GCRMN
Global Coral Reef Monitoring Network

CORDIO

Indian Ocean Commission

Coral reef status report for the Western Indian Ocean (2017)

Edited by

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under scientific coordination of

CORDIO

In the framework of the Nairobi Convention Coral Reef task Force and ICRI

Nairobi Convention

ICRI
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Indian Ocean Commission

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FFEM Fonds Français pour l'Environnement Mondial

ICRI International Coral Reef Initiative — GCRMN Global Coral Reef Monitoring Network

Main Findings

- In 1998, coral reefs in the Western Indian Ocean crossed a threshold, due to impact of the 1st global bleaching event in that year.
  - On average, coral cover declined by 25% - from 40% before 1998 to 30% after 1998.
  - Algal cover increased by 2.5 times after 1998, from 15% before to about 35% after.
  - Fish community structure is now dominated (about 80% of biomass) by small-bodied herbivores and detritivores.
- In 2016, the 3rd global bleaching event impacted the WIO, with 30% of reefs showing evidence of high or severe bleaching, but only 10% showing high or severe mortality.
- The threat from all major drivers of reef decline has increased and is projected to continue to increase in the coming decades - ocean warming and acidification, fishing pressure, human population growth and development in the coastal zone, expanding global trade.

The future

- While resistance of corals to the 2016 bleaching event was significant (2/3 of affected corals recovered) and the decline in coral cover resulting from the bleaching event was less than in 1998, the recovery potential of reefs is likely to be less than in 1998 due to the lower coral cover, higher algal cover, and increasing role of algal-herbivory dynamics.
- The broad-based coral reef monitoring community in the Western Indian Ocean is active, but would benefit from increased investment and stability, and more secure data management and sharing practices.
- Management of local threats and increasing the coverage of effective management to meet 2020 and 2030 targets will be needed to buy time for coral reefs, while countries increase their commitments to achieve the Paris Agreement.

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About this report. This report provides an update to the regional sections in the Global Status reports publication by the GCRMN in 1999, 2000, 2002, 2004 and 2008. It is a joint output of the Global Coral Reef Monitoring Network (GCRMN), the Indian Ocean Commission, Coastal Oceans Research and Development in the Indian Ocean (CORDIO), the United Nations Environment's Nairobi Convention Coral Reef Task Force and the International Union for the Conservatoin of Nature Species Survival Commission's (IUCN-SSC) Coral Specialist Group.

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Maps were produced from open source country and coral reef layers by James Mbugua from CORDIO East Africa. The designation of geographical entities in this report, and the presentation of the material, do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, or area, or of its authorities, or concerning the delimitation of frontiers or boundaries.

Indian Ocean Commission — Biodiversity shared treasure — Funded by the European Union — Fonds Français pour l'Environnement Mondial — Nairobi Convention — Coral Specialist Group — CORDIO

The Western Indian Ocean contains 16% of the world's coral reefs, and the region is now thought to host the second peak of coral reef biodiversity globally.

The coral reef ecosystems underpin the economies of the countries in the region, particularly fisheries and tourism sectors, and provide livelihood opportunities and income for local communities. However, anthropogenic threats at all scales, such as from fishing, development and climate change, are all increasing with human population growth and local to regional development.

Western Indian Ocean coral reefs experienced widespread coral bleaching during the first global coral bleaching event in 1998, in which 30-50% of corals were estimated to have died. It was also affected by what has been dubbed the "3rd global coral bleaching event" in 2016, documented in this report.

This coral reef status report for the Western Indian Ocean summarises data from monitoring programmes in Comoros, France, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania. It has been prepared in the context of the International Coral Reef Initiative as a joint output of the Global Coral Reef Monitoring Network through national and sub-regional networks and the Nairobi Convention Coral Reef Task Force. The report includes national chapters on the state of coral reefs up to 2016, impacts of the global bleaching event in 2016, and current information on pressures, management and policy responses relevant to coral reefs in each country.

Included are regional synthesis chapters on the overall trends of reef health, the bleaching event in 2016, and on large scale drivers and projections for the region in the coming decades. The report finds that while reefs in some countries have recovered successfully since 1998, the overall state of coral reef health has stayed at the same level since the 1st global bleaching event in 1998, and has suffered another, though smaller, decline in health in 2016.

The report provides a valuable baseline for preparation of the next steps towards the strengthening of regional networks during 2017-2020 through improving data management and reporting processes, and developing options for open access to reef monitoring data in accordance with international guidelines. It is expected that the report will support all countries of the region to sustainably manage their coral reefs and associated biodiversity for the well-being of coastal populations and their posterity.

Support for preparation of the report was mainly provided through a cooperative arrangement of the European Union and the Indian Ocean Commission through a Biodiversity Program, with the scientific coordination of Coastal Oceans Research and Development – Indian Ocean East Africa.

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Reconnaissant l'importance des valeurs socio-économiques et écologiques des récifs coralliens et de la problématique de leur dégradation généralisée, les pays de l'océan Indien occidental, à travers la Commission de l'océan Indien et la Convention de Nairobi, se sont alignés sur l'Initiative internationale pour les récifs coralliens (ICRI) et notamment son Réseau mondial de surveillance (GCRMN) pour contribuer à la gestion durable de ces écosystèmes vitaux.

Il s'agit particulièrement d'un cadre régional qui a été mis en place pour le suivi de l'état des récifs coralliens et de leur biodiversité associée.

Ce rapport présente la dernière compilation et une évaluation quantitative des données sur la santé des récifs coralliens, realisées par les réseaux nationaux de surveillance des récifs, sous la coordination du réseau regional, et vient actualiser les précédents rapports GCRMN publiés de 1999 à 2008.

L'objectif principal de ce rapport est de fournir des informations actualisées sur l'état des récifs coralliens de la région, y compris l'impact du troisième événement mondial de blanchissement des coraux de 2016.

Les objectifs secondaires visent à: a) illustrer des modèles généraux qui expliquent l'état de santé des récifs et les perspectives de gestion durable, et b) présenter les facteurs de changement régionaux et leur impact au cours des prochaines années pour aider les pays dans la prévision des impacts et la régénération des récifs coralliens.

La première partie du rapport fournit un aperçu régional, documentant les tendances quantitatives de 1992 à 2016 sur la santé des récifs coralliens de l'océan Indien occidental, des algues et des poissons à partir des données provenant de 822 sites récifaux répartis sur 9 pays. Il documente également le blanchissement et la mortalité des coraux au début de 2016, sur la base de 699 observations du blanchissement des coraux, provenant de 54 organisations et plus de 80 observateurs dans les 9 pays.

La deuxième partie du rapport, préparée par les réseaux nationaux de suivi des récifs, présente les chapitres nationaux sur l'état des récifs jusqu'en 2015/2016 et les observations sur le blanchissement des coraux en 2016.

La santé globale des récifs. Les résultats indiquent que la couverture corallienne a considérablement diminué dans la région immédiatement après l'événement de blanchissement de 1998, et dans les années qui ont suivi, la couverture corallienne moyenne est restée à environ 30%, soit une baisse de 25% par rapport aux niveaux initiaux. La couverture d'algues a augmenté rapidement de 1998 à 2000, jusqu'à environ 35% au cours des 15 dernières années, soit un niveau 2,5 fois plus élevé qu'en 1998. Agrégés au niveau régional, les taux de recouvrement des coraux et des algues sont restés essentiellement les mêmes dans la période postérieure à 1998, mais la couverture en coraux durs a considérablement varié entre les pays. Les Seychelles et le Kenya ont subi la plus grande mortalité des coraux en 1998, mais depuis lors, ils ont montré une bonne récupération des coraux. L'Afrique du Sud a enregistré de légères augmentations de la couverture corallienne depuis le début de la surveillance. Les autres pays (Comores, France-Réunion, Madagascar, Maurice, Mozambique et Tanzanie) ont tous montré un déclin progressif de la couverture globale depuis le début de la surveillance.
La structure de la communauté des poissons a également montré un changement important. Probablement avant le blanchissement de 1998 (et certainement avant l'avènement de la forte pression de pêche au cours des décennies précédentes), la structure des groupes fonctionnels aurait été diversifiée, témoin d'un réseau alimentaire équilibré. On note un changement allant

vers une forte dominance des herbivores et des détritivores (environ 80% de la biomasse des poissons) et, de plus en plus, par des individus à corps plus petits de ces groupes fonctionnels.

Blanchissement des coraux - 2016. Le deuxième plus grand événement de blanchissement de l'Océan Indien Occidental a eu lieu en 2016, avec un peu plus d'un tiers des sites affectés par un blanchissement sévère avec un pic entre avril et mai 2016. Les Seychelles ont été les plus touchées par ce phénomène avec plus de 50% des observations sur les sites affichant un blanchissement élevé ou extrême, suivies par la Tanzanie et l'île Maurice. Heureusement, les niveaux élevés et extrêmes de blanchissement ne se sont pas traduits par le même niveau de mortalité corallienne, avec moins de 10% des sites signalant une mortalité sévère. Toutefois, la région n'a pas survécu complètement, puisque plus de 70% des rapports enregistrent un certain niveau de mortalité.

L'avenir? Les récifs coralliens de l'océan Indien occidental semblent être passés d'un état pré-1998 à un état post-1998, avec une couverture corallienne de 25% inférieure et une abondance en algues 2,5 fois supérieure. Pendant près de 2 décennies, la couverture en corail et en algues ont été équivalentes, ce qui pourrait être un indicateur précoce que, à l'échelle régionale, les récifs s'approchent d'un seuil au-delà duquel ils peuvent être dominés par des algues ou par d'autres invertébrés de corail non dur. Cela peut être aggravé par les communautés de poissons qui se caractérisent par des réseaux trophiques désormais moins complexes, au sein desquels les individus herbivores et détritivores de petite taille sont dominants.

Il est difficile de prédire exactement quelles sont les implications de ces tendances régionales dans la structure de la communauté des poissons, des coraux et des algues. La couverture corallienne a connu un autre déclin en raison de l'événement de blanchiment de 2016, mais heureusement le déclin a été d'environ 10%, moins de la baisse de 25% enregistrée en 1998. La pression de la pêche sur les récifs continue d'augmenter avec la croissance de la population humaine et la migration vers les zones littorales. Cela fait accroître la pollution et l'eutrophisation sur les récifs coralliens, fournissant un carburant ascendant au rôle croissant des algues et du régime herbivore / détritivore comme processus dominants. Le changement climatique en cours entraîne déjà une augmentation plus importante du blanchissement des coraux et des événements pathologiques, et l'acidification va de plus en plus nuire à la capacité des coraux à résister à d'autres menaces. Dans les années à venir, la couverture d'algues continuera-t-elle à augmenter au-dessus du niveau de la couverture en corail dur? Et si cela se produit, à mesure que de plus en plus de récifs individuels déclinent, sera-t-il de plus en plus difficile pour les récifs coralliens de revenir à un état dominé par les coraux depuis le niveau local vers les niveaux national et régional ?

Les résultats du suivi des récifs coralliens de 1992 à 2016 donnent une image claire de l’état des récifs coralliens dans l'océan Indien occidental. Bien que l'état actuel soit raisonnablement bon en termes de couverture de corail, la couverture d'algues élevée peut être un signe de vulnérabilité aux changements futurs. Les changements climatiques doivent être abordés dans le monde entier, les émissions de gaz à effet de serre doivent être fortement réduites pour atteindre les niveaux de l'Accord de Paris, pour avoir l'espoir que les récifs coralliens résistent et se remettent des menaces majeures. D'autre part, les facteurs de déclin locaux doivent également être réduits autant que possible pour limiter le nombre et les interactions entre les menaces. La promotion d’une « gestion efficace » de toutes les zones coralliennes est un objectif qui devrait interesser les parties prenantes clés intervenant sur les récifs tels que les pêcheurs et les opérateurs touristiques, car ce sera le seul moyen de tirer durablement profit des récifs coralliens dans un monde réchauffé et de plus en plus peuplé.

Recommandations

La santé régionale des récifs - En ce qui concerne la santé globale des récifs coralliens dans l'Océan Indien occidental:

- Les pays, les gestionnaires des récifs et les utilisateurs de ressources dans toute la région devraient reconnaître que la santé des récifs de la région a subi un déclin après l'événement du blanchissement coralline massif de 1998.
- De même, l'événement du blanchissement en 2016 signifie probablement une deuxième étape dans le déclin des récifs à l'échelle régionale.

Conclusion - il est impératif de mettre en place des mesures de gestion encore plus fortes que celles de la période 1999-2015 pour maximiser la santé des récifs coralliens. En reconnaissant cela au moyen de mécanismes régionaux et continentaux et dans les reseaux récifs nationaux, les politiques de gestion et de développement côtier seront essentielles pour motiver et faire respecter les actions plus larges nécessaires pour faire face à la dégradation de la santé des récifs à l'avenir. La mise à l'échelle des efforts doit être suffisante pour couvrir la superficie de 10% de zones bien gérées envisagées dans ODD 14 objectifs 2 et 11 d'Aichi d'ici 2020, avec une cible claire à long terme de 30% d'ici 2030.

Actions et interventions - devraient se concentrer sur la capacité de résilience et de récupération des récifs coralliens, ainsi que sur les systèmes de gestion pour protéger les récifs coralliens:

- Améliorer la gestion des aires protégées, des zones de pêche et d'autres zones d'utilisation afin de minimiser, à zéro, si possible, les impacts sur les habitats critiques. La connectivité locale, nationale et régionale et l'intégration des zones protégées et les principes de bonne gestion devraient être une priorité.
- Améliorer la portée et la couverture des outils de gestion des zones, y compris le suivi, les cartes de l'habitat, les évaluations économiques et autres.
- Promouvoir toute la gamme des modèles de gestion, y compris les domaines administrés par le gouvernement, gérés conjointement avec les communautés locales et privés. S'assurer que le personnel est à des niveaux appropriés, avec des programmes de formation pour renforcer les capacités et faire face à la mobilité du personnel.
- Gérer les pêches pour maintenir la diversité des taxons et des groupes fonctionnels et limiter les impacts sélectifs sur les groupes trophiques clés (consommateurs secondaires / prédateurs ainsi que les herbivores). Des zones de fermeture de pêche temporaire sont nécessaires pour maintenir la structure de la communauté de poissons dans les domaines clés, mais une gestion efficace des pêches peut être suffisante dans des zones plus larges pour maintenir les fonctions écologiques du poisson.
- Gérer et réduire les facteurs ascendants qui favorisent la croissance des algues, y compris les eaux usées dans les villes côtières et les zones touristiques, les débits de sédiments, les nutriments des rivières et le ruissellement de surface. Le changement d'affectation des terres et la gestion des déchets sur les terres sont les principaux mécanismes pour effectuer ces changements, de sorte que la gestion des récifs devrait être pleinement intégrée aux mesures de gestion des terres.

- Élaborer des objectifs quantitatifs pour les interventions de gestion, en reconnaissant que les changements d'état (augmentation de la couverture corallienne) peuvent être très difficiles à atteindre, et que des cibles plus subtiles telles que les processus (taux de croissance par rapport aux taux de mortalité, recrutement de corail, taux d'herbivores, etc.) seraient nécessaires.
- Soutenir et institutionnaliser les programmes de suivi des récifs coralliens, liés aux besoins locaux pour la gestion des récifs et des zones côtières. Ceux-ci devraient être conçus pour fournir une image localement pertinente de la santé des récifs, en utilisant des indicateurs pertinents pour la gestion afin d'identifier rapidement et de manière fiable les actions avec des résultats positifs à haut de gamme et à répliquer. Les liens stratégiques, par exemple avec les universités et d'autres institutions de soutien, devraient être construits pour maximiser la durabilité.
- Soutenir la recherche et le développement d'outils de restauration et de réhabilitation avec des succès démontrables, qui seront inclus dans les plans de gestion des ressources récifales et des ressources naturelles en general. Le « succès démontrable » peut être à plusieurs niveaux: croissance réussie et survie des coraux; L'accumulation d'autres taxons, la diversité et les interactions écologiques autour des coraux transplantés; Valeur ajoutée de l'emplacement de ses services - dans les secteurs de la pêche, du tourisme ou d'autres secteurs. Il est essentiel que des objectifs réalistes et réalisables soient définis pour les projets afin que les investisseurs et les parties prenantes ne s'attendent pas à des avantages qui n'ont pas encore été démontrés par une méthode de restauration particulière.
- Un renforcement du soutien national à la recherche ciblée et multidisciplinaire devrait être élaboré sur des sujets tels que les maladies des coraux, la restauration, la résistance au climat, la dépendance sociale aux ressources et d'autres.

Conclusion - *au niveau des différents sites des récifs coralliens, inverser les moteurs de la dégradation et promouvoir les facteurs de récupération et de résilience seront essentiels et doivent être réalisés à divers niveaux pour atteindre les objectifs locaux mentionnés ci-dessus.*

Au niveau national dans chaque pays de la région – tenant compte de certaines particularités des différents pays, des recommandations du chapitre national sont soulignées ci-dessous:

Comores	Les menaces prioritaires incluent la sédimentation, le ruissellement urbain / agricole et l'extraction du sable. Le parc national Mohéli, en cours de transformation en réserve de biosphère pour toute l'île, offre des opportunités pour mettre en évidence une gestion intégrée des interactions terre-mer. Un ancrage institutionnel du réseau national récif au réseau national des aires protégées en association avec l'Université des Comores et ONGs actives serait souhaitable.
Kenya	Avec un fort engagement des communautés locales et des utilisateurs des ressources, renforcer les réseaux aux niveaux local, national et régional est indispensable. Appliquer et renforcer les politiques et stratégies pour la protection et la restauration des récifs coralliens.
Madagascar	L'ampleur de la menace pour les récifs et les niveaux élevés de pauvreté nécessitent des actions allant bien au-delà de la gestion traditionnelle. Renforcer la résilience et la capacité d'adaptation au changement climatique - des récifs et des personnes.
Maurice	Développer la surveillance des récifs coralliens dans les îles et les récifs de Maurice. Harmoniser et normaliser les méthodes et protocoles pour la collecte de données sur le terrain.
Mozambique	Rétablir la coordination et le soutien à la surveillance des récifs coralliens au niveau national, y compris pour sécuriser les données de manière centralisée. Préparer les stratégies de gestion des récifs et les plans pour l'extraction de gaz naturel au large des côtes.
Réunion	Continuer les réponses intensifiées et diversifiées pour la conservation des récifs coralliens, pour répondre aux pressions sociales et politiques qui sont en augmentation. Améliorer la capacité du réseau de suivi des récifs à démontrer l'efficacité des actions de gestion et à informer les décisions, grâce à la production d'indicateurs robustes.
Seychelles	Élaborer un plan d'action national pour la conservation des récifs coralliens, dans le contexte de la législation et des stratégies de développement existantes. Renforcer le réseau national de surveillance des récifs coralliens pour préparer un statut national des récifs coralliens tous les 2 ans et partager des métadonnées sur les récifs coralliens aux Seychelles.
Afrique du Sud	Inclure des sites et des paramètres supplémentaires dans le programme national de surveillance des récifs coralliens. Développer la protection des récifs plus loin en mer pour retenir les récifs de la pêche illégale et vers le nord pour une collaboration transfrontalière avec l'aire marine protégée partielle de Ponta da Ouro au Mozambique.
Tanzanie •	Harmoniser et normaliser les méthodes et protocoles pour la collecte de données sur le terrain. Lier le groupe de travail spécialisé et le réseau national sur les récifs coralliens afin qu'ils travaillent vers un objectif commun. Travailler avec les agences des parties prenantes concernées dans l'éradication de la pêche à la dynamite.

Conclusion: *l'engagement national envers la protection et la gestion des récifs coralliens doit être plus élevé que jamais, en mettant l'accent sur les besoins nationaux, tout en intégrant les stratégies de gestion avec les pays voisins et au niveau régional.*

Recognising the importance of coral reefs socio-economic and ecological values and their general degradation, countries in the Western Indian Ocean (WIO) through the Indian Ocean Commission, and Nairobi Convention have aligned with the Global Coral Reef Monitoring Network (GCRMN) of the International Coral Reef Initiative (ICRI) to contribute to sustainable management of the vital ecosystems. A regional framework has been set up for monitoring the status of coral reefs and its associated biodiversity.

This report presents the latest compilation and quantitative assessment of data on coral reef health by the regional monitoring networks in the WIO, adding to the global GCRMN reports published from 1999 to 2008.

The **main objective** of this report is to provide updated information on the status of coral reefs in the region, up to and including the impact of the 2016 third global coral bleaching event. Secondary objectives are to a) illustrate broad patterns that explain the differing health status of various reefs, and the prospects for reef management in relation to this, and b) present regional drivers of change and how they may evolve in coming years, to help countries in planning for impacts and recovery of coral reefs.

Part I of the report provides a regional overview, documenting quantitative trends for Western Indian Ocean reef corals, fleshy algae and fishes based on data from 822 reef locations from 1992 to 2016, from 9 countries. It also documents coral bleaching and mortality in early 2016, based on 699 reports of bleaching from 54 organizations and over 80 observers across all 9 countries. Part II of the report presents country-level summaries of coral reef monitoring up to 2015/16 and observations of coral bleaching in 2016, distilled from national reports prepared by the National Coral Reef Task Forces (where applicable) from each of the countries.

Overall reef health. The results indicate that hard coral cover declined substantially across the region immediately after the 1998 bleaching event, and in the years since, average coral cover has remained at about 30% which is 25% lower than pre-bleaching levels. The subsequent increase in algae cover lagged by a year, rising rapidly from 1998 to 2000, then remaining at about 35% for the last 15 years, 2.5 times higher than before 1998. Aggregated at the regional level, both coral and fleshy algal cover have remained essentially the same in the post-1998 period, however coral cover has differed greatly among countries. The Seychelles and Kenya suffered the greatest mortality of corals in 1998, but since then have shown good recovery of corals. South Africa has shown slight increases in coral cover since monitoring started. The other countries (Comoros, France, Madagascar, Mauritius, Mozambique and Tanzania) have all shown a progressive decline in overall cover since monitoring began in each country.

In the past, coral cover was higher, algae cover low, and fish diverse and abundant (above). Now, coral cover is lower, algal cover is equal to coral and increasing, and fish populations are low (below).

Fish community structure has also shown an important change. Presumably before the 1998 bleaching (and certainly before the advent of heavy fishing pressure in earlier decades), functional group structure would have been diverse, representing a balanced food web. It has now shifted to strong dominance by herbivores and detritivores (about 80% of fish biomass), and increasingly, by smaller-bodied individuals of these functional groups.

Coral bleaching - 2016. The second largest bleaching event in the WIO occurred in 2016, with just over one third of reported sites affected by severe bleaching at its peak in April-May 2016. Seychelles was the most affected by bleaching with over 50% of reported sites showing high or extreme bleaching, closely followed by Tanzania and Mauritius. Fortunately, the high and extreme levels of bleaching did not translate into the same level of coral mortality, with less than 10% of sites reporting severe mortality. However, the region did not survive completely un-scathed with over 70% of reports recording some level of mortality.

The future? Western Indian Ocean coral reefs seem to have shifted from a pre-1998 state to a post-1998 state with 25% lower coral cover and 2.5 times algae abundance. For almost 2 decades, coral and algal cover have been equivalent, which may be an early indicator that at the regional scale, reefs are approaching a threshold past which they may become dominated by algae, or by other non-hard coral invertebrates. This may be exacerbated by the fish communities also shifting from more complex to simpler trophic webs in which herbivory and detritivory by small-sized fish are dominant processes.

