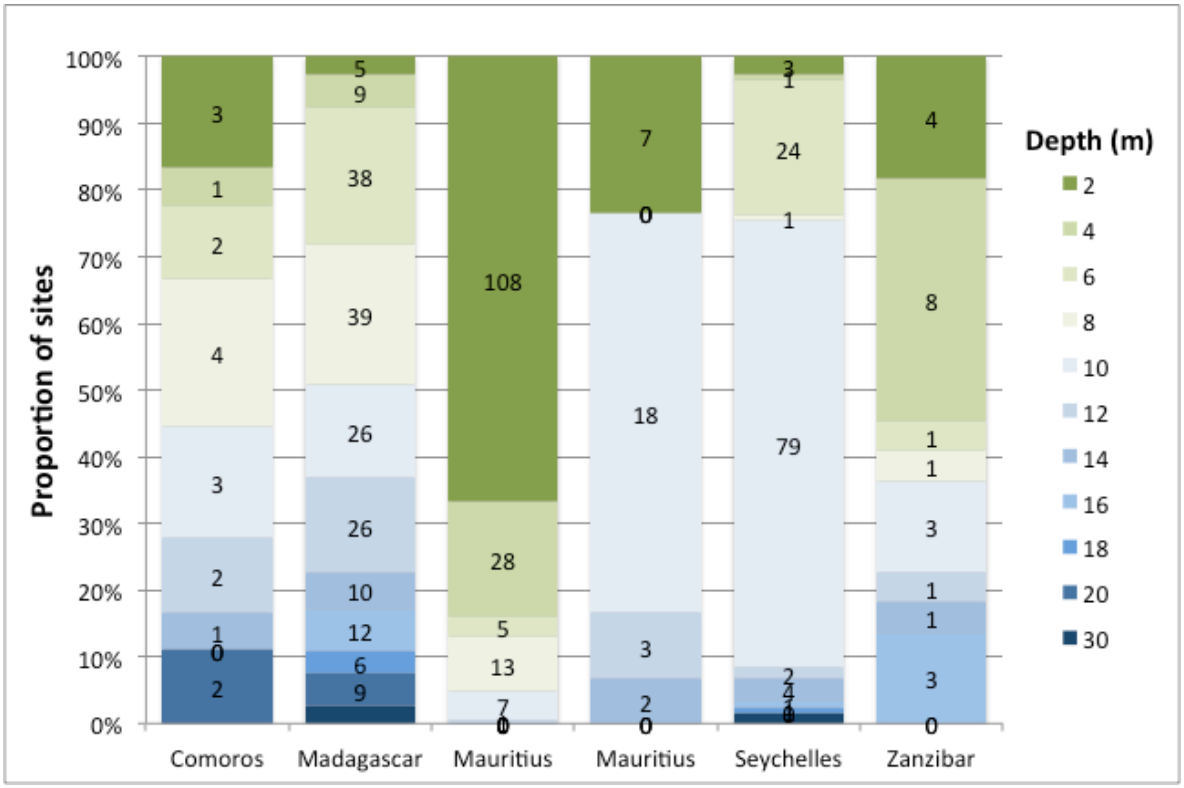

Fig. A4. Depths of monitoring sites among countries of the SWIO, showing the number (labels in each colour code) and proportion (y axis), from the surface to 30 m deep.