Exactly what the implications of these regional trends in coral and algal cover and fish community structure are likely to be is difficult to predict. Coral cover experienced another step decline due to the bleaching event of 2016, but fortunately the decline in the order of 10%, is less than the 25% decline documented in 1998. Fishing pressure on reefs continues to increase with human population growth and migration to the coastal zones. The latter will also drive up pollution and eutrophication on coral reefs, providing bottom-up fuel to the increasing role of algae and herbivory/detritivory as dominant processes. Ongoing climate change is already inducing more frequent major coral bleaching and disease events, and acidification will increasingly undermine the ability of corals to resist other threats. In coming years, will algal cover continue to increase above the level of hard coral cover? And if this happens, as more and more individual reefs decline, will it become harder and harder to return coral reefs to a coral-dominated state from local to national and regional levels?

The results of coral reef monitoring from 1992 to 2016 paint a clear picture for coral reefs in the Western Indian Ocean. While the current state is reasonably good in terms of coral cover, the high algal cover may be a sign of vulnerability to future changes. To have any hope of coral reefs resisting and recovering from major threats, climate change must be addressed globally with greenhouse gas emissions reduced sharply to meet the Paris Agreement levels. On the other hand, local drivers of decline must also be reduced as far as possible to limit the number of and interactions between threats. Increasing 'effective management' to all coral reef areas is a goal that should be attractive to key reef stakeholders such as local and national government, fishers and tourism operators, as this will be the only way to sustainably derive benefits from coral reefs in a warming and increasingly populated world.

Recommendations

Regional reef health – in relation to the overall health of coral reefs in the Western Indian Ocean:

- Countries, reef managers and resource users across the region should recognize that the health of the region's reefs has undergone a step-decline after the 1998 mass coral bleaching event
- Similarly, the bleaching event in 2016 likely means a second step-decline in reef health regionally
- An institutional anchorage of the national reef network to the national network of protected areas in association with the University of Comoros and active NGOs would be desirable

Conclusion - to maximize coral reef health, it is imperative to implement even stronger management measures than those in place from 1999-2015,. Recognizing this through regional and continental mechanisms, and in national coral reef, coastal management and development policies, will be essential to motivate for and enforce the broader actions needed to cope with the likely reduced health of reefs in the future. Scaling up of efforts needs to be sufficient to meet the 10% coverage of well-managed areas envisaged in SDG 14 Target 2 and Aichi Target 11 by 2020, with a clear long term goal that this should increase to the broadly accepted 30% target by 2030.

Actions and interventions – should focus on building the resilience and recovery ability of coral reefs, as well as of management systems to protect coral reefs:

- Improve the management of protected areas, fishery grounds and other use-areas to minimize and even eliminate impacts to critical habitats. Local, national and regional connectivity and integration of protected areas and management principles should be a priority.
- Improve the scope and coverage of area-based management tools, including monitoring, habitat maps, economic valuations, and others.
- Promote the full range of management models (regimes), including government-run, co-managed and privately-managed areas. Ensure staffing is at appropriate levels, with training programmes to build capacity and cope with staff turnover.
- Manage fisheries to maintain taxon and functional group diversity, and limit selective impacts to key trophic groups (secondary consumers/predators as well as herbivores). No-take areas are necessary to maintain fish community structure in key areas, but effective fisheries management may be sufficient in broader areas to maintain the ecological functions of fish.
- Manage and reduce bottom-up factors that promote algal growth, including sewage from coastal towns and tourism areas, river discharge of sediments and nutrients, and surface runoff. Land-use change and waste management on land are the primary mechanisms for effecting these changes, so reef management should be fully integrated with land-based management measures.

Develop quantitative targets for management interventions, recognizing that state changes (increase in coral cover) may be very challenging to achieve, and more subtle targets focused on processes (growth vs. mortality rates, coral recruitment, herbivory rates, etc.) may be needed.

Support and institutionalize coral reef monitoring programmes which are tied to local needs for reef and coastal zone management. These should be designed to provide a locally-relevant picture of reef health, using management-relevant indicators to quickly and reliably identify actions with positive results. Strategic links, for example with universities and other supporting institutions, should be built up to maximize sustainability.

Support research and development of restoration and rehabilitation tools which have shown demonstrable success. These tools can then be included as components of reef and resource management plans. 'Demonstrable success' can be at multiple levels - successful growth and survivorship of corals; accumulation of other taxa, diversity and ecological interactions around the transplanted corals; increased value of the location for its services - in fisheries, tourism or other sectors. It is essential that realistic and attainable goals are set for projects so that investors and stakeholders do not expect benefits that have not yet been demonstrated by a particular restoration method.

Greater national support for targeted and multi-disciplinary research should be built, on topics such as coral diseases, restoration, climate resistance, social and resource dependence, and others.

Conclusion *- at the level of individual coral reef sites, reversing the drivers causing degradation and promoting drivers of recovery and resilience will be essential particularly at levels to meet the area-based targets mentioned above.*

National – certain particularities of individual countries from the national chapter recommendations are highlighted below:

Comoros	Priority threats include sedimentation, urban/agricultural runoff and sand harvesting. Moheli National Park, in transforming from an MPA to an island management system offers opportunities to showcase integrated management of land-sea interactions. Institutional anchoring of the national reef network to the national network of protected areas in association with the University of Comoros and active NGOs would be desirable.
Kenya	With the rapid growth in community and resource user engagement, strengthening and networking at local, national and regional levels should be promoted. Apply and strengthen policies and strategies for coral reef protection and restoration.
Madagascar	The scale of the threats to reefs, and high poverty levels need actions to go far beyond traditional management Build resilience and adaptive capacity to climate change – of reefs, and people.
Mauritius	Expand coral reef monitoring to the outer islands and reefs of Mauritius. Harmonize and standardize methods and protocols for field data collection.
Mozambique	Re-establish coordination and support for coral reef monitoring at the national level, including for securing data centrally. Prepare reef management strategies and plans for offshore natural gas mining.
Reunion	Continue intensified and diversified responses for coral reef conservation, to respond to mounting social and political pressures. Improve ability of monitoring network to demonstrate the effectiveness of management actions and inform decisions, through production of robust indicators.

Seychelles	Develop a policy and national plan of action for the conservation of coral reefs, in the context of existing legislation and development strategies. Strengthen the national coral reef monitoring network to prepare a national status of coral reefs report every 2 years and to share metadata on coral reefs in the Seychelles.
South Africa	Include additional sites and parameters in the national coral reef monitoring programme. Expand reef protection farther offshore to buffer reefs from illegal fishing, and northwards for cross-border collaboration with Ponta da Ouro partial MPA in Mozambique.
Tanzania	Link the national coral reef task force and monitoring networks, so that they work towards a common goal Work with stakeholder agencies in eradication of dynamite fishing

Conclusion - *national commitment to coral reef protection and management needs to be higher than ever before, with relevant focus on national needs and simultaneous integration with management strategies of neighbouring countries and the region.*

SHORT CONTENTS

DETAILED CONTENTS

1 REGIONAL CHAPTERS

1.1 Introductory sections

The Western Indian Ocean region is recognised as one of the richest areas in the world for marine and coastal biodiversity (UNEP-Nairobi Convention/WIOMSA 2015). However, this wealth is exposed to various threats due to human activities and changing climatic conditions. Recognising the significant socio-economic and ecological values of coral reefs and their associated ecosystems, countries in the region through regional cooperation frameworks (Indian Ocean Commission, Nairobi Convention), have aligned with the International Coral Reef Initiative (ICRI) to try to provide solutions to these issues, including a regional framework for monitoring and reporting on the status of coral reefs.

Two sub-regional nodes make up this structure, created under the Global Coral Reef Monitoring Network (GCRMN) in 1998 – the South West Indian Ocean (SWIO) islands of the Comoros, Madagascar, Seychelles, Mauritius, France/Reunion, identified as Node No. 3 of the GCRMN, and the mainland Eastern and Southern African countries of Kenya, Tanzania, Mozambique and South Africa, as Node 4. With the creation of the Coral Reef Task Force (CRTF) of the Nairobi Convention in 2001 the 2 nodes were joined in a single regional network.

Several projects have supported these coral reef networks through funding from the European Union to the Indian Oean Commission (the IOC-EU Regional environment program, Regional Sustainable coastal zone management (ReCoMaP) and the ISLANDS program), IOC-GEF-World Bank coral reef Programme and AFD-FFEM Regional network of marine protected area. Capacity building in coral reef mappings, monitoring protocols and databases management of national teams as well as equipment were provided since 1998 to 2014. Regular national and regional reporting was conducted and contributed to global coral reef status reports published by GCRMN.

The Indian Ocean Commission's Biodiversity project, funded by the European Union is aimed at strengthening national and regional capacities in the management of biodiversity and coastal ecosystems to contribute to the conservation and sustainable use of resources (promotion of bio-sustainable applications). From 2014 to the present, it has supported capacity building and coordination of coral reef monitoring under the CRTF/GCRMN umbrella, and the compilation of this report.

This report presents the first compilation and quantitative assessment of data on coral reef health by the regional monitoring networks. It is modelled after the Caribbean regional report led by Dr. Jeremy Jackson and the IUCN Global Marine and Polar Programme (GMPP) published in 2014 (Jackson et al. 2014). It also follows the recent reorientation of the GCRMN, to focus on regional frameworks and capacity building, as recorded in minutes and decisions of the ICRI General Meetings in recent years (2014-2016).

The aims of this report are to:

1. update the status of coral reefs in the countries of the region;
2. reinvigorate the GCRMN coral reef networks of the region through a common reporting process;

3. strengthen and refocus monitoring methods, and strengthen the monitoring and reporting teams in the region, to produce more coherent and consistent data and reporting;
4. contribute to the global GCRMN reporting process as part of its focus on regional reporting;
5. provide a quantitative update for future editions of the Regional State of Coast report published in 2015 by the Nairobi Convention Secretariat (UNEP/WIOMSA 2015);
6. improve the provision of knowledge to support better conservation and management of coral reef assets and resources; and
7. recommend priority actions for the sustainable use and management of coral reefs.

The overarching objective of this undertaking is to understand what is happening to coral reefs in the region including why some reef areas or individual reefs are doing better than others, and if any broader guidance on reef management can be provided to the countries. Coral reefs in the region experienced a devastating bleaching event in 1998, which wiped out approximately 16% of living coral in the region. In response to this unprecedented event, there has been a large increase in scientific research conducted in the region, as well as attention to expand and strengthen management of coral reefs.

Another key aim of this reporting process is to assist policy makers and reef-managers by strengthening the use of coral reef information in management, with a view to conserving or improving the health of coral reefs and increasing the degree to which they can sustainably support people into the future. Sub-Saharan Africa, including the countries of the Western Indian Ocean, is undergoing a population and economic boom in the first half of the 21st century that will likely transform the region economically and demographically. The whole region will account for half the increase in global population between now and 2100, coinciding with a time when climate change is altering natural and agricultural ecosystems fundamentally. With the UN Agenda 2030 and its Sustainable Development Goals providing global targets for development for the first part of this century, we also present some long term drivers that are already affecting coral reef health and will likely determine the outcome for reef health by the turn of the century.

This report documents quantitative trends for Western Indian Ocean reef corals, fleshy algae and fishes based on data from 822 reef locations from 1992 to 2016, covering 9 countries of the Western Indian Ocean[1]. A section in each national chapter, and a separate regional chapter are dedicated to reporting the Third Global Bleaching Event, which substantially affected the region in early 2016.

The main body of the report is in two sections. Part I provides an overview of regional status and trends from long term monitoring data (1.2), impact of the 2016 bleaching event from targeted 'response' monitoring of the event (1.3), and trends in long term drivers affecting reef health (1.4). Part II presents summaries of national status reports prepared by each country as part of the overall reporting process. The reports were prepared by national teams, listed as authors and contributors, and edited for consistency of maps, figures, tables and text. Access to the original national reports is possible through the lead author of each chapter.

1 Only Somalia is missing from the reporting, as coral reef monitoring data is absent from the country.

1.1.1 Acknowledgments, sponsors, and supporters

Producing this report would have been impossible without the voluntary contributions of many people who are working to study, monitor, and conserve the coral reefs of the Western Indian Ocean. We wish to specifically thank the Indian Ocean Commission and its Marine Programme under the leadership of Ms. Gina Bonne and coordinated by Said Ahamada. The coordinators of the IOC-EU Biodiversity, IOC-EU ISLANDS and IOC-FFEM Sustainable Coastal zones management projects – Didier Schlachmyulder, Christophe Legrand and Adele de Toma – and their support staff, including Pierre Peries and Mihary Randrianarivelo, who provided great support at different phases building up to this report. The Memorandum of Understanding between the Nairobi Convention and the Indian Ocean Commission provided the policy umbrella for this report, and we acknowledge Mr. Dixon Waruinge of the Nairobi Convention Secretariat, and Jerker Tamelander of the UN Environment Coral Reef Unit for their support. Support for capacity building and networking was also provided through the Reef Resilience network and forum, and we acknowledge Kristen Maize and The Nature Conservancy for their support. Maps showing coral reef monitoring stations were produced by James Mbugua.

Direct funding for the report was provided by the European Union through the Indian Ocean Commission Biodiversity Project managed by Landell Mills Consortium. Additional funds supported contributors from non-beneficiary countries of the Biodiversity Project, from the Western Indian Ocean Marine Science Association (WIOMSA) and the Building capacity for ecossytem and biodiversity assessment in the Southern African region (NCAP) support to the South African National Biodiversity Institute (SANBI). CORDIO provided co-funding in the form of partial salary support.

The regional Coral Reef Task Force was established by the Conference of Parties to the Nairobi Convention to coordinate coral reef issues and monitoring in the region, and four of its original members – Jean Maharavo, Said Ahamada, Jude Bijoux and David Obura – were active in this reporting.

The authors and contributors in the national chapters, and the institutions listed for them, are the backbone of this report and the editors and IOC project staff thank them for their involvement and contribution. The following lists all people and institutions that contributed data to this report:

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1.1.2 Methods/Approach

Quantitative data on WIO coral reefs has been collected by a diversity of programmes, focused mainly on marine protected areas, programmes run by research institutes and/ or individual research projects led by local or foreign researchers. Much of the data is unpublished and held in insecure spreadsheets on personal computers, and some of it is published in the grey literature.

Plate - Diver implementing a Line Intercept Transect. c. David Obura.

The regional reporting process was announced and advertised to the marine management, conservation and science communities of the region through the preparatory activities and workshops of the IOC's ISLANDS and Biodiversity projects in 2013-2015, the Conference of Parties to the Nairobi Convention in June 2015 and the Scientific Symposia of the Western Indian Ocean Marine Science Association (WIOMSA) in October 2014 and October 2015. Given the prior investment in regional and national network structures, and strong interest from the countries and contributing institutions to use this framework, our approach departed from that taken by the Caribbean reporting process, where direct approaches from the regional team to individual data owners and scientists was the principal approach. We used the national and regional reef networks established under the Nairobi Convention and GCRMN, comprising the two sub-regional GCRMN networks for the SW Indian Ocean islands, and the mainland African coast, both of which are grouped in the regional Coral Reef Task Force of the Nairobi Convention.

Given the hiatus in activity in these networks and the national Coral Reef Task Forces (NCRTF) established in the 2000s, revitalization of these structures was undertaken by the IOC ISLANDS and Biodiversity projects, in a series of activities from 2013-2016. To support this reporting, a number of network meetings were held, including two regional workshops (in Mauritius, February 2015 and Zanzibar, May 2016), several national workshops, and a half-day special session at the 9th WIOMSA Scientific Symposium (Durban, November 2015). The NCRTF focal points, assisted by a national consultant contracted by the IOC, led the process of contacting national data contributors. Depending on the country, one or two workshops were held to agree on how to bring together their data, analyse it, and write a national report. These efforts were supported by the regional team, with CORDIO coordinating the data and writing process and providing assistance for Anglophone countries and Mozambique, and MAREX providing assistance for Francophone countries. When required the regional team assisted the national teams in contacting data owners and requesting their contribution.

A Data Sharing Agreement was prepared to secure data owner's rights, such that the data collected would only be used for this reporting process. Any further development of the regional database compiled by this process will require a new agreement.

1.1.3 The data

For this analysis we focused on data collected using GCRMN methods of intermediate level or higher. This is the principal recommended methods for monitoring reefs in the GCRMN since the mid 1990s and based on the English et al. 1995 methods manual and other GCRMN manuals (English et al. 1995, Hill and Wilkinson 2004, Conand et al. 2000, 2001, Obura 2014). We did not include more basic methods typically used by citizen, volunteer and community programmes due to compounding problems of accuracy and reliability of data. Similarly we only accessed data voluntarily provided by the data owners under a Data Sharing Agreement. Thus significantly more data is available (though not accessed for this report) in the personal and institutional datasets of some scientists and institutions (principally Non-Government Organizations) that did not submit data, and in the datasets of volunteer-based programmes. Importantly data from early monitoring efforts has been lost in some countries, emphasizing the critical need for securing data.

Given the challenges in using and sharing primary data – both for the Intellectual Property and ownership rights of data providers, and for the complexity and variation in methods and raw data types – we decided to use summary data for this report. That is, we collated the mean value of a variable from a particular station or site, at each sampling interval (e.g. percent coral cover). This is the level of data of primary use to managers and decision-makers. While considerable information is lost in not using the variance among sampling units at a site, we note that in most reporting for management and for national and regional reporting, the variance within sites is very rarely reported or used. We refer to the level we used as 'site summary' data.

With the additional consideration of promoting increasing open-ness in data provision and access (see section 1.1.5), we felt a focus on mean site-level data will provide an acceptable compromise between the rights and publication options of data owners, and the added value of data sharing to the broader community.

We obtained data from 51 monitoring programmes or individuals and 70 datasets (Table 1.1.1), comprising 2504 surveys of corals, 1619 surveys of algae and 1491 surveys of fish from 822 locations across the 9 countries (Table 1.1.1, figure 1).

Table 1.1.1. Summary of the numerical extent of data collected from the Western Indian Ocean. (see table 1, p 22, Caribbean).

	Coral	Fleshy Algae	Fish	Overall
Countries	9	7	7	9
Locations/Sites/Stations	697	471	372	822
Datasets	42	36	24	70
Individual surveys	2504	1619	1491	3995
Start Year	1992	1992	1999	1992
End Year	2016	2016	2016	2016
Years surveyed	25	25	18	25

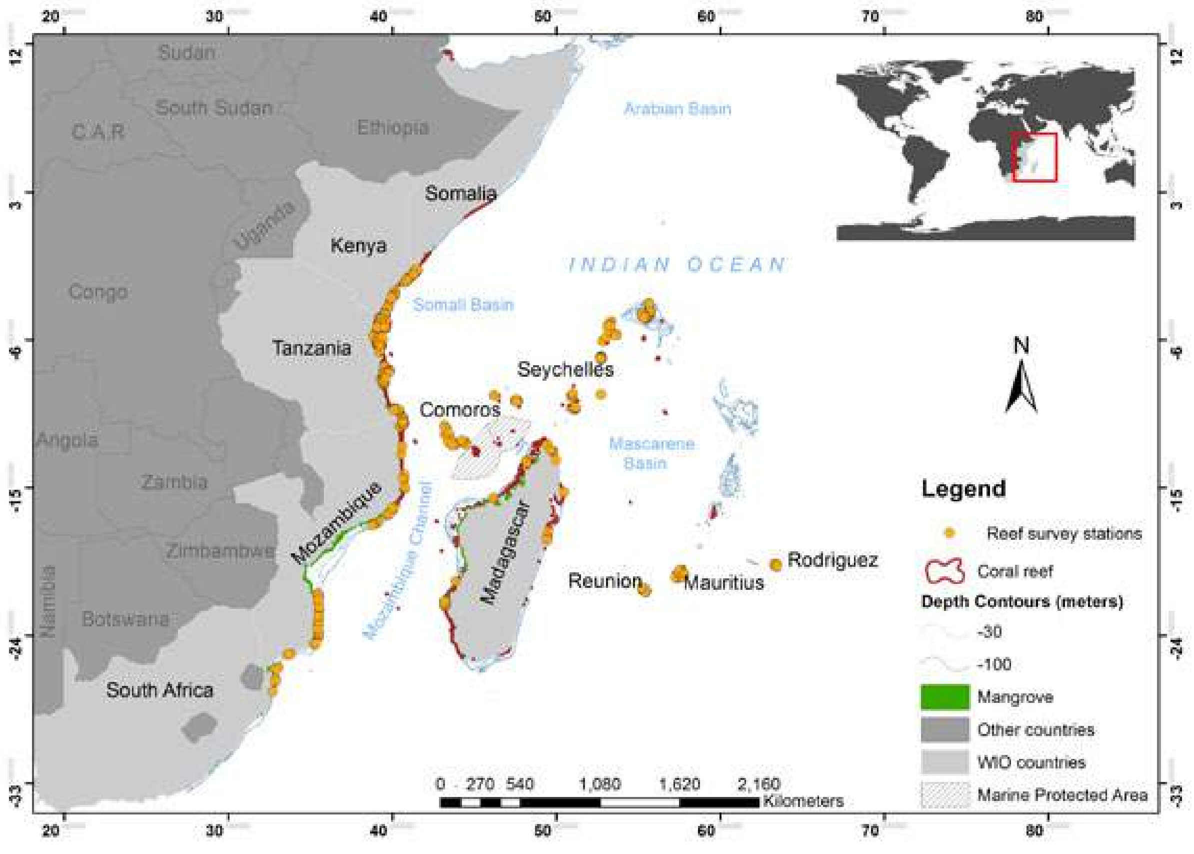


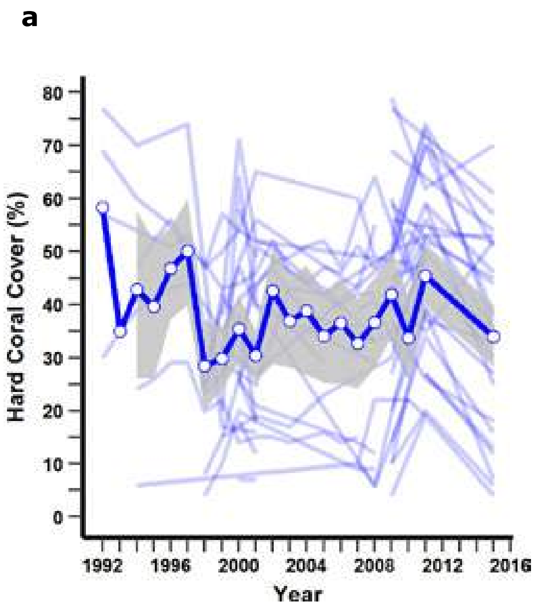
Figure 1.1.1. Map of monitoring stations and sites for which data is included in this report, across the Western Indian Ocean.

1.1.4 Analysis

National data was compiled by the national Coral Reef Task Forces, with data contributions from different programmes being merged into a common spreadsheet - one for benthic data and one for fish. Data was compiled at the level at which it was collected (e.g. coral growth form or genera), corresponding to levels and codes specified for countries of the region (Obura 2014), prior to being aggregated.

Given the long time period (approximately 25 years), instability of funding for monitoring in the region and personnel and institutional changes, most national datasets include significant discontinuities in data series, with old sites being terminated, new sites started and gaps within the data from individual sites. Additionally, progressive drift in monitoring methods does occur over time (Obura 2013 documents this for the island states), which can undermine the robustness of long data series. Therefore, analysis is focused on illustration of variation among site means, while emphasizing the overall trend.

At the national level, benthic data is presented graphically by plotting lines for coral cover for all monitoring sites over time, overlain by a mean line and 95% confidence interval of the mean (see fig. 1.1.2a). This helps to show the mean trend, certainty over the estimate of the mean, individual variation of all sites monitored in a year, and discontinuities in data from individual sites (including starting and stopping of sites). The method visually emphasizes the outlier sites beyond the 95% confidence limit, and how they may influence the mean and confidence interval. For comparisons among datasets, such as coral versus fleshy algae, and in regional comparisons between countries, we graph the mean and confidence limits (fig. 1.1.2b).



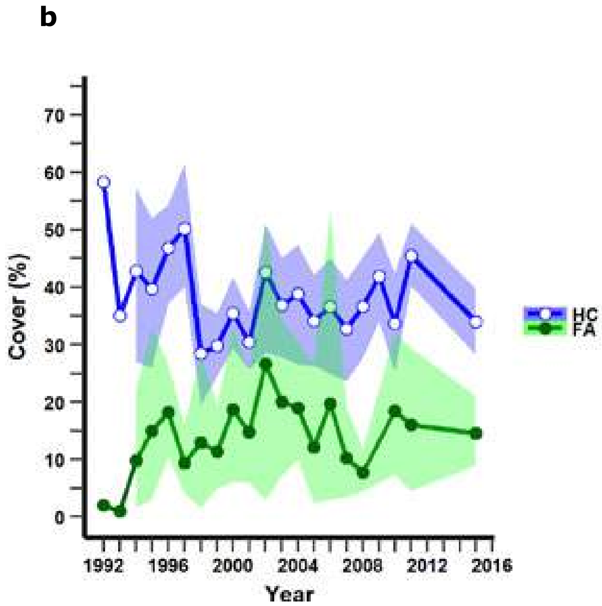


Figure 1.1.2. a) Trend in hard coral cover; b) Trend in mean cover of live coral (blue, open circles) and macro algae (green, closed circles). Data from Tanzania, see figure 2.9.2.

Fish data was more sparsely reported than benthic data, with many gaps in monitoring where it was done. The range of fish taxa monitored also varied considerably among programmes and countries, as did the focus at family or individual or indicator species level, making aggregating fish data to single biomass or abundance estimates impossible. Thus, data is presented for each family monitored in a country (see fig. 1.1.3)[2]. We plot individual points for fish density (and biomass where possible) for all monitoring sites over time, overlain by a mean line and 95% confidence interval of the mean. Points were chosen rather than lines, as variation in fish numbers is very high from one year to the next, a common feature in fish data, and the paucity of sites and years resulted in a distracting jumble of lines. As for benthic data, comparisons among countries are done using the mean and confidence limits.

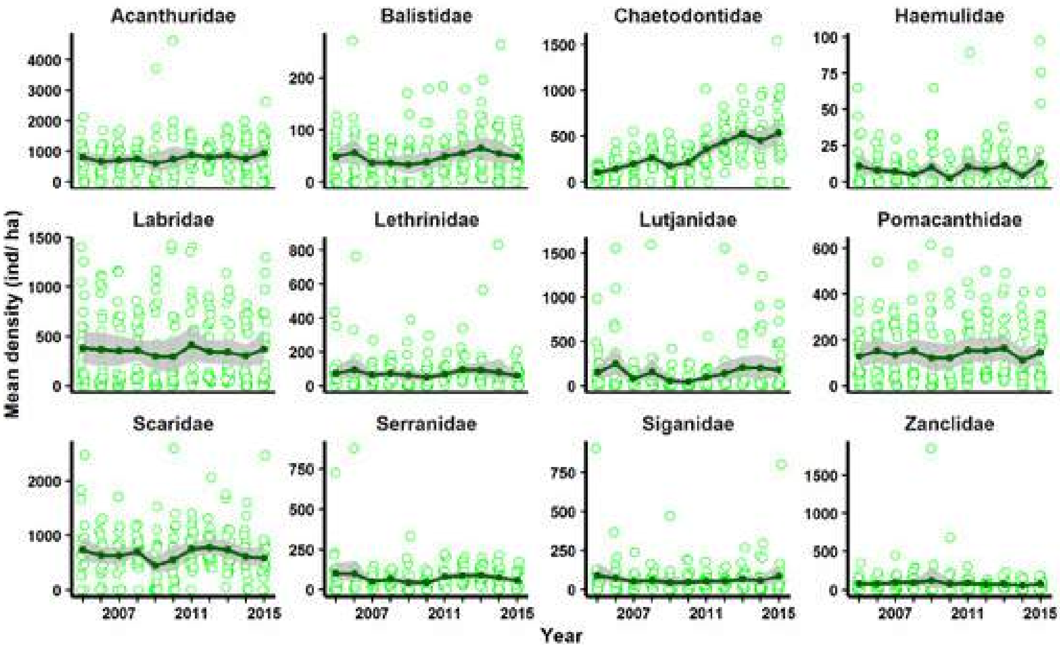


Figure 1.1.3: Fish abundance on coral reefs. Data from Seychelles, see fig. 2.7.5.

For the regional comparisons we restricted the sites used to only those with 4 or more years of data, to avoid the high variance associated with inclusion of sites with only one-off samples and to reduce break-points in the data between sites with <4 years of sampling compared to more (for example, many short-period sites were sampled only at the beginning, or only at the end, of the time period). As mentioned earlier, variation in methods for counting fish were very high, preventing strong comparisons among countries. In addition, some counts of fish were extremely high, possibly due to large aggregations of fish at underwater features (e.g. deep ledges), so we decided to exclude records with abundance values greater than 8000 ind/ha. These counts greatly skewed the data and graphs making it hard to view more standard estimates, and we had concerns over the accuracy of such high numbers as they are based on estimation of total numbers, rather than being able to count all fish individually.

2 with the exception of Kenya and Tanzania where monitoring included the full diversity of families observed. For these national chapters, we selected only those families that were most commonly reported across the region.

1.1.5 Data archiving and access

This reporting effort represents the first compilation and quantitative assessment of data on coral reef health by the regional monitoring networks, though this has been done in research-focused publications (e.g. McClanahan et al. 2014, Atewerbehan et al. 2011). In spite of prior efforts in securing data in databases, in particular the COREMO database, and in national coral reef monitoring networks, data archiving and management is still rudimentary among WIO monitoring programmes, countries and networks. An effort to develop a common database platform for use by monitoring teams supported by the ISLANDS project was discontinued in 2014, and a new platform under development in France, the BDROI (Base de Données Récifs Océan Indien) promises to provide a secure platform, but is not yet operational.

All contributors provided the mean (and in some cases standard deviation) of their results at site level (e.g. mean per cent cover of coral genera, algal categories, and mean abundance of fish species or taxa by size classes). Data supplied at higher resolutions of classification were aggregated to total hard coral, fleshy algae and fish families (see methods).

The data have been compiled into two databases – one on yearly mean percent cover of hard coral and fleshy algae by site and year; and another on mean abundance (and biomass if fish size data was collected) of fish taxa by site and year. These databases are the first regional databases on coral and algal cover, and fish density and biomass to be held in formal networks hosting the GCRMN processes – the Indian Ocean Commission's Marine Programme, and the Nairobi Convention's Coral Reef Task Force.

Securing these databases and making them useful (see Costello et al. 2014), establishing mechanisms for contributors to repopulate them on a periodic basis, and establishing criteria and permissions for access and use of the data are topics that will be developed following publishing of this report. This will help support Western Indian Ocean countries in protecting and potentially restoring their coral reefs, and assist managers at local levels and in agencies with responsibilities for coral reef management. An accessible database will also support national- and regional-level reporting, such as in convention processes such as the Nairobi Convention, the Convention on Biological Diversity's Aichi Targets, and the United Nations' Sustainable Development Goals. The 2015 State of Coast report was based on information from the literature, whereas its next revision, as well as of the World Ocean Assessment, can be supported quantitatively by this database and its continued development. The GCRMN and ICRI will play a role in supporting this process, and integrating this database with global resources, such as the Ocean Biogeographic Information System (OBIS).

Plate: Mature coral community, Pemba Island, Tanzania. c. Jerker Tamelander

1.2 Long term monitoring 1992 - 2015

Authors: *David Obura and Mishal Gudka*

1.2.1 Introduction

This section presents the results of long term monitoring across all 9 countries that submitted national reports in section 2. The level of investment in monitoring varied greatly among countries. Several countries sampled more than 30 sites in a year, with many having less than 15 (fig. 1.2.1). Reunion had the greatest consistency of sampling with 14 sites most years of monitoring. South Africa has the most consistent sampling and length of sampling period, but from only 1 site. In recent years, the greatest effort in monitoring has been in Madagascar and Seychelles, with 30-40 sites being monitored in the last 5-7 years.

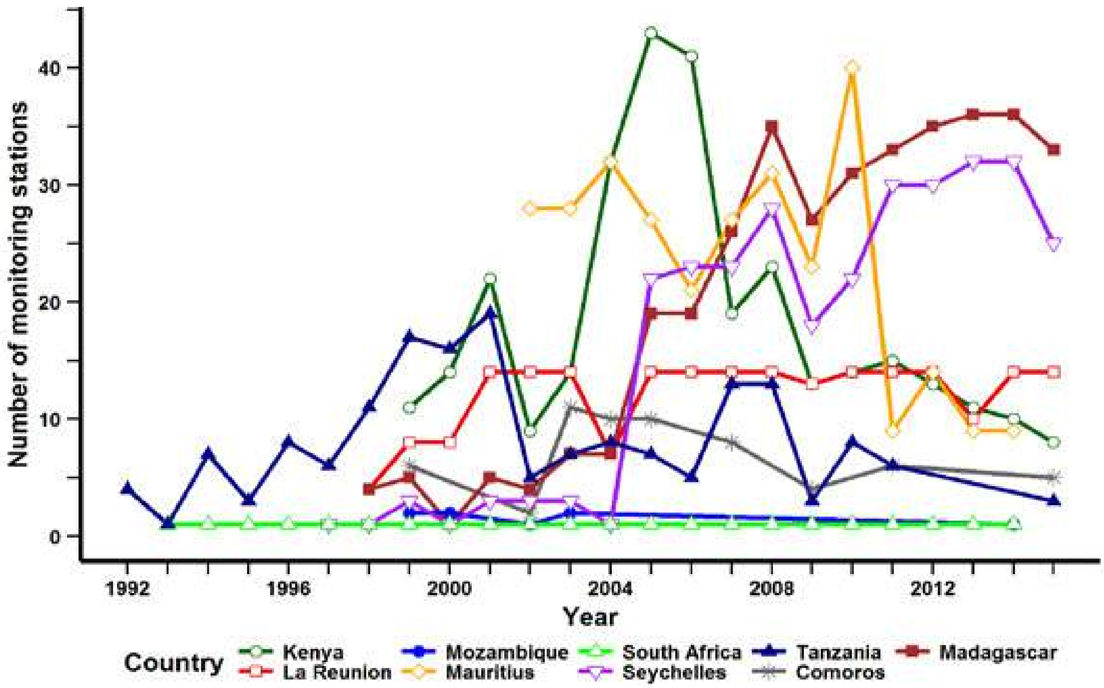


Figure 1.2.1. Effort in benthic monitoring across all countries from 1992-2015, for sites with more than 4 years of data. 2016 is excluded as very few countries reported data in 2016, and from few sites.

For this regional analysis, we only included sites with 4 or more years of sample data, though the years in which these may have been collected varied widely.

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Contributors & acknowledgements: *we would like to acknowledge all the national data contributors and chapter authors, and their institutions. The full list of contributors provided in section1.1.1.*

1.2.2 Coral cover

Prior to the mass bleaching event in 1998, average coral cover from data submitted for this report was about 40%, then fluctuated around 30% from 1999 to 2016 (fig. 1.2.2). Coral cover varied widely across the countries. Only two countries (Tanzania and South Africa) have data prior to 1997 but with low replication (1 in South Africa, 6 in Tanzania), though the addition of Seychelles in 1997 validates the high coral cover shown by the Tanzanian line (the low value for South Africa is due to being in marginal conditions for hard corals, Celliers and Schleyer 2002). From 1998 onwards Seychelles shows the high impact of bleaching reported from the 1998 coral bleaching event (Wilkinson et al. 1999, Goreau et al 2000). The decline in coral cover in Kenya is not shown in data submitted for this analysis (which started in 1999), but is known from other data: pre-1998 data from Kenya was at about 28% (McClanahan et al. 2007, Atewerbehan et al. 2011), slightly below but comparable to the regional mean values between 1995-1997 of around 40% shown here.

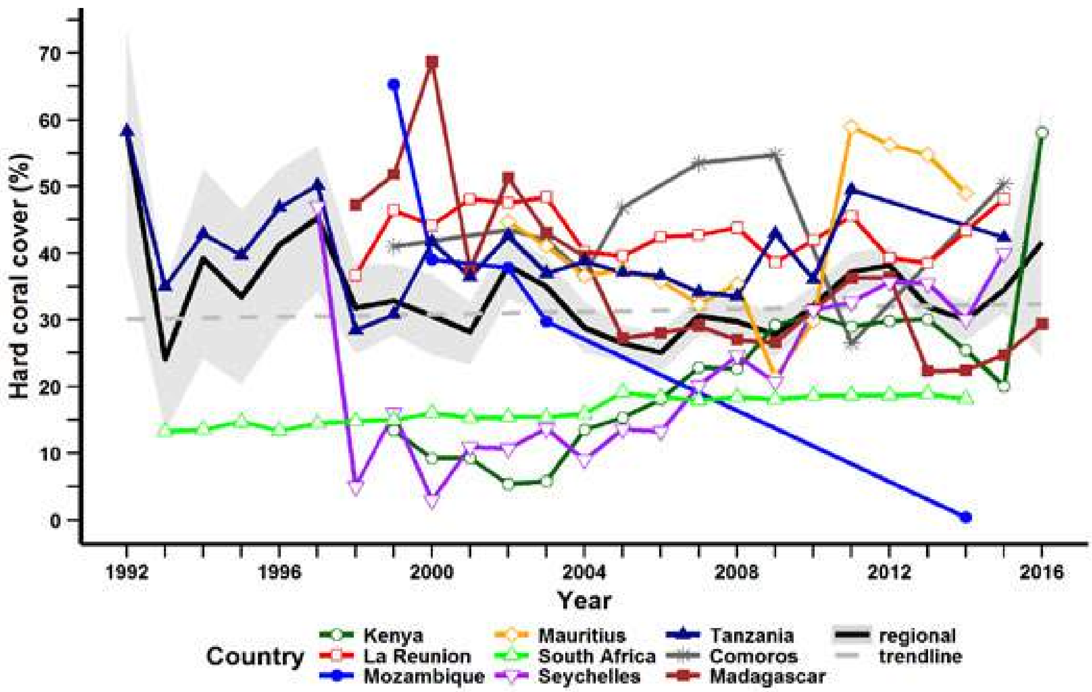


Figure 1.2.2 Mean coral cover across all 9 countries with data in the WIO (coloured lines with symbols), the regional mean with 95% confidence limits around the mean (black line and grey shading) and a linear regression line on the regional mean (grey dashed line, y = 0.095x + 30.071). Excluded are all sites with < 4 years of data. Gaps in years of monitoring are shown by the absence of symbols on the national lines.

In most other countries, coral cover has been very variable but started at higher levels of between 30-50% at the beginning of this series around 2000, ending in a broader spread, from 20-60% in 2014-16. Thus, taken all together, the regional mean (about 30%) and the linear regression line across all points show no overall decline from 1999 to 2016.

More detailed patterns on a country-by-country basis are shown in fig. 1.2.3. Apart from Tanzania, none of the countries had replicated monitoring before 1998 so the impact of the bleaching event in that year is not apparent. For Tanzania, the impact is shown as a sharp decline of mean cover of about 30%, but rapid recovery in the next 2-5 years masks this decline and it does not stand out from the overall linear decline over the whole time period from 1992-2011. For the Seychelles, although the decline is not shown in this data, the catastrophic impact is shown by the extremely low coral cover values reported in 1998 compared to values of about 40-60% pre-bleaching (Ahamada et al 2008). South Africa did not experience bleaching-related mortality in 1998 (Celliers and Schleyer 2002).

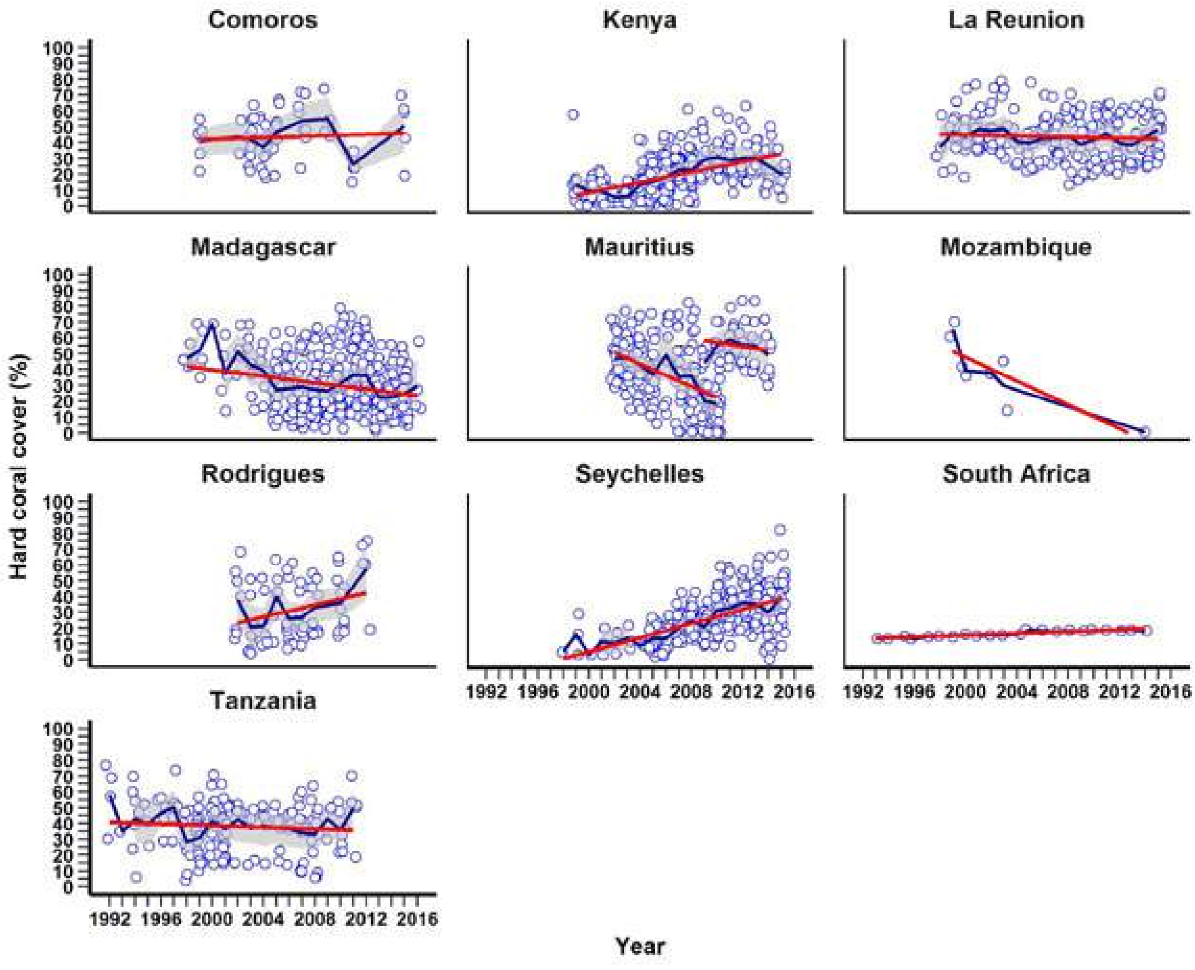


Figure 1.2.3. Hard coral cover by country for all years of monitoring (excluding sites with < 4 years of data). Individual site records (blue circles), the mean and 95% confidence interval (dark blue line and grey shading) and linear regression (red line) are shown. Due to discontinuities in data collection, Mauritius data is separated into Rodrigues and two sets of sampling on Mauritius Island (see Mauritius chapter for details). Additional filtering criteria to reduce outliers due to varying sampling protocols includes exclusion of Seychelles pre-1998 bleaching data, Tanzania 2015 data and Kenya 2016 data.

Three groups of countries are apparent, considering trends in the post-bleaching period from 1999 to the present:

- **Increasing coral cover** is shown strongly for the Seychelles and Kenya, both undergoing significant recovery of coral communities from 1998 to 2015. The line for Rodrigues is ambivalent: a slow increase is apparent in sites reported up to about 2010, but the omission of low-cover sites in the last year of monitoring imposes a larger increase that is misleading. Hard coral cover has increased over the last 25 years in South Africa, perhaps due to slight warming from colder conditions considered marginal for hard corals, and thus improving conditions for coral growth (Celliers and Schleyer 2002, Porter and Schleyer 2017).

- **No overall change in coral cover** is shown for Comoros, Reunion and Tanzania, though there is clearly high variation around the mean in each year in all three countries, and both increases and decreases across subsets of time during the monitoring period. For Comoros and Tanzania, inconsistency in sites being monitoring is apparent (e.g. in 2009 in the former, and 2002-2007 in the latter). Reunion has the most consistent dataset with 14 sites monitored annually throughout the period, with only one missing site-by-year combination.

- **Declining coral cover** is shown in Madagascar, Mauritius and Mozambique, though the dataset in Mozambique is too sparse to draw firm conclusions. Recent monitoring and reef assessments in coral reefs in the north of Mozambique do not have sufficient years of data, so have been excluded. In Mauritius, two lines are shown to distinguish two different sets of data, with each of these showing a decline. Madagascar has a data set that is very geographically dispersed, with initially a strong decline in the early 2000s, slight increase in coral cover from 2008-2010 then a sudden drop likely due to bleaching in 2010 and recovery since – but the linear trend is an overall decline.

Across all countries, the 1999 – 2015 period displays overall stability of coral cover with some reefs and countries improving, and others declining. This period of stability is sandwiched between the pre-1998 period of healthier reef condition (but not shown well in the included datasets) and the post-2016 period, when a significant decline in some countries occurred due to widespread bleaching in 2016 (see section 1.3). Unfortunately, with reduced effort in coral reef monitoring in the last 3-5 years, only a few countries were able to repeat monitoring of reefs in 2016 to document coral cover in a way that could be included in these long-term time series.

The high coral cover in countries that started coral reef monitoring after 1998 may reflect biased selection of sites that did not suffer high mortality, as new monitoring programmes tend to preferentially select 'good' reefs to track future trends, rather than a random or stratified selection of sites that would include some low-condition reefs. High-cover reefs may stay stable or suffer a decline in coral cover, resulting in a net negative trend. By contrast, reefs that suffered high mortality in 1998 might either remain in a poor state, or show recovery, which may vary from low to high. Thus, the early years of data (1999-2005) in this monitoring series may overstate the level of coral cover, and the latter years may under-represent recovery from a low state.

1.2.3 Fleshy algae

Algae data were not reported from all countries, but an overall comparison with coral cover is possible (fig. 1.2.4). Here, fleshy algae combines turf and filamentous algae, macro-algae and calcareous algae or *Halimeda*. However, different monitoring programmes recorded algal cover quite differently, so caution is necessary in interpreting combined results. The general decline in coral cover spanning the 1998 bleaching event, from the early 1990s to about 2001 is mirrored by a clear increase in fleshy algae from 1994 to 2000/2001 (fig. 1.2.4). After 2001, algal cover remains high across the region, at a similar level to coral cover.

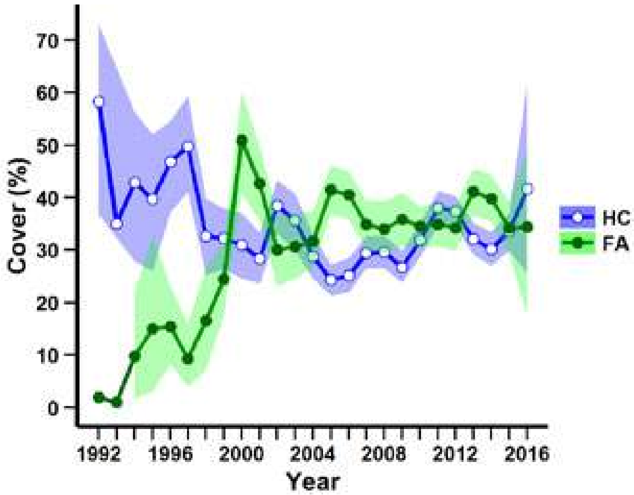


Figure 1.2.4. Regional averages of Hard coral and fleshy algae cover using countries where algal cover was collected (mean and 95% confidence interval). Excludes monitoring stations with < 4 years of data.




Plate. Algal competition with corals following coral mortality from various causes. Upper row - heavily grazed eroding surfaces with thin turf and coralline algae. Lower row - growth of fleshy-algae competing with corals. Photo credit: lower right - Pierre Perries, other images - David Obura.

Lowest levels of fleshy algae were reported from Mauritius, Seychelles and Tanzania (fig. 1.2.5). Highest levels of fleshy algae were found in Kenya, Reunion and Madagascar. In Madagascar (2004) and Kenya (1998) a sharp increase in fleshy algal cover is shown – in the latter certainly due to coral mortality and invasion by algae occupying the newly available space. In general, fleshy algae shows an inverse response to changes in coral cover, increasing where coral cover declines, and in some cases, decreasing progressively as coral cover recovers – such as in Kenya, Mauritius and Tanzania. In the Seychelles, fleshy algae cover has remained low irrespective of coral cover levels.

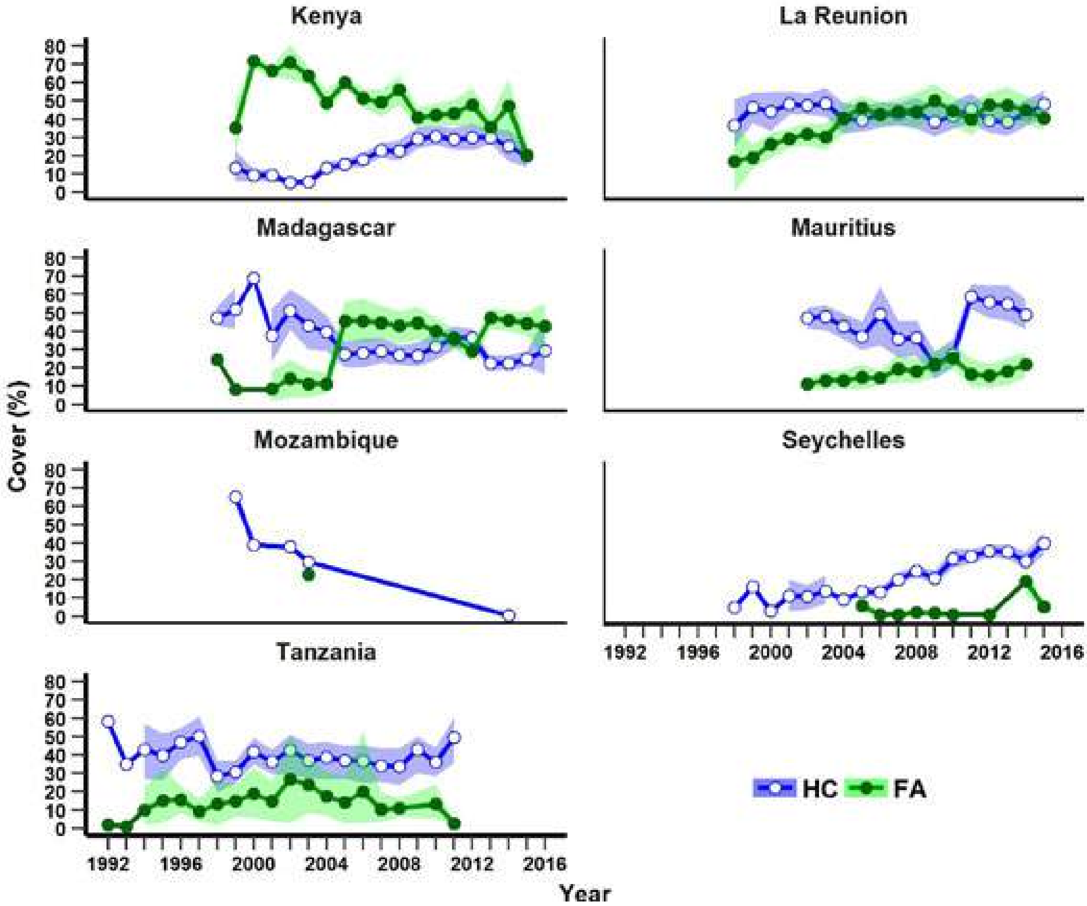


Figure 1.2.5. Hard coral and fleshy algae cover in countries where algal cover was collected (mean and 95% confidence interval). Excludes monitoring stations with < 4 years of data.

1.2.4 Coral/algal interactions

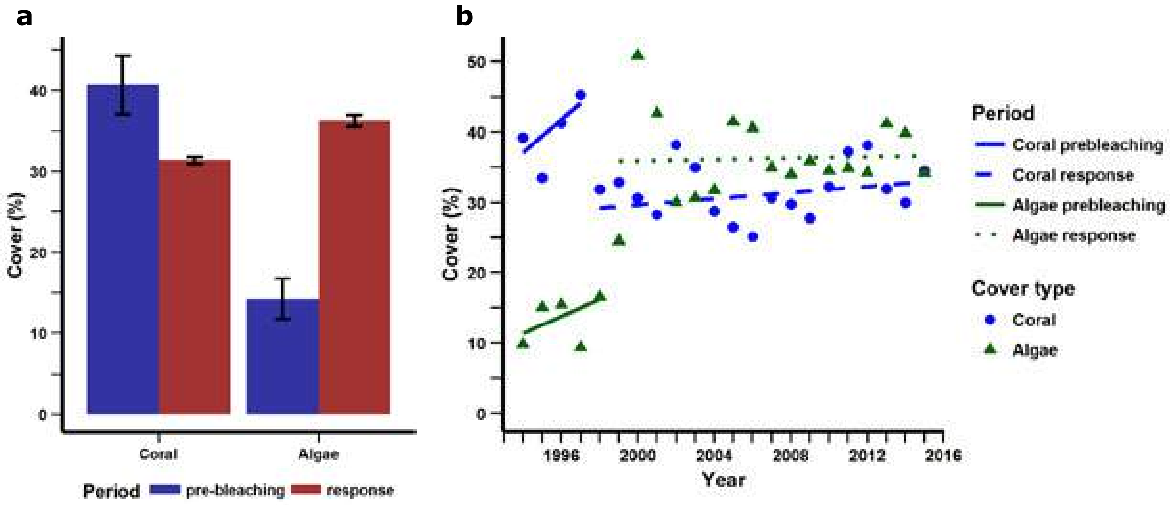


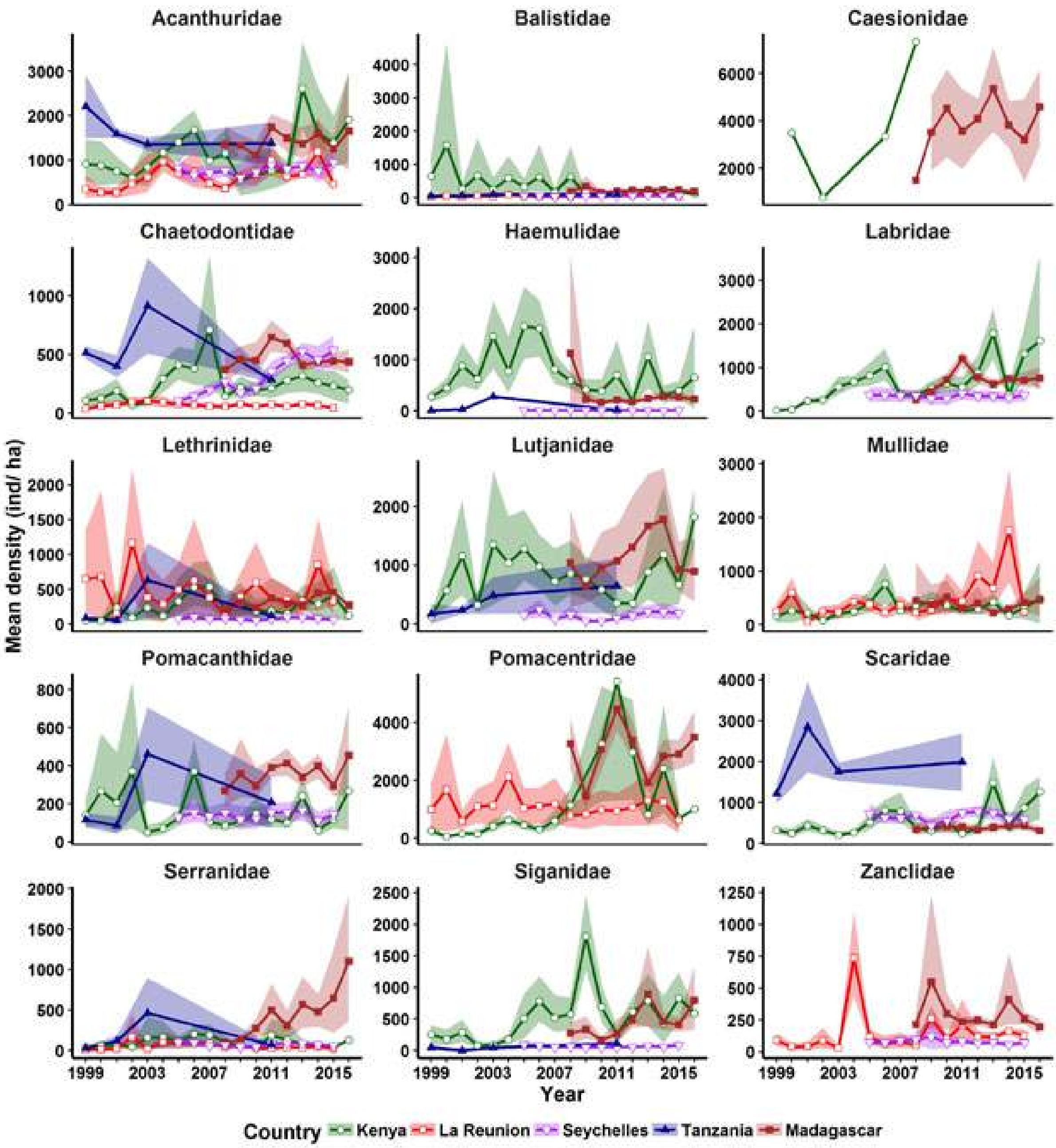
Figure 1.2.6. Hard coral and fleshy algae cover for pre-bleaching and post-bleaching (response) years: a) mean and standard error of all sites, and b) scatterplot with linear trend lines for each category. Data from 1992 and 1993 are from very few sites (6 for corals, 2 for algae), so are not included. For corals, pre-bleaching data is from 1994-7 and 'response' data is from 1998-2015; for fleshy algae, pre-bleaching data is from 1994-98 and 'response' data is from 1999-2015. Only stations with 4 or more years of data are included in the analysis.

Coral cover was high from 1994-97 at 40.7±3.6 % (mean ± se), and fleshy algae was at 14.2±2.5 % between 1994-1998. With bleaching and mortality in 1998, coral cover declined immediately with a subsequent slow increase, but average cover from 1998-2015 was 31.3±0.4 %. The response in the cover of fleshy algae lagged by one year, increasing to 25% in 1999 and then 50% in 2000. From 1999-2015, fleshy algae cover remained the same, at 36.3±0.7 %.

These results indicate that the immediate loss of coral was in the order of 30% from 1997 to 1998, but over the 20-year average from 1999-2015 was 25% below pre-bleaching levels. The increase in algae lagged by a year and was greater in magnitude, increasing by 3.5 times from 1998 to 2000, and by over 2.5 times over the long term from 1999-2015 compared to 1994-98. Both coral and fleshy algal cover have remained essentially the same in the post-bleaching period.

1.2.5 Fish

a - density



b - biomass

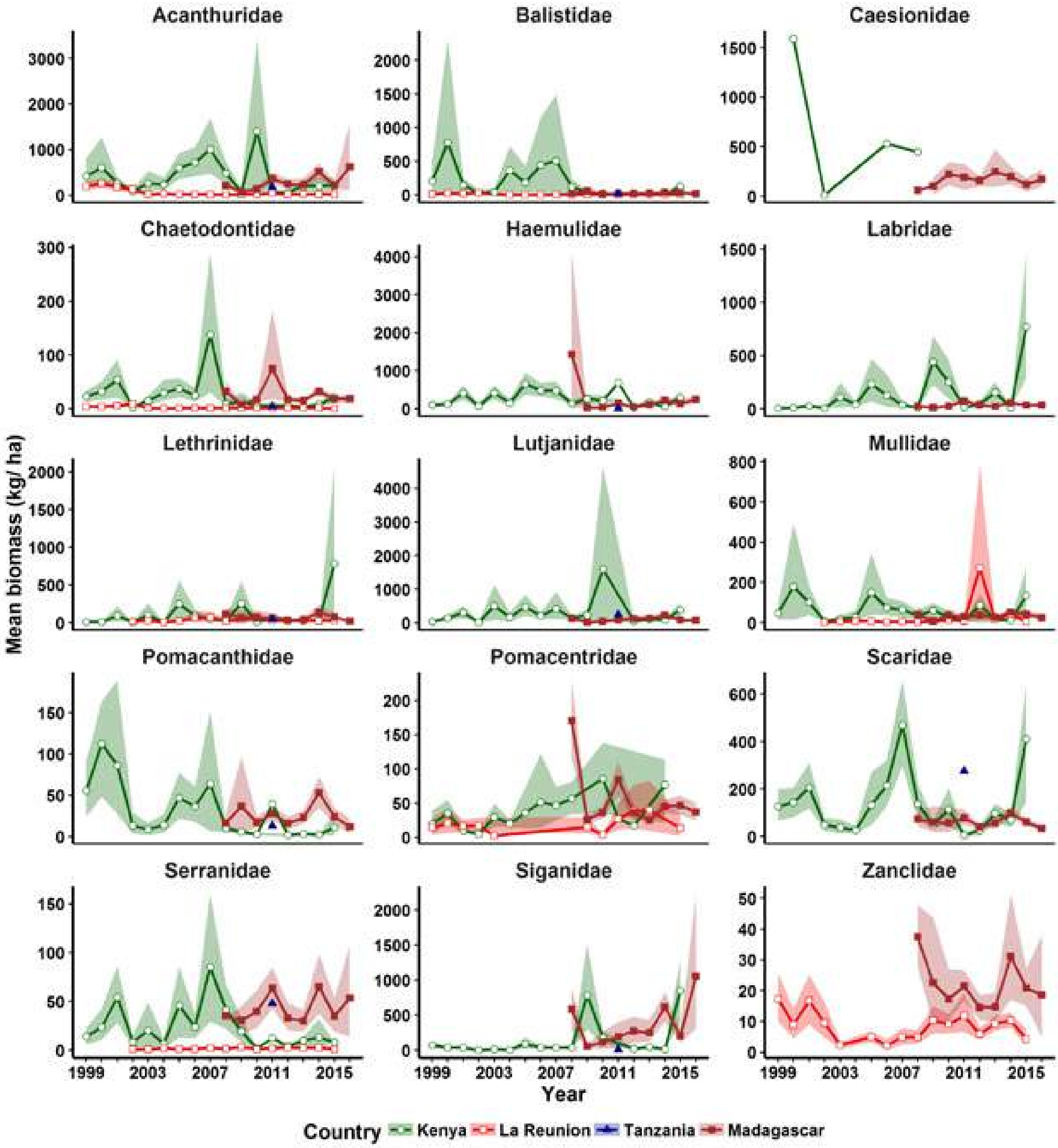


Figure 1.2.7. a) Density (individuals per ha) and b) biomass (kg per ha) of fish greater than 5 cm total length, by family. Only sites with 4 or more years of data are included, restricting the figure to 5 countries. Shaded coloured areas represent the 95% confidence interval for each country.

There are large gaps in the fish datasets, making it impossible to do a full regional analysis. Not all countries measured fish, the focal taxa varied considerably even within target families of fish, methods varied and there have been large gaps in monitoring in some countries. We therefore present results in aggregate form, by family and functional group.

Five countries had sufficient data to compare densities of fish (fig. 1.2.7): Kenya, Madagascar, Reunion, Seychelles and Tanzania, but only four, excluding Seychelles, to compare biomass. High variation in fish density and biomass are evident across countries and for several families. Within countries, some show large fluctuations between years, in some cases of over 3-5 times and more. This variation in methods exacerbates the very high variability that is inherent in underwater visual census of fish (Samoilys and Carlos 2000), limiting the conclusions that can be made.

The families recorded can be grouped into four functional groups, noting that this ignores some minor variance in feeding strategy in some of the families: herbivores and detritivores (Acanthuridae, Siganidae), piscivores and omnivores (Serranidae, Lethrinidae), invertivores (Balistidae, Pomacanthidae) and corallivores (Chaetodontidae). Aggregating across the four countries with biomass data shows that herbivores and detritivores were dominant over the other functional groups (fig. 1.2.8a-d) and increased in abundance (density) and biomass over the time period. Piscivores & omnivores and corallivores showed an increase in abundance but stable biomass, while invertivores had stable abundance but declining biomass. The increase in corallivore abundance occurred from about 2003 to 2006, likely reflecting recovery of corals following the 1998 mass mortality event, and then fluctuating numbers since then. The dominance of herbivores & detritivores is shown more strongly by comparing their abundance and biomass against the other functional groups combined (fig. 1.2.8e, f), where they show a larger increase in abundance, and an increase in biomass whereas the biomass of the other groups combined declined. The trend lines in fig. 1.2.8 are shown to be indicative of long term changes, though high natural variation in fish counts, and variation in methods cautions against statistical analysis.

A number of conjectures are suggested by this broad-brush analysis across four countries.

Herbivores and detritivores – the increase in density and relative abundance of herbivores and detritivores (Acanthuridae, Siganidae) is indicative of a number of potential drivers: a) the increasing role of algae following mass mortality of corals and increases in turf and fleshy algae documented in some countries (see sections 1.2.3 and1.2.4 above), b) potential impact of fisheries on higher trophic levels.

Piscivores, omnivores and invertivores – grouped together, their overall abundance is increasing, but biomass is declining. This suggests that fishing pressure may be high and at threshold level, with an effect of decreasing the size class of individuals.

Corallivores – the increase in abundance from 2003-2006, and stability since then, is indicative of recovery in coral communities following the bleaching event in 1998, and gives some comfort in the ability of biodiversity associated with corals to recover relatively rapidly after a major bleaching event.

Sizes - the differential between increases in abundance and smaller or negative changes in biomass is indicative of greater relative abundance of smaller fish compared to larger fish.

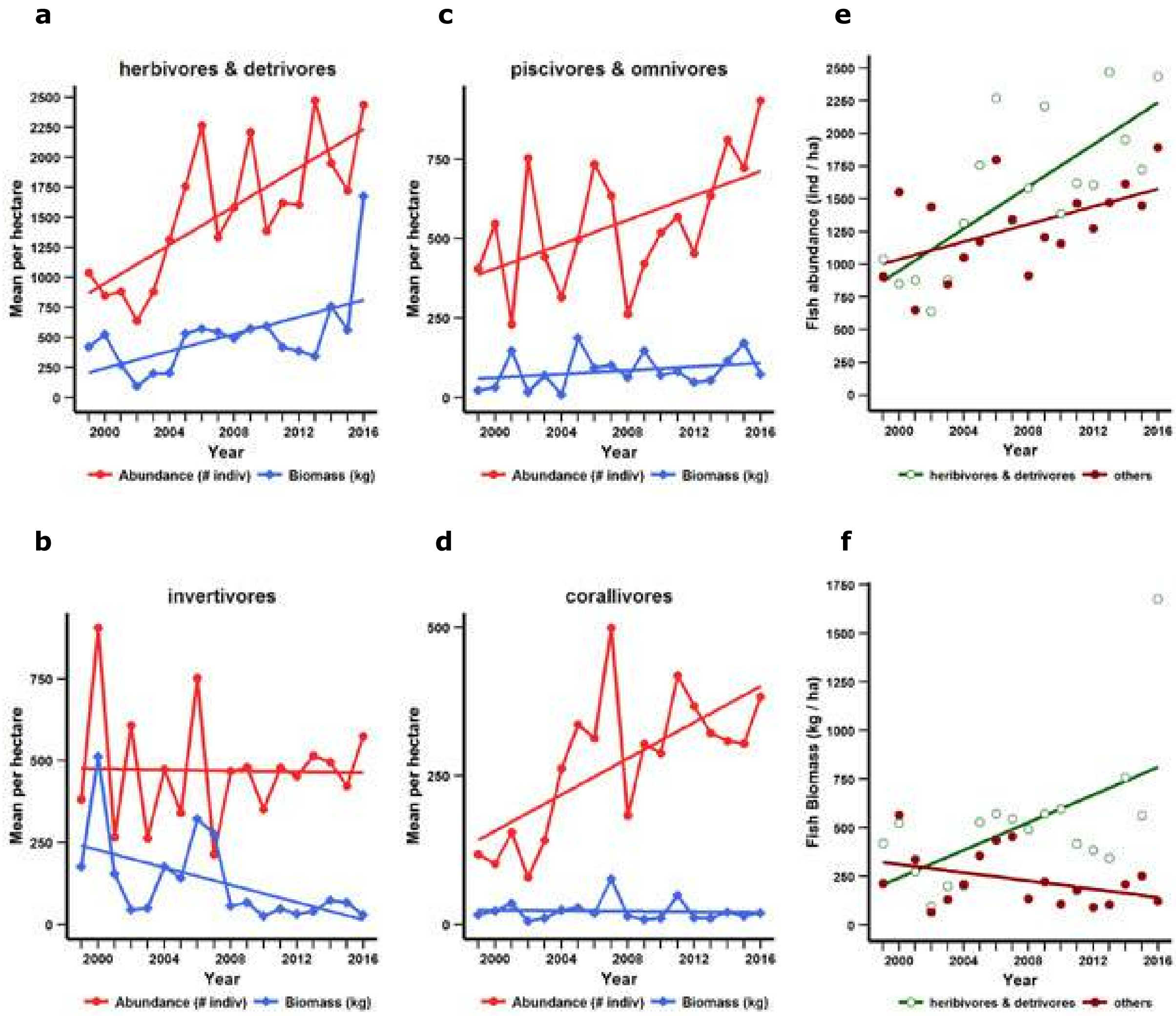


Figure 1.2.8. Density (individuals per ha) and biomass (kg per ha) of the functional groups of fish: a) herbivores & detritivores (Acanthuridae, Siganidae), b) invertivores (Balistidae, Pomacanthidae), c) piscivores & omnivores (Serranidae, Lethrinidae), and d) corallivores (Chaetodontidae) across four countries (Kenya, Madagascar, Reunion and Tanzania). Comparison of herbivores and detritivores versus other functional groups combined are shown for e) abundance (individuals per ha) and f) biomass (kg per ha). Trend lines are shown to illustrate change across all years. Only stations with 4 or more years of data are included.

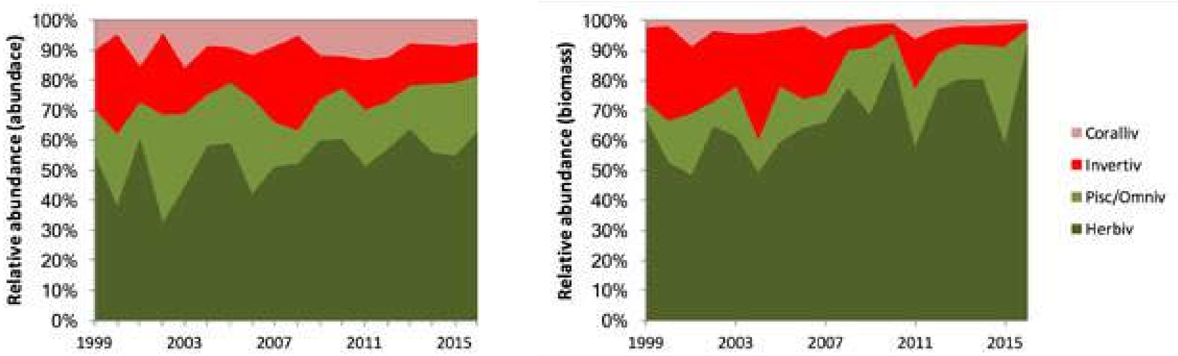


Figure 1.2.9. Relative abundance of fish functional groups by abundance (left) and biomass (right).

Plate. School of mixed herbivores - rabbitfish (siganids), parrotfish (scarids) and surgeonfish (acanthurids), St. Brandons Island, Mauritius. Photo credit - David Obura.

When fluctuation between years in abundance and density is excluded by comparing the relative abundance and biomass of functional groups (fig. 1.2.9), the increasing dominance of herbivores & detritivores is preserved. Across all the groups surveyed, it appears that the role of herbivory in the reef system, both from an energy/supply perspective (greater energy supplied through algae) and top-down perspective (greater relative abundance and dominance of herbivores), is increasing. And that this is occurring under overall fishing levels that may be driving down the size of fish – research from Kenya has demonstrated simplification of the fishery dynamics of reefs there, illustrated by increased dominance of just 2-3 fish species (two herbivores and one omnivore) in the catch of multiple gear types, over the same time period (Samoilys et al. 2017).

1.2.6 Summary of results

The benthic data suggest that across the WIO region, coral cover declined by about 25% (from ≈40 to 30%, fig. 1.2.6) from pre-1998 to 1999-2015 time periods. This loss represents an immediate loss following the 1998 bleaching event, as from 1999-2015 there has been no substantial increase or decrease in overall coral cover. A bigger change occurred in the algal community, increasing by about 2.5 times (from ≈15 to 35%), also instantaneously after the 1998 bleaching event, with little overall change from 1999 to 2015. This regional stability hides a great deal of variation at the site and country levels, with patterns of increasing, stable and decreasing coral cover across sites and countries. This complementary step-change in hard coral and algal cover highlights the significance of major bleaching events, and corroborates the expectations for phase shifts between coral- and algal-dominated reef states (Hughes et al. 2003, Mumby 2006).

Following this, the outcome of the 2016 bleaching event may be significant (see section 1.3). The higher levels of algal cover now compared to before 1998 may impede coral recruitment and recovery to a greater extent than occurred after 1998, an example of the ratchet effect along the pathway from coral- to algal-dominated reefs. The question is what will it mean if regional average coral cover drops to 25% and below, while regional average algal cover increases towards 50% and above (see fig. 1.2.6)? Will this still represent a 'coral reef' in a coral-dominated state, or be closer in function to an algae-dominated reef? The 1998-2015 reef state may represent a boundary condition of a coral-dominated phase near the edge of resilience, from which a major impact may tip it into a state dominated by algae or other invertebrates.

The fish community has also shown a significant change. Presumably before the 1998 bleaching (and certainly before the advent of heavy fishing pressure over previous decades), it was likely in a 'more diverse predator-dominated state' (Sandin et al. 2012, Graham et al. 2016) with more balanced food webs. Now, it has shifted to strong dominance by herbivores and detritivores, and increasingly, by smaller-bodied individuals of these groups. Analogous to the benthic community having been shifted to the edge of a coral-dominated state, the fish communities might have been shifted from more complex trophic dynamics to a simpler food web in which herbivory by small individuals is a more dominant process. Pristine coral-dominated habitats may not have supported such an imbalance towards herbivory that is now enabled by high algal biomass.

If the role of herbivory and herbivorous fish in the region is increasing, this emphasizes the need to understand how best to manage herbivores. This is because a simplification in reef dynamics and greater dominance of one process may make reefs vulnerable to sudden shifts. This is particularly true if herbivores in turn become depleted through high fishing pressure, causing one or a few herbivore functional groups or species within these groups to become dominant, eroding functional redundancy and increasing the possibility of unforeseen large impacts from even small changes in the remaining species populations (Bellwood et al. 2003). Further, an additional decline in coral cover (e.g. from a bleaching event such as in 2016), and/or fertilization of algal growth through eutrophication, may result in further increase in algal cover, inhibition of coral recovery and stimulation of herbivore populations through greater food provision. Thus the role of herbivores and the need to understand how their dominant status may control reef dynamics increases in importance. However, these findings are correlative and across a broad geographical range. The details of interactions likely vary greatly by location, and need to be developed through research.

Plate. Reefs then (left) and now (right). In the past, coral cover was higher, algae cover low, and fish diverse and abundant. Now, coral cover is lower, algal cover is equal to coral and increasing, and fish populations are low.

A significant increase in national commitments to coral reef management and shifting drivers to promote coral growth, reducing drivers of algal growth and actively managing fisheries to ensure ecological balance will be essential to reverse the progression demonstrated here of a step-decline in reef health following mass bleaching. The coral bleaching event in 2016 now provides a test case, a strong incentive, and an opportunity to meet this challenge. The good news is that factors related to these drivers can be managed actively – managing nutrient and other forms of pollution (bottom-up controls on algae and corals) and fishing (top-down controls on fish, and thereby on algae). However, the window of opportunity to maximize reef health before future threats reach critical levels, particularly of warming due to climate change, is narrow (see section 1.4) but real, and the prominence of coral reefs in global Conventions (Aichi Target 10 of the Convention on Biological Diversity) and for achieving the Sustainable Development Goals (cf. Oceans Conference on SDG 14 in June 2017 in New York) provide the motivation for increasing management to needed levels.

Lastly, the importance of securing and sharing data is highlighted by this report. The power of the results could have been greatly improved if data from early years had not been lost in some cases, data that have previously been part of this long term reporting process had not been with-held, and data that exist in the literature and from past projects were available for this process. Greater effort to compile all existing datasets is still needed, and for this compilation to be secured and sustained for consistent access in the future. With increasing recognition of the dire situation affecting reefs globally, all data collection processes can play a role in improving the provision of information for management and decision makers at all levels. At the same time data sources are proliferating, and the value of single datasets in isolation (e.g. for scientific publications) is diminishing while their value as part of larger compilations (e.g. in national and global assessments, and meta-analyses) is growing. Developing appropriate databases and protocols, identifying appropriate levels of data for sharing, securing attribution of data ownership (to data collectors, management agencies, countries) and developing time standards for providing access can all contribute to improve the sharing and use of data.

1.2.7 Recommendations

The health of coral reefs requires active management and interventions as pressures increase from extraction, pollution and local population growth, and global drivers such as climate change and markets. The results suggest the following:

- coral health has remained stable at the regional level from 1999 to 2015, which is indicative of recovery of some reefs since 1998, and degradation of others. Overall, this represents a step-decline from pre-1998 heath levels, of 25%. Management of reefs across the region should recognize this explicitly, and include an explicit restoration/rehabilitation consideration for all managed reefs;
- the second largest bleaching event in the WIO occurred in 2016, and this potentially means a second step-decline in reef health regionally. It is imperative to put in place even stronger management measures than in the 1999-2015 period to maximize recovery, and a greater focus on restoration/rehabilitation that is effective at scale. Additionally, given the unavoidable decline in coral cover and increase in algal cover these events entail, to adopt management goals and targets based on reversing these trends when/if they occur;
- key management interventions may include:
  - focus on restoration/rehabilitation as components of all reef and resource management plans, considering potential actions across all zones/habitats within the ambit of the plan;
  - manage fisheries with some of the following considerations: maintain taxon and functional group diversity within herbivore functional groups, reduce pressures on piscivore, omnivore and invertivore functional groups to enable their recovery to higher biomass levels, consider size-selective regulations to promote recovery of large fish sizes;
  - manage bottom-up factors that promote algal growth, including nutrient and other pollution, direct disturbance and other threats that cause coral mortality and increased algal cover, etc
  - develop more quantitative targets for management interventions, such as abundance/biomass thresholds as indicators of reef function (e.g. McClanahan et al. 2013); incorporation of algal cover thresholds as rapid indicators of recovery ability of coral communities, etc.

Support and stability for monitoring programmes is essential, requiring action on the following components:

- monitor the first post-bleaching year (2017) to determine initial impact of the event;
- all monitoring programmes should build their capacity to collect fish data alongside benthic data, following standard protocols;
- objective selection and continuity of sites – the sites that should be part of long term monitoring programmes need to be identified on appropriate criteria, and then maintained over the long term, to avoid bias in datasets, and arbitrary addition/termination of sites. An immediate task for contributors to this report is to confirm their priority sites from previous years, identify gaps that need to be filled, and ensure ongoing commitment to long term sites;

- the frequency of monitoring, whether annual, or sub-annual (e.g. every 3 years) should be as regular as possible;
- methods for monitoring, including identification, need to be stable over time. They can be enhanced and improved, but teams must ensure that continuity of the basic variables, such as hard coral cover, is maintained with historical records;
- archiving and sharing of data. Standards and practices for securing data and sharing it for scientific, management and/or national objectives should be established and implemented to provide the best dataset possible to inform understanding, assessments and decision-making at multiple levels. Standards for open access to data, and sharing of data into global databases should be developed, to maximize exposure of coral reefs from the region in the global context for funding and protecting reefs and the benefits they provide.

Networking of coral reef monitoring programmes within and between countries:

- is an essential support mechanism for local to national monitoring, including for capacity building, data security and reporting, and should be supported whenever possible through opportunities that emerge from various organizations, projects and donors;
- strengthening of the regional reef networks, revitalization of the regional Coral Reef Task Force and alignment and engagement with the Global Coral Reef Monitoring Network should continue.

1.3 The 2016 coral bleaching event in the Western Indian Ocean – overview

Authors: *Mishal Gudka and David Obura*

1.3.1 Introduction

When corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues (zooxanthellae), causing them to lose their colour and in some cases turn completely white (fig. 1.3.1). The severity of bleaching varies and if corals become very stressed and weakened as a result of inadequate supply of energy from zooxanthellae, they become more susceptible to diseases and mortality.

One factor causes widespread bleaching that can affect entire regions, increase in Sea Surface Temperature (SST) above long-term maxima. A 1-2°C increase that persists for several weeks is enough to cause bleaching. If the stress caused by bleaching is not severe, the coral will recover. However, if the stress is severe and algal loss is prolonged, the coral eventually dies. Coral bleaching brought on by climate change coupled with events such as the El Niño Southern Oscillation is widely seen as the largest and most pervasive threat to coral reefs around the world. As global temperatures continue to rise due to climate change, the frequency of mass coral bleaching events is increasing.

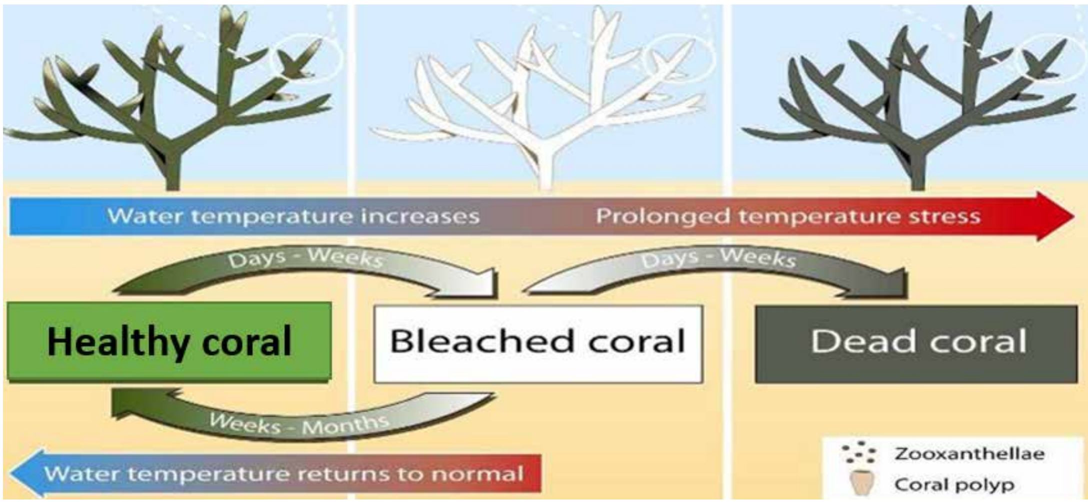


Figure 1.3.1 Stages of coral bleaching. (Source Marshall, P. and Schuttenberg, H. 2006. A Reef Manager's Guide to Coral Bleaching. GBRMPA, Australia).

The Western Indian Ocean (WIO) has already experienced an extreme bleaching event in 1998, as well as less severe events in 1983, 2005, 2007 and 2010. The 1998 bleaching event occurred as a result of abnormally high summer temperatures, combined with strong positive phases of the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), which led to extreme sea water temperatures. The event caused extensive bleaching of about 90% of corals in the Seychelles and more than 50% in many other locations. As a consequence, coral mortality varied between 50-80% at a site level, and accounted for a total loss of 16% of healthy reefs in the region (Wilkinson 2000).

In October 2015, the National Oceanic and Atmospheric Administration (NOAA) declared the current event, which began in the North Pacific in summer 2014, as the third global coral bleaching event after those in 1998 and 2010[3].

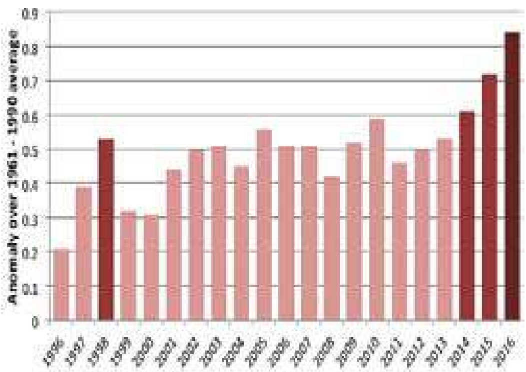
1.3.2 The 2016 event

The last three years have been among the hottest ever recorded globally, with each successive year outdoing the record set in the previous one (fig. 1.3.2a). Both the Indian Ocean Dipole and El Niño indices (fig. 2, right) were positive at the end of 2015 and into 2016, though the IOD was declining at the time that bleaching started in the WIO in January-February. In late 2015, the El Niño index exceeded the previous record of 3.0 set in 1997-98. The combination of record hot conditions for 2014-2016 and the in-phase high positive values for both Pacific and Indian Ocean dipoles, made for very high bleaching risk in the WIO. This continued the strong bleaching conditions already reported for the Caribbean and Pacific in 2015, and co-occurring in the Great Barrier Reef in 2016.

3 http://www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coral-bleaching-event.html. Accessed 20 November 2016.

Affiliation: *CORDIO East Africa.*
Contributors & acknowledgements: *we would like to acknowledge Tammy Holter (Scuba-Do Diving, Zanzibar) and Ulli Kloiber (Chumbe Island Coral Park) for developing the online reporting form for coral bleaching for the Western Indian Ocean. The full list of contributors to this online form is listed in section 1.3.7.*

a



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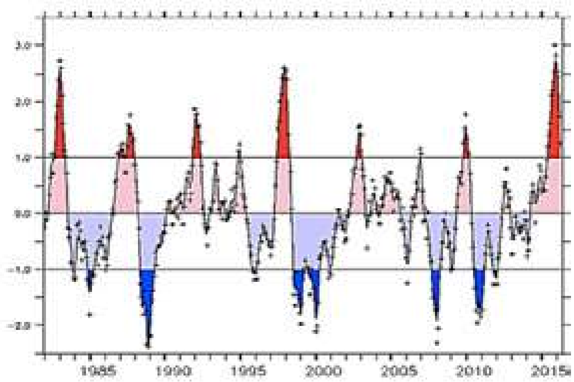
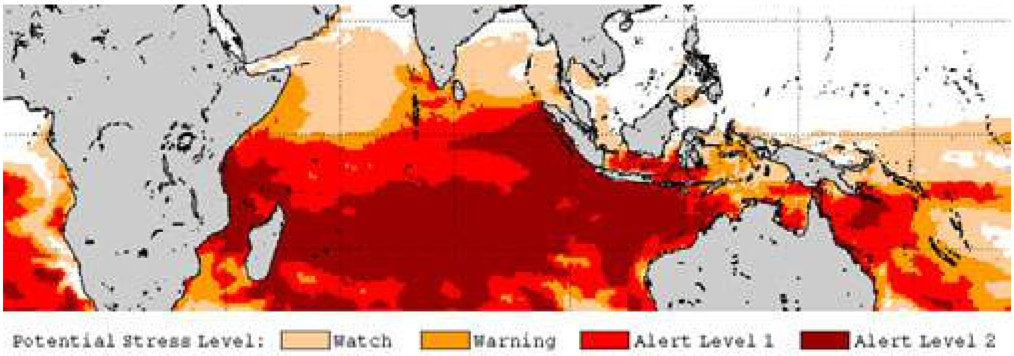


1.3.3 The regional response towards bleaching

With the high level of bleaching forecast, and ongoing coordination of coral reef monitoring and reporting in the WIO, the Indian Ocean Commissions' Biodiversity Project supported a regional response plan for the bleaching event (Table 1):

Table 1.3.1. Regional bleaching response plan elements



Element	Explanation
Mobilization of experts/ coordinators	Six country and three regional experts (IOC, CORDIO East Africa and MAREX, Reunion), were mobilized for the technical facilitation and implementation of the plan. The national experts coordinated compilation of regional monitoring data and alignment of bleaching responses, while the regional experts led with capacity building, regional alerts and compilation of bleaching data.
Capacity building	Two training workshops in bleaching assessments and monitoring were undertaken. 1) Grande Comores (April 2016 by MAREX) for 12 technicians from Comoros, Madagascar and Mauritius. Coral bleaching monitoring strategies were prepared for Comoros and Madagascar. 2) Zanzibar (May 2016, by IOC, CORDIO), regional Coral Reef Task Force workshop, with 22 participants from across the WIO. In addition small grants were provided to local NGO's to conduct and report assessments as case studies for the region, in Tulear, Madagascar (Young Researchers Organisation) and Rodrigues (Shoals Rodrigues).

WIO Coral Bleaching Monitoring Guide	Published in 2016 by the IOC and CORDIO in English and French. It is a quick guide to bleaching observation methods for the Western Indian Ocean, and contains a standardized methodology at three different detail levels - basic, intermediate & high (http://commissionoceanindien.org/fileadmin/resources/images/biodiversite/publications/Biodiversity-coralbleaching1.pdf and http://cordioea.net/bleaching_resilience/wio-bleaching-2016/)
Coordination and Awareness creation	a) Training material disseminated online through the Reef Resilience Network Forum b) Held a sensitization conference at the University of Comoros on bleaching ecological and socio-political issues. c) A detailed bleaching assessment with bleaching mapping based on satellite images was conducted for Mozambique channel islands and Reunion with the involvement of several local scientists, managers, and national institutions[4]
WIO Coral Bleaching Alert	Since 2007, CORDIO has been preparing and disseminating regional bleaching alerts to various partners during the local 'summer' (Jan – May) each year. In 2016, an alert was sent out every two weeks to partners across the region, informing them about the latest climatic and bleaching developments.
Indian Ocean Online Bleaching Reporting Form	CORDIO EA created an online bleaching form in collaboration with partners in Tanzania[5] to provide a simple tool where basic level bleaching observations could be reported throughout the region in a consistent manner (http://bit.ly/2kCktuw http://cordioea.net/bleaching_resilience/wio-bleaching-2016/).
Bleaching Observations 2016	Bleaching data collected from various partners across the region was managed and compiled, and the data was displayed on a map on the CORDIO EA website at http://cordioea.net/bleaching_resilience/io-coral-bleaching-alert/.

4 BECOMING Programme (Blanchissement Corallien dans le Sud-Ouest de l'océan Indien) : Project BECOMING 2016. MAREX/Institut de Recherche et de Développement/Université de La Réunion/Agence des Aires Marines Protégées/Parc Naturel Marin de Mayotte/Parc Naturel Marin des Glorieuses/Terres Australes et Antarctiques Françaises/Réserve Naturelle Marine de La Réunion/Réserve National Naturelle de Bouzi/DEAL Réunion/Union Européenne/Initiative Française pour Les Récifs Coralliens

5 *Scuba-Do Diving and Chumbe Island Coral Park.

Plate left. Bleaching Assessment in Fumba, Zanzibar (May 2016) Photo credit: Pierre Perrie; right. Bleached coral in St Leu Reunion (March 2016) Photo credit: Julien Wickel

A total of 699 observations were submitted online on the bleaching event, from 54 organisations and over 80 observers from seven different sectors (see section 1.3.7). The majority of contributors were from the NGO sector (27), and 329 observations were submitted by research programmes, with the majority of these coming from detailed studies in the BECOMING project (fig. 1.3.4). These results make it clear that monitoring and response observations need to be supported financially and by organizational structures, requiring investment and commitment of resources.

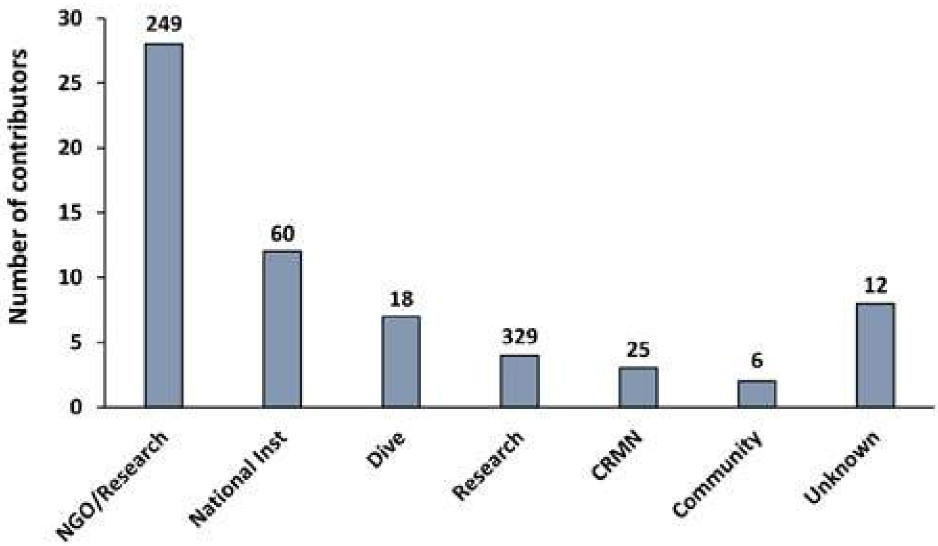


Figure 1.3.4. Number of contributors from each sector. CRMN - regional or national Coral Reef Monitoring Networks. Numbers above bars indicate the number of observations/records submitted by each group.

1.3.4 Results

Bleaching was first reported unusually early around the Comoros archipelago at the start of January 2016 (fig. 1.3.5). The frequency of reports of severe bleaching increased after the 20th of March with reports from SW Madagascar, the Mascarene Islands (Reunion, Mauritius, Rodrigues), Tanzania and Seychelles. Severe bleaching peaked in April (and see fig. 1.3.6a) with continued observations from the southern locations and increasing reports in northern Tanzania, Kenya and the Seychelles. Bleaching started to dissipate in May with lingering severe bleaching in Kenya and Seychelles, and in most locations bleaching ceased by June and July. The progression of bleaching and mortality by month (fig. 1.3.6) shows over 40% of sites experiencing high or extreme bleaching in April, and this translated into peak mortality of about 15% of sites showing high or extreme bleaching in June.

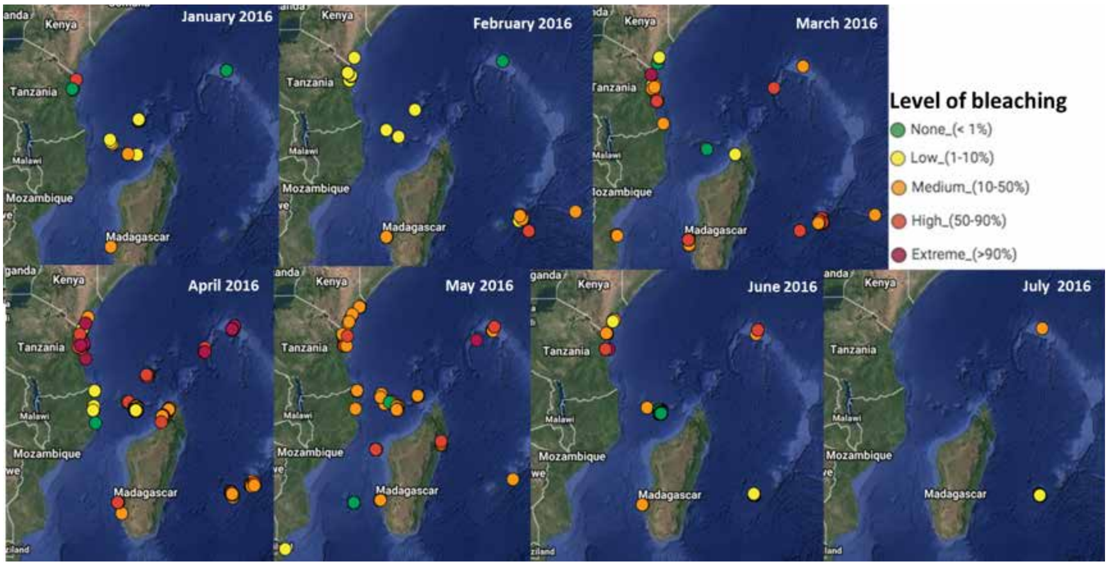


Figure 1.3.5. Monthly progression of bleaching reported by observers from around the WIO

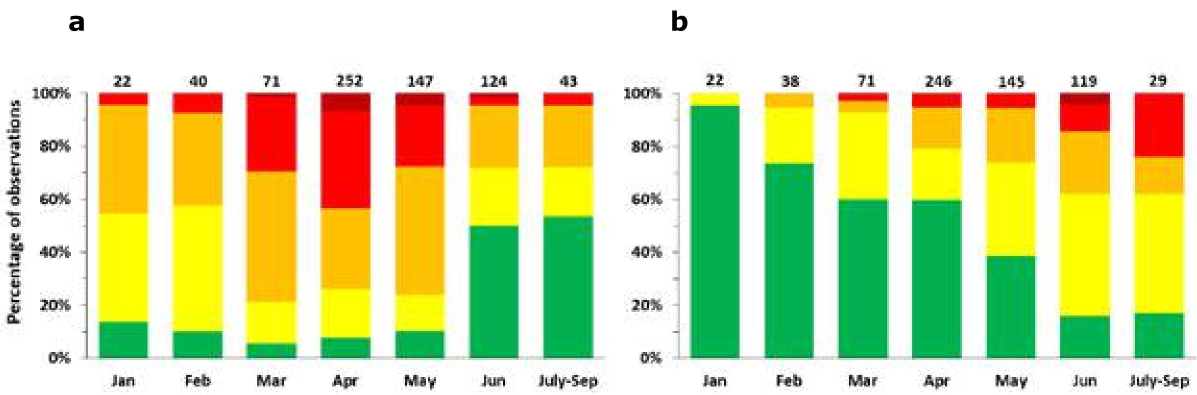


Figure 1.3.6. Monthly breakdown of 2016 WIO (a) bleaching and (b) mortality observations submitted online. Categories are estimates of percentage coral cover bleached at a site, and the columns show the proportion of reports in each category. Numbers above the columns indicate the number of reports in each month.

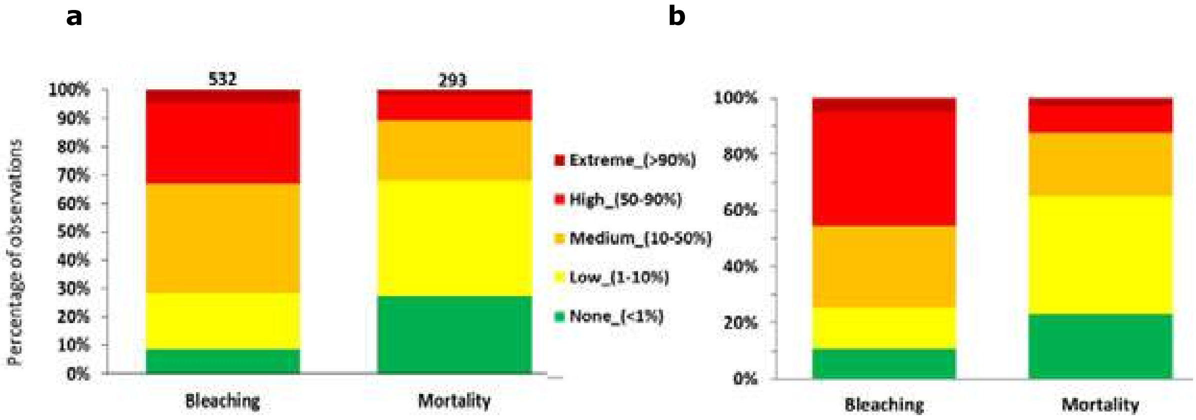


Figure 1.3.7. Overview of the total impact of the 2016 bleaching event in the WIO is shown by comparing the overall bleaching records up to the end of May, when bleaching had just passed its peak, to mortality from May onwards, when corals were either recovering or dying. a) all sites, and b) sites that were surveyed both during peak bleaching phase and re-surveyed during the post-bleaching phase (n=104). Categories are estimates of percentage coral cover bleached at a site, and the columns show the proportion of reports in each category. Numbers above the columns indicate the number of reports.

Between the months of January-May, just over 35% of reported sites were affected by severe bleaching (greater than 50% of the coral cover had bleached), and only 10% of sites were unaffected (fig 1.3.7a). However the high and extreme levels of bleaching did not translate into the same level of coral mortality later in the year (May-September), with less than 10% of sites reporting severe mortality. This pattern is the same for sites that were re-surveyed both during and after the bleaching event (fig. 1.3.7b). However, it is important to note that the region did not survive completely un-scathed with almost 80% of sites experiencing some mortality due to bleaching.

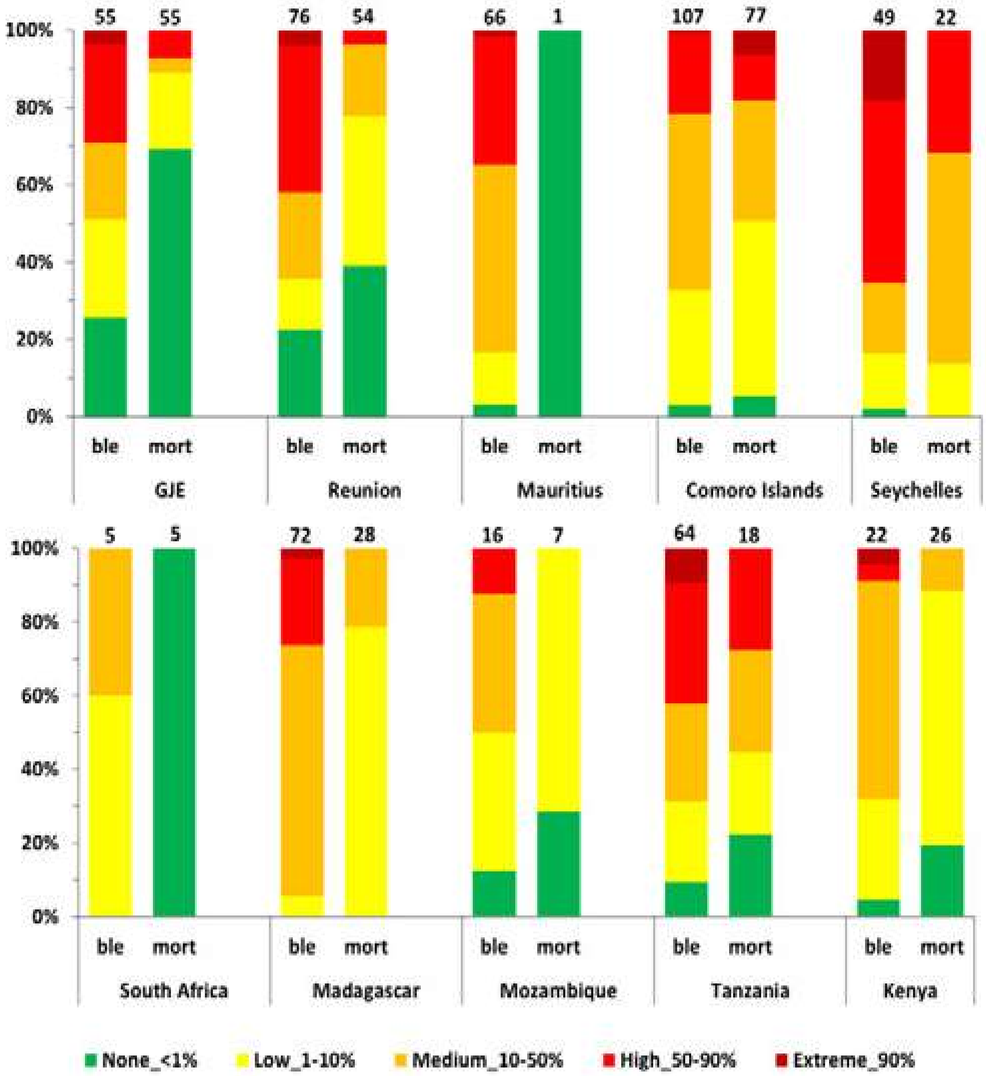


Figure 1.3.8. Breakdown of 2016 bleaching and mortality records for small islands (top) and mainland and Madagascar sites (bottom). Bleaching observations are from January-May, and mortality May-September. Categories are estimates of percentage coral cover bleached at a site, and the columns show the proportion of observations category. Numbers above the columns indicate the number of reports. GJE – Mozambique Channel islands- Glorieuses, Juan De Nova, and Europa islands.

Seychelles (fig. 1.3.8), was the most affected by bleaching with over 50% of reported sites showing high or extreme bleaching, and almost all sites showing some bleaching, along with Madagascar, Tanzania and Mauritius. In Madagascar (principally the SW) and islands in the Mozambique Channel and Reunion, about 30% of sites were reported with high or extreme bleaching. It is important to note that for all results, there is the possibility of an overestimation in the percentage of severe bleaching, due to a bias towards only reporting observations when bleaching occurred. As with the overall results, it is clear that the amount of severe bleaching reported for each country is much higher than the amount of severe mortality, indicating that coral recovered.

1.3.5 Discussion

On a global scale, the 2015-16 coral bleaching event is considered the longest event in history[6]. It has affected more reefs than any previous global bleaching event, including several reefs that have never bleached before e.g. the northernmost Great Barrier Reef. Although the WIO experienced widespread and severe bleaching consistent with that experienced in other regions, most of the region was spared the high coral mortality experienced in other parts of the world, as well as the devastating mortality caused by past events such as that of 1998.

There are several possible reasons that might explain why the majority of corals were able to recover from the bleaching they experienced, and as a result mortality was lower than expected in 2016:

- Sudden regional cooling from April onwards reducing duration of thermal stress – cyclone Fantala cooled waters north of the Mascarene islands in the southern Seychelles islands during April, and may have had a widespread effect;
- Acclimation by corals exposed to three progressively hotter years, starting in 2014;
- Adaptation and selection from the 1998 bleaching event and subsequent minor bleaching events;
- Loss of vulnerable genotypes and populations since 1998, leading to lower diversity but more resistant coral communities.

1.3.6 Recommendations

The following recommendations can be made, focused on network support, capacity building and knowledge generation:

Network support

1. increased participation in national and regional bleaching data collection should be prioritized, with a lead role played by the national Coral Reef Task Force (CRTF) coordinators;
2. bleaching observations should be reported online to broader national and regional contexts. The WIO bleaching resources at http://bit.ly/2kCktuw and http://cordioea.net/bleaching_resilience/io-coral-bleaching-alert/should continue to be maintained by CORDIO;
3. ensure that each country has at least one partner mandated and sufficiently prepared to carry out bleaching response plans where feasible;
4. ensure that the lessons learned from the 2016 event are used to inform and improve the planning and preparation for monitoring bleaching for the next event;
5. Formulate steps to improve involvement and capacity of national institutions to undertake bleaching response plans

6 http://www.noaa.gov/media-release/el-ni-o-prolongs-longest-global-coral-bleaching-event. Accessed 20 November 2016

Capacity building and key technical skills

6. Continue to organise and/or support training workshops aimed at building capacity for coral bleaching monitoring and assessment in preparation for the next event;
7. Increase capacity of national institutions, researchers and CRTF to identify coral at a genus level;
8. Hold training workshops for ground-truthing of remote sensing images, image analysis and GIS reporting.

Knowledge

9. Use remote sensing to map bleaching, especially in collaboration within the footprint of the SEAS-OI initiative (la Reunion) to provide satellite images for IOC member countries.
10. Organise and fund a resilience study to better understand the factors that affect reefs' ability to resist or survive and recover from bleaching;
11. Commission more research to study how bleaching impacts fish communities in the medium-term.

1.3.7 Data contributors

Organisation	Observers
African Impact	Connie, Celeste Alex Botha, Karin
Albion Fisheries Research Centre, Mauritius	Vikash Munbodhe
andBeyond	Mnemba Island Dive and Conservation Team
Arocha Kenya	Peter Musembi
BECOMING Project 2016	MAREX/Institut de Recherche et de Développement/Université de La Réunion/Agence des Aires Marines Protégées/Parc Naturel Marin de Mayotte/Parc Naturel Marin des Glorieuses/ Terres Australes et Antarctiques Françaises/ Réserve Naturelle Marine de La Réunion/Réserve Nationale Naturelle de Bouzi/DEAL Réunion/Union européenne (Xème FED régional océan Indien)/ Initiative Française pour Les Récifs Coralliens.
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IUCN	Joana Trindade
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Kenya Wildlife Service	Jillo Katello Wato
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Madagascar Coral Reef Network/IOC/ MAREX	Madagascar Coral Reef Network
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MAREX	Julien Wickel
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marinecultures.org	Christian Vaterlaus, Thomas Sacchi
Masoala Marine Park	Jean Baptiste Zavatra
Mauritian Wildlife Foundation	Reshad Jhangeer-Khan
Mauritius Oceanography Institute	Bacha Gian Suraj and others
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Reef Doctor	Apolline Mercier
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Sound Ocean Ltd	Jason Rubens
Tanga Coelacanth Marine Park	January Ndagala
Tanga Tourism Network Association	Sibylle Riedmiller

Organisation	Observers
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Ten Degrees South	Isobel Pring
UMAMA	Zamil Maanfou
UniLúrio	Isabel Marques da Silva
Universidade Federal do Rio de Janeiro	Linda Eggertsen
Vrije Universiteit Brussel (VUB)	Filip Huyghe
WCS Madagascar	Komeno Roberto
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Young reSearchers Organisation Madagascar	Danny Kornelio Ravelojaona
Other	Alan Sutton
	Alexandra Gigou
	Jan Robinson
	Patrick Harbeland
	Rob miller
	Whitney Goodell
	Yara Tibirica
	Youssouf Dahalani

1.4 Long term regional drivers and responses

Author: *David Obura*

1.4.1 Introduction and rationale

As mentioned in the introduction, sub-Saharan Africa, including the countries of the Western Indian Ocean is undergoing a population and economic boom in the first half of the 21st century that will undoubtedly transform the region economically and demographically. Sub-Saharan Africa will account for half the increase in global population between now and 2100 at a time when climate change is altering natural and agricultural ecosystems fundamentally. With the UN Agenda 2030 and its Sustainable Development Goals providing global targets for development for the first part of this century (box 1), we present an overview of some long term drivers that are already affecting coral reef health and will likely determine the outcome for reef health by the turn of the century.

The purpose of this section is to stimulate readers to think of the long term context that coral reefs will be experiencing in coming decades, to help frame planning and decisions around coral reef conservation and management, and to help identify how to meet the CBD Aichi Targets and SDG Targets relevant to coral reefs.

1.4.2 Drivers

1.4.2.1 Population

The total national populations of WIO countries adds up to 212 million (Table 1.4.1). Different totals were derived from spatial population layers to show the number of people directly impacting the coastal zone, via major drainage bases (134 million), those living in a coastal strip of 100 km (56 million) and those living in coastal administrative districts (54 million). The urban population in the coastal zone of the WIO is 19 million.

Population growth in eastern African countries remains relatively high (fig. 1.4.1a) and is projected to stay that way for several decades (Africa Economic Outlook 2016), resulting in a population increase of 50% from 2015 to 2030, the year the Sustainable Development Goals are to be met. By the end of the century, total population is projected to be 4 times higher than in 2015, at over 800 million people. Coastal populations generally grow at twice the national average (Neumann et al. 2015), and attraction of people to rivers and water sources also results in population growth in drainage basins. Therefore rapid growth in all aspects of population that may affect coral reefs may be expected to be high in coming decades.

Table 1.4.1 Human population size of countries in the Western Indian Oean (WIO). National population, population in major drainage basins (including adjacent countries, grouped by which country the river enters the sea), coastal strip 100 km wide, coastal administrative districts, and coastal urban population. All data (except urban population) is based on gridded population data from CIESIN 2016. Counts derived for each column are explained in the notes.

Country	National [a]	Drainage basins [b]	Coastal strip (100km) [c]	Coastal 'districts' [d]	Coastal urban [e]
Comoros	729,023	729,023	729,023	867,104	160,870
Kenya	46,561,365	15,300,176	3,476,169	2,866,577	1,189,920
Madagascar	23,404,924	4,108,025	12,039,534	11,776,706	4,610,500
Mauritius	1,164,269	1,164,269	1,164,269	1,070,128	114,860
Mozambique	25,936,031	73,601,622	11,026,878	11,810,805	4,007,690
Reunion	848,431	848,431	848,431	801,919	713,292
Seychelles	85,603	85,603	85,603	62,839	89,903
Somalia	9,709,526	25,592,235	2,262,672	9,659,994	2,881,227
South Africa	55,083,702	3,328,060	16,656,695	8,553,896	
Tanzania	48,688,786	9,171,773	7,902,314	8,336,793	5,390,668
Total	**212,211,661**	**134,929,218**	**56,191,589**	**55,806,761**	**19,158,930**

Sources:
a- National totals
b- by river drainage basins, with populations from neighbouring countries assigned to the country holding the river mouth. Source: Global Runoff Data Center, GRDC),
c- population within a 100 km buffer from the coastline
d- administrative units derived from the Global Administrative Boundaries (GADM) dataset, but at different levels based on differing systems for each country.
e- Urban population source: Citypopulation.de. Retrieved 14 October 2016, from http://www.citypopulation.de/

Affiliation: *CORDIO East Africa.*

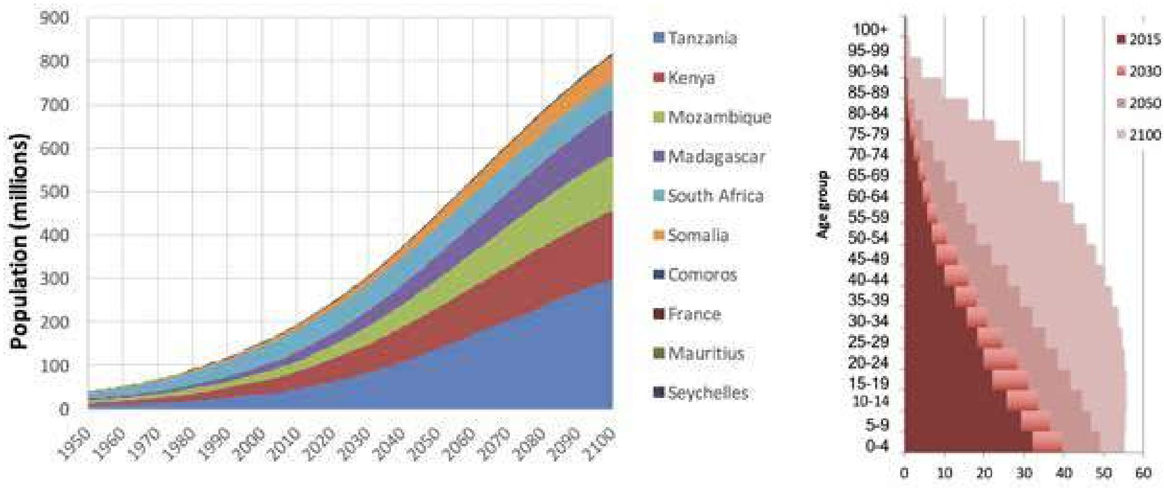


Figure 1.4.1 Western Indian Ocean national populations based on United Nations median projections, from 2015 to 2100. a) total populations for each country by year, ordered by populatoin total in 2100, b) total population by age group for the region, in 2015, 2030, 2050 and 2100. Source UNESA 2015.

One potential saving grace of the current population pyramid is that growth in age-classes of working-age adults will be higher than in other age classes until close to the end of the century, so a 'demographic dividend' is expected in the region that will help fuel economic productivity and reduce the number of dependents per adult (Africa Economic Outlook 2016).

1.4.2.2 Economic growth

East and southern African countries are among the poorest globally, however in recent decades economic growth in some WIO countries, particularly South Africa, Kenya and Tanzania has accelerated (fig. 1.4.2a), and GDP growth rates in others with currently-low GDP has remained high, such as in Mozambique, and is climbing in others (e.g. Madagascar, Mauritius; fig 1.4.2b). Improvements in the general quality of life, as measured in the Human Development Index is positive across all the countries (fig. 1.4.2c) in spite of ongoing challenges.

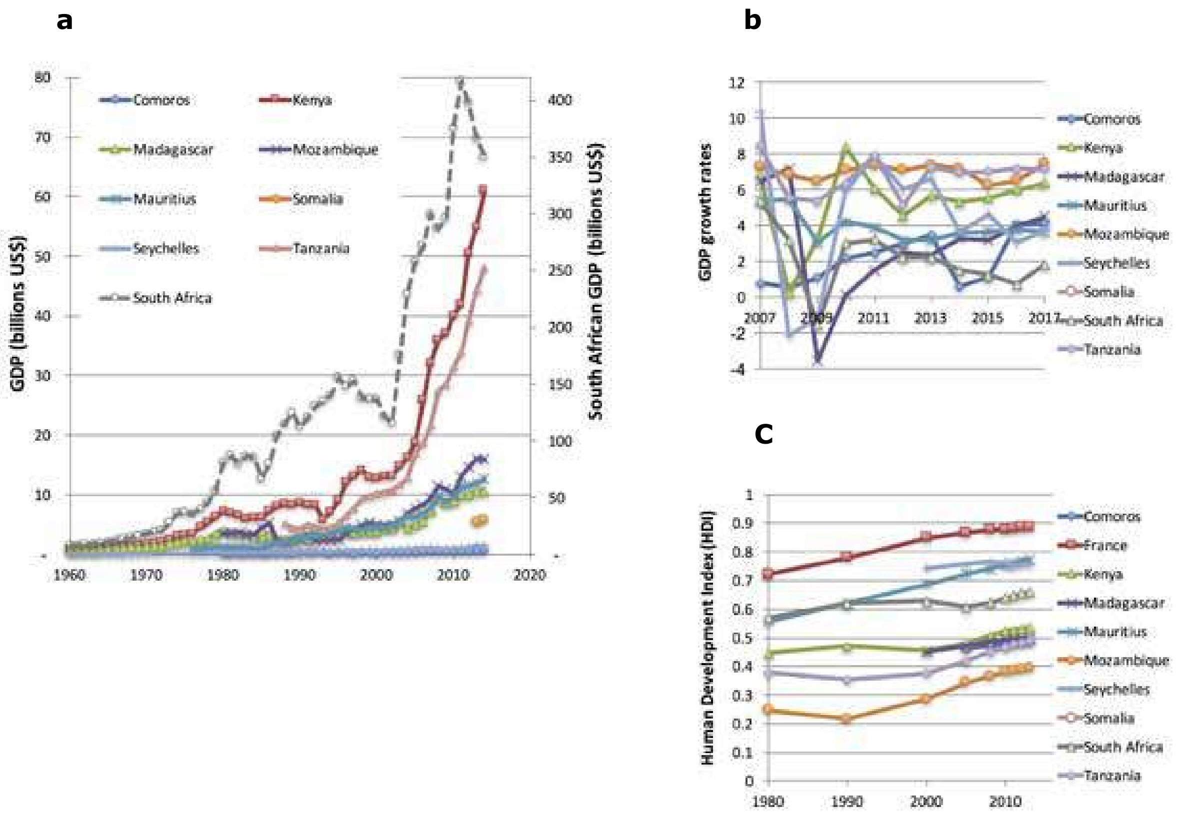


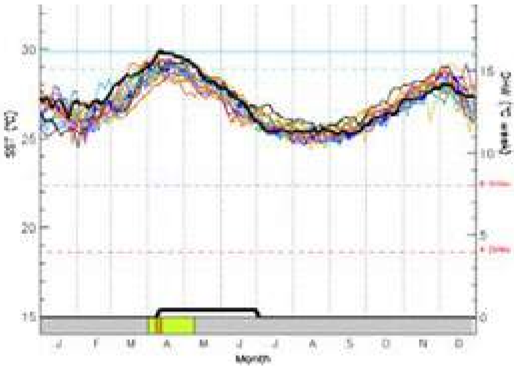
Figure 1.4.2. Economic statistics for countries of the Western Indian Ocean. a) Gross Domestic Product (GDP), from 1960 to 2014. Note that South African data is plotted against the separate y axis on the right. Source: World Bank 2016. b) GDP growth rates for WIO countries. Source: Africa Economic Outlook statistics. C) Human Development Index from 1980 to 2010; Source: UNDP, 2014. Data is omitted from some countries and territories, depending on the source.

Transformations in economic productivity and practices expected in sub-Saharan Africa in coming decades are expected due to innovative energy sources, technology and the information revolution (APP 2015). Further, an energy boom from natural gas and petroleum deposits being found on land and in the sea is also expected, and will drive related economic activity and growth in the region.

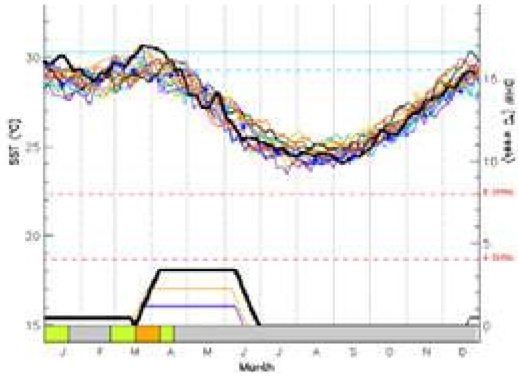
1.4.2.3 Recent climate

Figure 1.4.3 compiles composite graphs from the NOAA Coral Reef Watch programme for stations in each country of the Western Indian Ocean. The illustrated temperature conditions from 2001 to 2016 in colour coded lines, and, at the bottom of each graph, the amount of heat stress experienced at each location in Degree Heating Weeks.

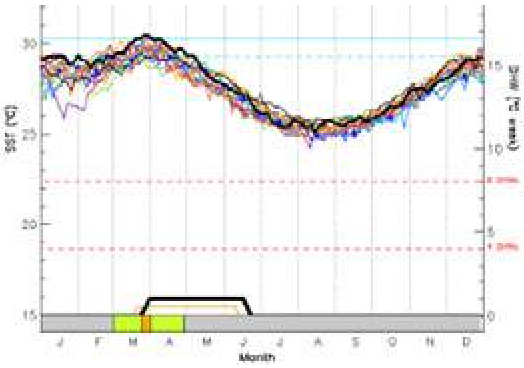
Kenya (Kiunga, north)



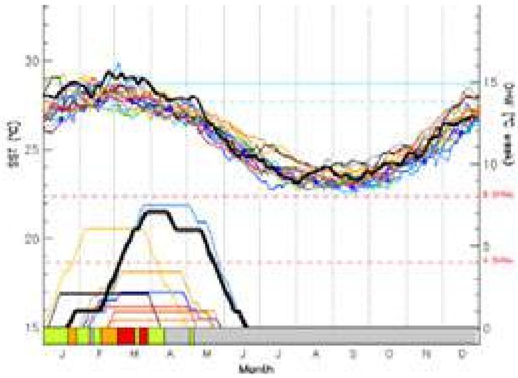
Seychelles (Aldabra)



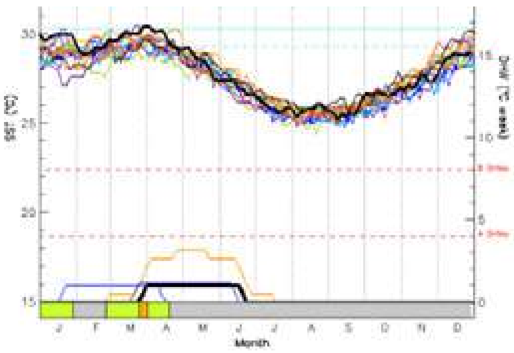
Tanzania (Zanzibar)



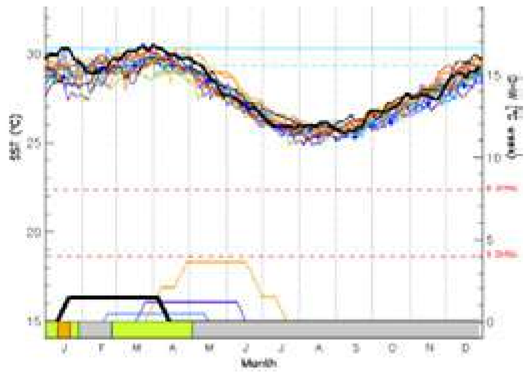
Mauritius (Blue Bay)



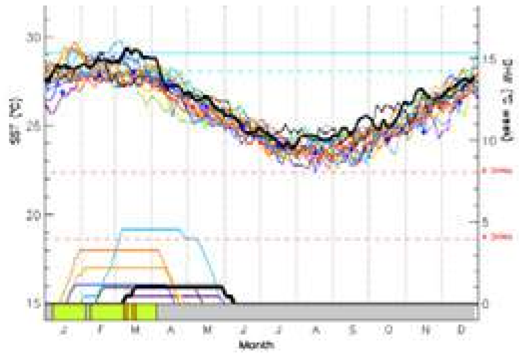
Comoros



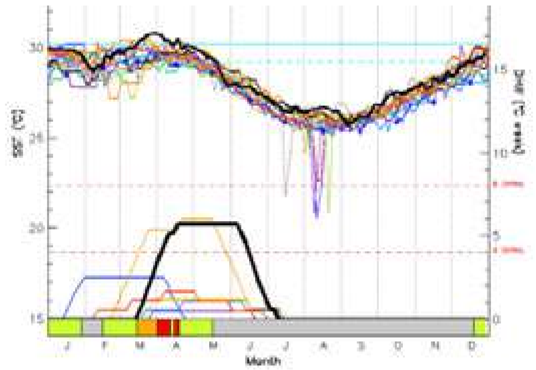
Mayotte



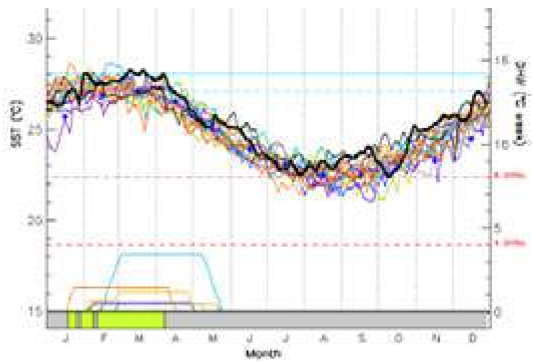
Mozambique (south, Inhambane)



Madagascar (Nosy Be)



South Africa



Reunion

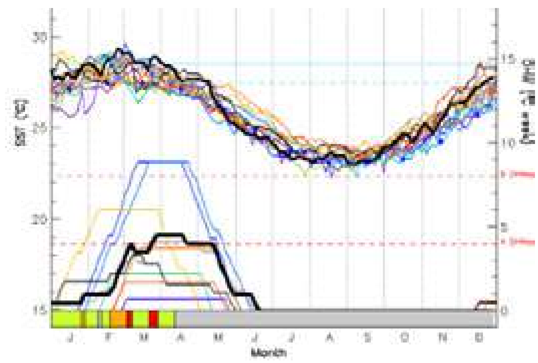


Figure 1.4.3. Multi-year sea surface temperature (oC) and thermal stress (Degree Heating Weeks) for 'virtual stations' provided by the NOAA Coral Reef Watch programme, from 2001 to 2016. Temperature is read off the y axis on the left hand side of each graph, thermal stress in Degree Heating Weeks is read off the right hand y axis. Critical levels are illustrated for temperature (dashed and solid blue lines) and thermal stress (dashed red lines). Source: NOAA Coral Reef Watch.

While figure 1.4.3 does not include data as far back as the 1998 bleaching event, it does illustrate how differently locations in the region are impacted by high temperature conditions in different years. Reunion, Nosy Be in Madagascar and Mauritius show the most frequent high temperature events across many years. The 2016 event was higher than in other years only in Nosy Be, Mauritius, Seychelles (Aldabra) and Kenya (northern Kenya), and was not experienced in South Africa or southern Mozambique (Inhambane). These observations are useful for interpreting bleaching results from the chapters, as well as patterns of bleaching at a regional level (section 1.3), and in considering how vulnerable locations may be to projected increases in temperature (section 1.4.2.4).

1.4.2.4 Projected climate

Predictions of biologically significant bleaching to coral reefs have been made by a UNEP-led project, to predict when severe coral bleaching (that occurs when thermal stress is greater than 8 Degree Heating Weeks (DHWs)) occurs twice per decade and annually (i.e. ten times per decade) under two representative warming scenarios from the IPCC (UNEP 2016). The scenarios selected are a 'no climate policy' scenario that assumes emissions increase unabated (RCP 8.5), and a scenario that assumes emissions peak around 2040 and then decline as a result of successful implementation of climate policies (RCP 4.5). In 2016, actual emissions concentrations were greater than what RCP8.5 projected for 2016 (van Hooidink et al. 2016). The analyses are available on UNEP live, at the URL https://uneplive.unep.org/theme/index/19#.WEcaRqJ97dQ).

Maps prepared from the analyses show the year in which twice-per-decade severe bleaching occurs (fig. 1.4.4). At this frequency of severe bleaching, growth and recovery of corals to mature sizes for reproduction is not possible. At this point, the recovery processes shown by many reefs in the region so far (see section 1.2 and Part 2) may decline to zero.

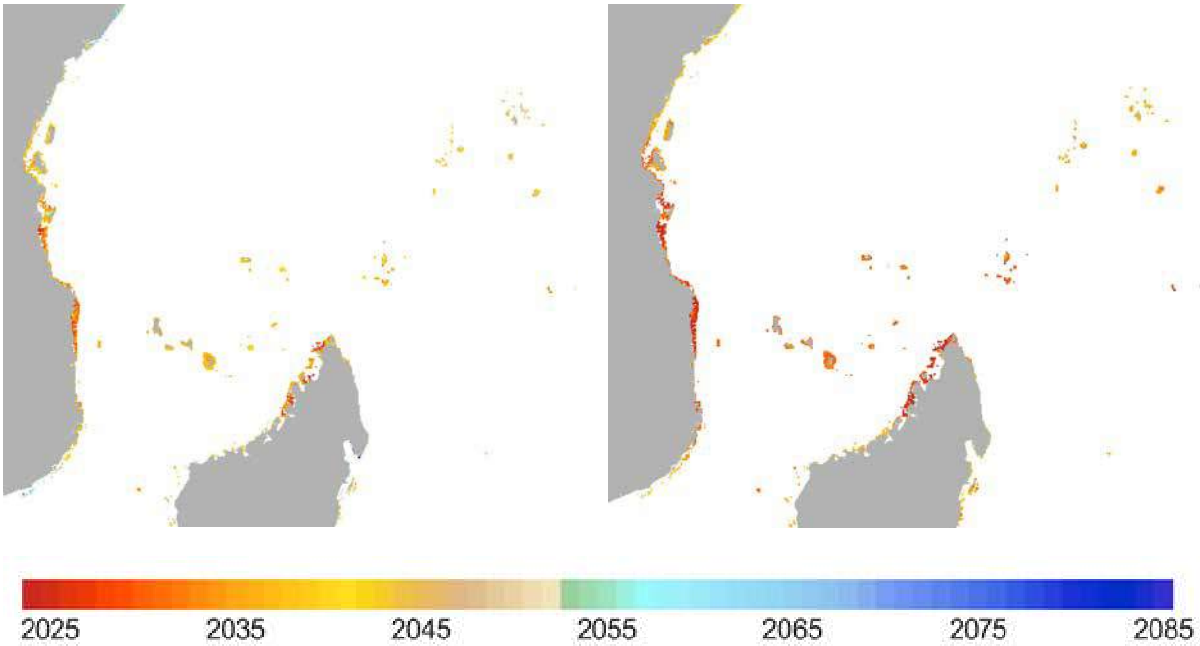


Figure 1.4.4. Forecast for bleaching twice per decade, under different climate scenarios - RCP 4.5 (left) and RCP 8.5 (right). Only a sub- section of the region is shown to make the colour coding more apparent. The shading indicates the year in which critical thermal stress is reached, ranging in the maps between 2025 (dark red) to light blues (about 2070). Source – UNEP, https://uneplive.unep.org/theme/index/19#.WEcaRqJ97dQ.

The maps show the high vulnerability of the central region of the WIO, around the northern Mozambique Channel, to severe and frequent thermal stress – with much of the sub-region affected under RCP 4.5 (between 2025 and 2040) as well as RCP 8.5 (between 2025 and 2030). The least susceptible regions in northern Kenya under RCP 4.5 (critical stress around 2060) are affected by 2040 under RCP 8.5.

Prior analyses of critical thermal stress include predictions by Sheppard (2003) and McClanahan et al. (2007). The former suggested critical thresholds would be reached first around 10-15oS in the 2030s, with the least susceptible regions facing critical stress around 2060-2070, patterns borne out by the analysis shown in fig. 1.4.4.

1.4.2.5 Combined threats to coral reefs

The Reefs at Risk global assessment identified the levels of local and global (climate change) threats on coral reefs separately (fig. 1.4.5). Local threats included overfishing and destructive fishing, marine based pollution and damage, coastal development, and watershed based pollution. For these threats the analysis found that a large proportion of the reefs in Kenya, northern Tanzania, northern Mozambique and Madagascar (although threat level varied significantly along the coast), Reunion and Comoros were at a high or very high risk. Seychelles and Mauritius reefs were the least threatened in the region. Country specific threats included overfishing in southern Kenya and dynamite fishing in Tanzania. One of the threats which was not included in this analysis, and which is likely impacting the Seychelles, is the fish trade with Asia of high-value species for live reef fish. By 2030, projections suggest that climate-related threats will increase overall threat levels to more than 85 percent. Particularly dramatic changes are predicted off Madagascar and Mozambique, due to the combination of acidification and thermal stress.

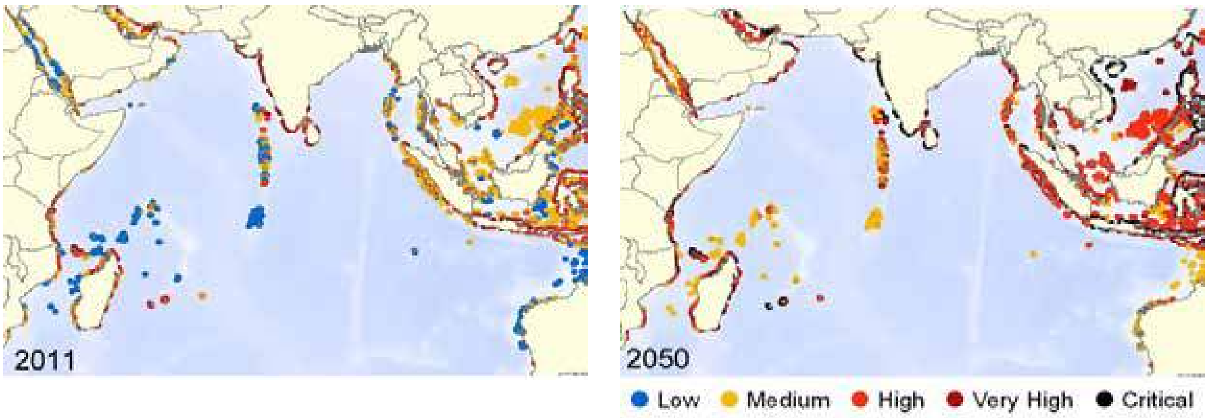


Figure 1.4.5. Maps of risk assessed for Indian Ocean coral reefs for 2011 (left) and 2050 (right). Colour coding of risk for individual reefs is shown in the legend at low, medium, high, very high and critical levels. Source - Burke et al. 2011.

1.4.2.6 Summary

An impression of the aggregate threat from local (population and economy-based) and global (climate and global drivers) sources is hard to appreciate. Population size and economic output multiplied together give an indication of the total impact of people. The continuing increases in both of these will result in exponential increases in local threats to coral reefs. At the same time, the lag effects of greenhouse gasses in the atmosphere are also kicking in to create a rapid acceleration in expected climate stress.

The levels of climate stress indicated in fig. 1.4.4, alongside local pressures from fishing, pollution and other sources are associated with the reef recovery and decline patterns reported in sections 1.2 and 1.3. That is, after the approximately 20-30% mortality of corals in 1998 from a climate event, there has been overall stasis in coral cover at a regional level, with as much decline in reef health in some sites as there has been recovery in other sites.

Given the increases in human population and economic drivers of local threats, and in projected climate threats from now till 2050 (fig. 1.4.5) it is very possible that the stasis in reef health from 1998-2015 (see Section 1.2.6) may change into progressive decline from 2016 into the future, unless responses to more effectively improve and protect reefs are increased dramatically.

1.4.3 Responses

1.4.3.1 Area-based and spatial management

Table 1.4.2 summarizes the area under management in Marine Protected Areas (MPA) and Locally Managed Marine Areas (LMMA) in countries of the WIO. Both the area and number of these are under flux in many of the countries, as commitments are expanding and new sites are being designated each year. The table identifies the "Aichi Target gap", that is, the difference between the current coverage of protected areas and Aichi Target 11, which is that 10% of EEZ area per country should be under effective protective management.

While there has been considerable effort in designating marine protection areas, the region was in 2016 still at less than one quarter of the target, with 2.4% of marine area protected. However, this figure is significantly less if the new whole-EEZ MPAs in the Mozambique Channel are not included, resulting in an area of 42,100 km^2 under protective management, or 0.78% of total EEZ area. It should be noted, however, that if just the coastal waters in which coral reefs are found, the percentage of reefs protected would be considerably higher.

Table 1.4.2. The area of MPAs and LMMAs in each country of the WIO, as of early 2015. The table also indicates the gap to achieving Aichi Target 10 for marine protection levels of 10% of the waters of each country. From Obura et al. 2017, with data derived from the World Database on Protected Areas (WDPA) with multiple updates that need to be confirmed.

Country	Current status of MPAs	Aichi gap	Implementation priorities
Comoros	• 2 MPAs and 2 LMMAs cover 0.09% of EEZ • Moheli Marine Protected Area to be transformed into an island biosphere reserve • Promise of Sydney commitment to reach 7% of all marine and coastal ecosystems protected by 2024	-9.9% Will be -3% after national target met	• National marine protected area project starting, focus on full implementation • Support development of LMMAs, engagement with MIHARI (Madagascar LMMAs) • Capacity building in management, and design/implementation of new MPAs and LMMAs
France (WIO)	• 3 large MPAs cover 11.28% of EEZ • New small-scale MPAs (18) similar in scale to LMMAs	+1.28%	• Improve effectiveness of management and environmental controls in heavily populated islands • Engage with adjacent countries to network MPAs to increase their resilience

Country	Current status of MPAs	Aichi gap	Implementation priorities
Kenya	• 6 national protected areas and 24 LMMAs cover 1.03% of EEZ	-9%	• National planning for network of MPAs and LMMAs
Madagascar	• 28 MPAs and >70 LMMAs cover 1.31% of EEZ • Promise of Sydney specifies # for expansion (3 times), but not size of LMMA target	-8.7%	• Complete current MSP process identifying priority sites for MPA and LMMA designation • Turn the Promise of Sydney LMMA commitment and distinction between terrestrial and marine PAs into specific area target for marine areas.
Mauritius	• 14 MPAs and 6 LMMAs cover 0.01% of EEZ	-10%	• Specify marine conservation and protection targets under the national Ocean Economy roadmap • Undertake MSP at national levels to identify priority areas for MPAs/LMMAs.
Mozambique	• 5 MPAs cover 2.54% of EEZ	-7.5%	• Implementation of the new large MPAs (Primeiras & Segundas) • Identification of LMMAs through fishery legislation in support of fishery cooperatives • National planning for network of MPAs and LMMAs • Capacity building
Seychelles	• 9 MPAs, 5 LMMAs cover 0.06% of EEZ • Committed to 30% of EEZ in MPA management under debt for adaptation swap	-9.9% Will be +20% after national target met	• Capitalization of trust fund to secure MPA commitment • Capacity building to ensure effective implementation of MPAs
South Africa[7]	• Nationally, 24 MPAs cover 0.67% of mainland EEZ. The Prince Edward Island MPA declared in 2013 increased the national MPA coverage by an additional 180,000km^2. • In KwaZulu-Natal province (in the WIO), 4 MPAs cover 0.67% of EEZ, or 2153 km^2. • MPA planning and zoning process very advanced under Operation Phakisa. Committed to 5% of EEZ in MPAs under this plan	WIO only: -9.3 % Will be -5% after national target met	• Confirmation and implementation of current MPA zoning plan • Assessment of next steps to meet Aichi Target 11 and SDG 14 goals
Tanzania	• Currently 7 MPAs, 13 LMMAs covering 2.92% of EEZ	-7.1 %	• National planning for network of MPAs and LMMAs
WIO total[8]	• MPAs and LMMAs cover 138,900km^2 (2.13%) and 16,700km^2 (0.26%) of WIO EEZs respectively, for a total of 155,500km^2 (2.39%)	-7.6 %	• Undertake regional planning for regional networks of MPAs/LMMAs, combining both national and regional targets and priorities

Source: Obura (2017).

7 For South Africa, figures are given separately for national coverage and for KwaZulu-Natal province alone – the latter being the only part of the country designated as part of the WIO.

8 For South Africa, the total for the WIO includes the area of EEZ and marine protected aeas in KwaZulu-Natal province only, and not the colder water/temperate southern and western coastlines of the country.

The historical focus of marine protection on MPAs is shifting as the demands on ocean space expand. In the context of Marine Spatial Planning, all human activities need to be managed to make the most of synergies and minimize conflicts among users and uses. In this framework, core protection in protected areas can also play a broader role for supporting services used by people in other management zones, such as for fisheries. The role of broader spatial management is increasingly being recognized in WIO countries, with national MSP processes underway in the Seychelles and South Africa[9], and may provide a stronger framework for managing all coral reefs in country's waters in the near future - commensurate with the growing pressures from multiple sources (Section 1.4.2).

1.4.3.2 Regional Climate strategy

A regional strategy for addressing coastal and marine climate change impacts in the WIO region was developed and produced in a report in 2011, led by the Western Indian Ocean Marine Science Association (WIOMSA), with financial support from the Swedish International Development Cooperation Agency (SIDA), contracted with International Resources Group (IRG) in Washington, DC. Further, a Regional Plan (including a strategy) for adaptation to climate change (PARA) for the Island States, was developed for Indian Ocean Commission by the ASCONIT-PARETO Consultants. These were presented at a regional conference in Mauritius in 2012 (WIOMSA/MOI 2012) that recognized the priority for supporting adaptation to climate change.

At national levels, countries of the region have been active in developing national strategies and action plans, and all the countries of the region submitted Intended Nationally Determined Contributions (INDCs) to reduce carbon dioxide emissions in the run up to the Paris Climate COP 12 of 2015, and adoption of the Paris Agreement. Four national INDCs mentioned coral reefs (Madagascar, Mauritius, Somalia and France), in terms of their vulnerability, observed impacts and adaptation/implementation plans.

Nevertheless consistent and active climate adaptation and mitigation strategies are not yet active in the region, but are urgently needed in the coming decades to motivate for effective reef protection in the face of the predicted impacts from climate change.

1.4.3.3 Aichi Targets

Coral reef ecosystems are mentioned explicitly in Aichi Target 10 of the CBD (Table 1.4.3). However, according to the mid-term assessment of how well countries were meeting the targets in 2015, the indicators associated with coral reef health were among the poorest performing. In fact, some of the indicators were moving away from the target e.g. coral reef health has been declining during the first half of the 2010-2020 period of the CBD's Strategic Plan for Biodiversity.

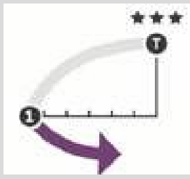
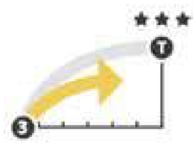
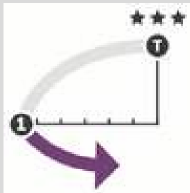
Coral reefs are also directly relevant in two other targets, including:

- Target 11 – the area under effective protection, with much of the marine protection (Table 1.4.2) being focused on coral reef ecosystems.

9 See http://seymsp.com/ and http://www.operationphakisa.gov.za/Pages/Home.aspx, respectively.

- Target 12 – extinction risk. Corals are among the most threatened of taxonomic groups globally (Foden et al., 2013), with over 33% of species being assessed as Threatened on the IUCN Red List of Threatened Species (Carpenter et al. 2008). Because many of the threatened species are restricted species from the Southeast Asian region, the proportion for the WIO is 22% Threatened (0% Critically Endangered, 2% Endangered, 20% Vulnerable). Another 29% are assessed as Near Threatened, only 41% as Least Concern (i.e. negligible threat of extinction) and 7% have not been assessed for lack of data.

Table 1.4.3. Summary of the three Aichi Biodiversity Targets most directly relevant to coral reefs. The indicator is obtained from the Global Biodiversity Outlook 3 (Secretariat of the Convention on Biological Diversity, 2014) and interpreted for the Western Indian Ocean.

Aichi Target	Text	Indicator	Comment
	By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.		Pressures and threats on coral reefs are increasing exponentially, and projected to continue to increase in the future.
	By 2020, at least … 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved …		Progress has occurred, but not sufficiently to be on track for reaching the target. The current area under protection is 2.4% in the WIO, and 0.7% excluding France
	By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.		Confirmed extinctions for reef species are challenging, but the status of coral reef species has declined, as pressures and threats have increased.

1.4.3.4 Sustainable Development Goals

Agenda 2030 and its Sustainable Development Goals were adopted by the United Nations General Assembly in September 2015, as the next phase of global commitments to sustainability, to be achieved by 2030. One goal, number 14, is focused on oceans, committing to *"Conserve and sustainably use the oceans, seas and marine resources for sustainable development"*. The other goals cover a range of other environmental, social and economic themes. The goals are intended to be 'holistic and indivisible', meaning that they cannot be implemented in isolation – there are key dependencies among them such that they need to be built up as a whole. For example, achieving goal 14 on oceans will also require addressing climate change (#13) and sustainable production and consumption (#12), to reduce pressures from these affecting ocean health.

Figure 1.4.6. The 17 Sustainable Develpment Goals. Source - UN.

Specific targets have been developed for each goal to help operationalize them, and for coral reefs, Targets 14.2, 14.3 and 14.5 are particularly important, dealing with protecting critical habitats, ocean acidification and the proportion of marine areas effectively managed. Target 14.5 reiterates Aichi Target 11, targeting 10% of marine areas to be effectively managed by 2020, and ensuring coherence among global conventions. Indicators for the SDG targets are under development, and coral reefs being a flagship marine and coastal ecosystem, and with the existing framework of the GCRMN, may provide key data to assess achievement of the SDG Targets. With a mid-term assessment of SDG Targets planned for 2020, coincident with Aichi Target reporting, the results from this and other GCRMN reports, updated to 2020, may provide significant inputs to assessing progress in meeting the Sustainable Development Goals.

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2 NATIONAL CHAPTERS

2.1 Comoros

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2.1.1 Summary

The Comoros archipelago consists of four islands in the Northern Mozambique Channel. Coral reef monitoring began in 1998 at ten sites across the islands of Grande Comoros, Anjoun and Moheli. Over the past 18 years, coral cover has varied between 38% and 64% for fore reefs and 19% and 47% for back reefs. While bleaching has occurred periodically, corals have remained resilient, increasing in cover after bleaching events. In 2016, an estimated 10%-60% of corals were bleached at survey sites. Common pressures on Comoros reefs include warming sea surface temperatures, fishing, sedimentation, and beach excavation. Responses lag behind these pressures and management efforts need to be strengthened at both national and local levels. A few examples of current activities with potential to improve coral reef conservation include: creation of a network of Marine Protected Areas (MPAs), Non-Governmental Organization support for local initiatives for fishery management on the island of Anjouan, and presence of an MPA to protect reefs off the southern half of the smallest island, Mohéli. Reefs of the Comoros would benefit from greater local and national management efforts targeting multiple pressures, as well as capacity building and consistent funding for reef monitoring.

2.1.2 Introduction

The Comoros archipelago lies in the Northern Mozambique Channel between Mozambique and Madagascar and is made up of four major islands: N'gazidja (Grande Comore), Ndzuwani (Anjouan), Mwali (Mohéli), and Maore (Mayotte) (fig. 2.1.1). The islands are volcanic in origin with a narrow shelf and fringing reefs of progressive ages and stages of development (Emerick and Duncan 1982). The youngest island, Grande Comore, has an active volcano, Karthala. Landward rise is steep, especially on Anjouan. Mayotte's lagoon covers 1500 km^2 and harbors at least 249 reef-building coral species while the remaining islands have a total of 430 km^2 of coral reefs with at least 195 reef-building coral species (Ahamada et al. 2008; Obura 2012).

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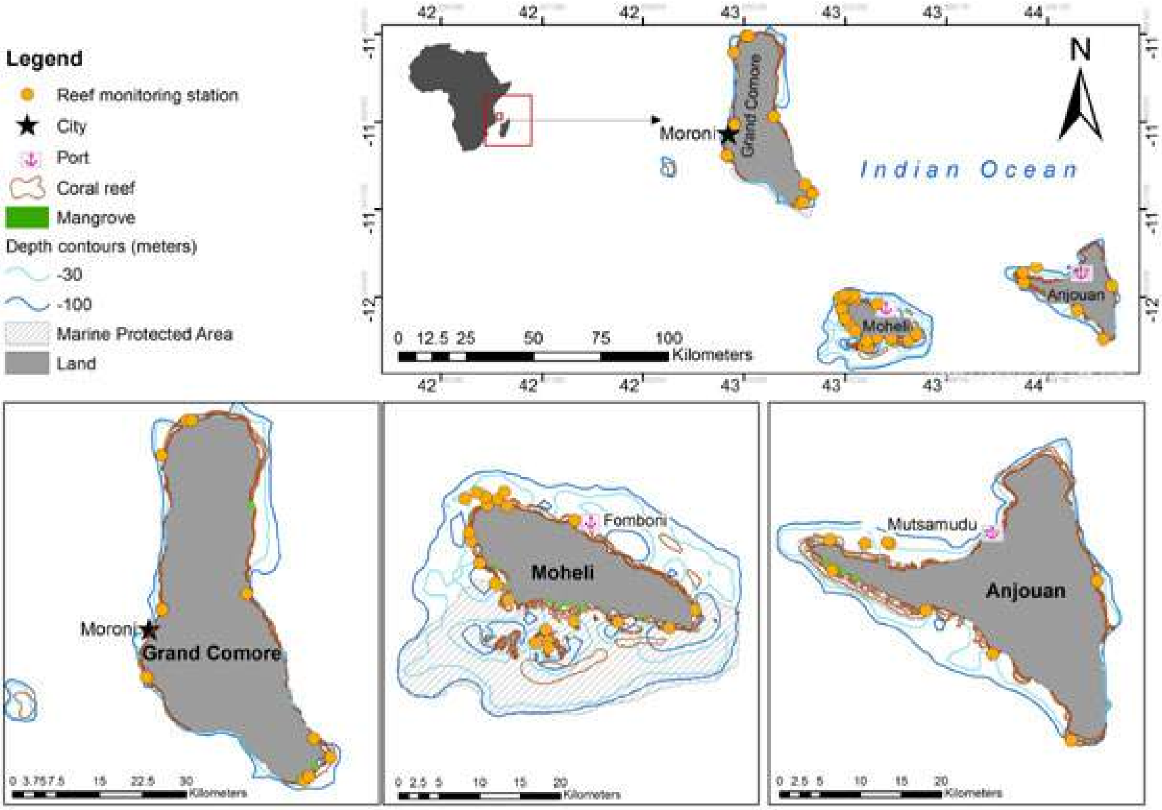

Figure 2.1.1 Comoros archipelago's (Grande Comore, Mohéli, and Anjouan) coral reefs and monitoring stations for which data was included in this study

2.1.3 Status and trends

Monitoring began in 1998 at 10 sites on the islands administered by the Union of the Comoros, Grande Comore, Anjouan, and Mohéli. Subsequent monitoring has targeted the same sites although data have been collected occasionally at an additional 24 sites. In 2015, reef monitoring took place at eight of the sites surveyed in 1998, with two new sites added in 2016. Across the 10 sites surveyed in 2015-2016, average coral cover was 64% on fore reefs and 40% on back reefs (fig. 2.1.2). Historical data are stored in COREMO database for surveys of live coral cover in 1999, 2002-2005, 2007, 2009, and 2011. National averages of live coral cover for each year were calculated from the available data, with between 3 and 26 sites surveyed in a year. Although there were notable declines in years with coral bleaching (2002 and 2010), coral cover increased in subsequent years and varied between 38% and 64% for fore reefs and 19% and 47% for back reefs.

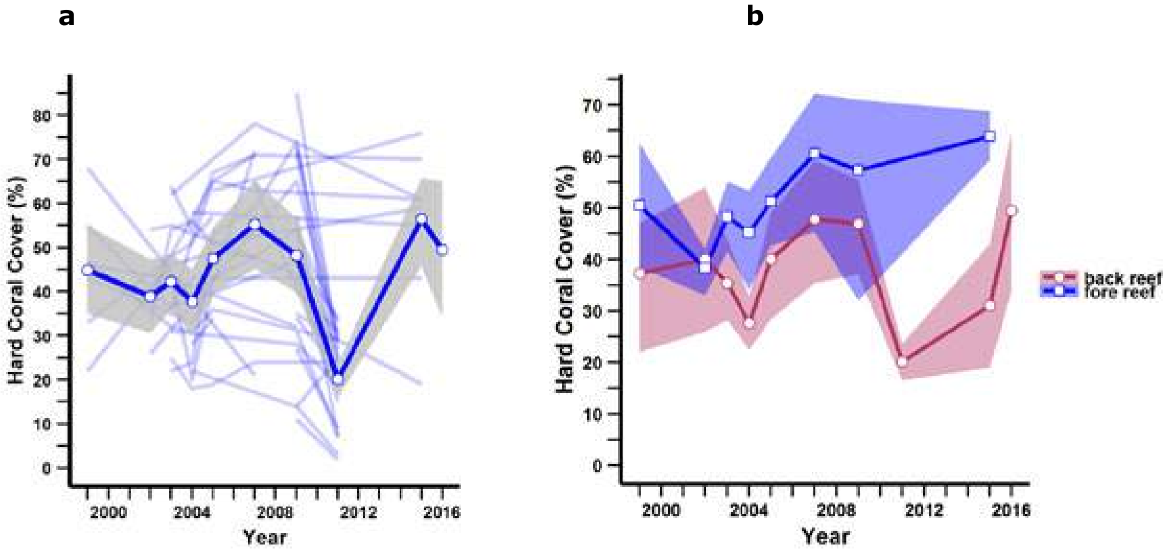

Figure 2.1.2. Trend in hard coral cover on a) all reefs in Comoros from 1998-2016 (national mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines); b) comparison by fore reef (blue line, open squares) and back reef (purple line, open circles) zones with 95% confidence limits of the mean (coloured shaded areas)

Algae cover was relatively low with an average of 4% on fore reefs and 13% on back reefs in 2015-16.

Fish and urchin abundance were available for only one site in 2015-16. Fish were identified and counted from a list of 30 species and were found with an abundance of 8000/ha. Urchin abundance was found to be 0.04 per m^2. Fish abundance and biomass are available for 2011 from 2 studies. In one, 30 species in four families and sub-families were counted at 20 sites giving a mean abundance of 3200 ind/ha and biomass of 1200 kg/ha (Freed and Granek 2014). In the other, over 180 species from 17 families were counted at 8 sites, with a mean abundance of 3000 ind/ha and biomass of 400 kg/ha (M. Samoilys, unpublished data).

2.1.4 Coral bleaching 2016

During the bleaching event of 2016, bleaching was observed at several monitoring sites beginning in November 2015. Using methods compiled in the regional bleaching manual (IOC 2016) and taught to observers in 2016, an average of 21.3% bleaching of coral cover was found across seven sites in April 2016 (fig. 2.1.3). Bleaching was also observed in April at Itsoundzou on Grande Comore (estimated at 10-50%) and at Vassy and Mlongo Mhu on Anjouan (censused at 41% and 45%, respectively). Although final mortality of corals was not measured, observations in October 2016 on Anjouan indicated final mortality was less than half for bleached corals. If generalized, this observation indicates mortality of live hard corals was less than 20%.

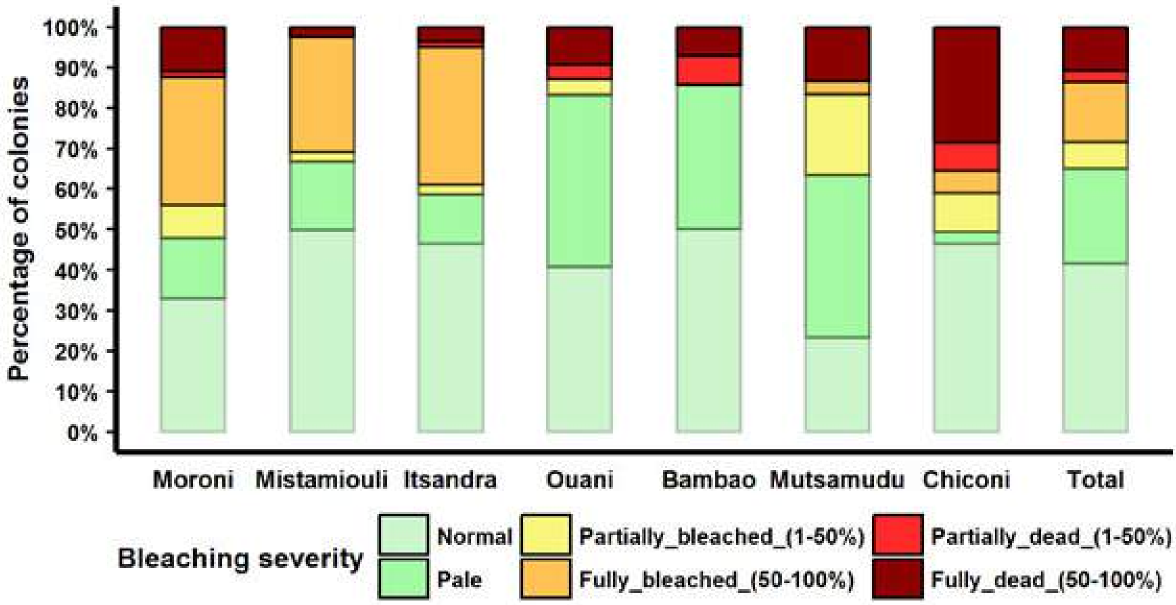

Figure 2.1.3 Coral bleaching and associated mortality recorded at seven sites in the Comoros in 2016. Categories represent the severity of bleaching and associated mortality reported as a percentage of coral cover at a site.

2.1.5 Drivers and pressures

Pressures common across all sites in the Comoros include warming sea surface temperatures and frequent small-scale fishing activity. A recent one-year survey of landings from a village on Anjouan indicated fishers caught an average of 22 kg (± 8 SE) per fisher per trip based on a sample of 77 fisher teams from a village of population near 1800 (Blue Ventures and Dahari, unpublished data).

Several sites are also subject to sedimentation from agricultural runoff and/or beach excavation, both of which are especially heavy on Anjouan. Other threats are present at select sites, including dynamite fishing (at Nkandzoni) and riverine deposition of sediment and household waste (at Wani).

2.1.6 Timeline

1975	Around this time new fishing gears were introduced on Anjouan that facilitated an increase in fishing pressure on coral reefs. Among the new gears were fishing nets made from synthetic materials and that had a smaller mesh size than traditional nets made from coconut fibers.
1998	First major bleaching event observed with monitoring.
2004	Comoros participated in the third GCRMN monitoring report. Minor bleaching (1-10% of observed corals) and steady recovery from 1998 bleaching event were observed.
2010	Second major bleaching event with monitoring in place. Reefs surveyed at 26 sites were found to be affected with between 17% and 68% bleaching.
2015/16	Third major bleaching event with 10% - 60% bleaching observed throughout survey sites.

2.1.7 Responses

Comoros is a signatory of the Convention on Biological Diversity and in 1998 developed a National Strategy for Conservation of Biodiversity that remains largely unapplied. Conservation efforts targeting fishing and rural development are mostly sporadic, consisting of projects spanning only a few years and dependent on political will and inconsistent funding.

Established in 2000, Mohéli Marine Park covers 404 km^2 of the waters off the southern half of Mohéli and currently remains the only Marine Protected Area in the Comoros. It is co-managed by the national government and local communities.

A National Protected Area Network is currently under development through a partnership between United Nations Development Programme and the national government. The Network includes plans to develop two more MPAs, one each on Grande Comore and Anjouan. The boundaries for the MPAs are not yet definitive and no management plans are yet in place.

The National Coral Reef Task Force established in 1998 continues to monitor coral reef sites, although issues of funding and personnel availability have hindered monitoring in some years.

Since 2008, a project turned-Non-Governmental Organization (Dahari) has been working consistently on Anjouan to improve terrestrial conservation and agriculture, including erosion attenuation and prevention. In 2015, Dahari formed a partnership with Blue Ventures and secured funding to begin efforts for local marine management, to include fisheries management and coral reef conservation. Monitoring of catch landings is underway as well as ecological and socioeconomic studies, with community-based management initiatives planned for 2017.

2.1.8 Discussion

Prior to 1998, a lack of awareness and political will for coral reef conservation meant that monitoring and management were non-existent. However, anecdotal reports indicate that reefs were intact and biodiverse, apart from areas with heavy transport use and/or coastal development. Comoros' coral reefs retain moderate to high coral cover, but pressures continue to rise, most notably from sea surface warming events and small-scale fishing, as well as land and coastal erosion and sedimentation on Anjouan in particular. National and site averages of coral cover remain relatively stable, with 2015 cover increasing from previous survey years. Bleaching continues to cause periodic declines in coral cover followed by periods of recovery, suggesting that reefs remain resilient to bleaching effects. In 2015-2016, bleaching was observed across several sites.

Historical data on fish abundance and biomass is insufficient to indicate trends. However, fishing pressure is pronounced throughout the Comoros and destructive gear is used in some areas. Reefs that are overfished will become more vulnerable to bleaching and other pressures, especially due to removal of herbivores that mediate coral-algal competition (Lirman 2000, McCook et al. 2001, Burkepile and Hay 2010).

2.1.9 Recommendations

Comoros reefs would greatly benefit from management efforts that target multiple pressures at both local and national levels. Currently, community initiative is the primary driver of local management efforts. Local management could be strengthened through capacity building and support from NGOs, local government, and interactions with other communities with successful management initiatives. The proposed Protected Areas could improve management at both local and national levels if they include capacity building for effective co-management and are developed with commitment from both government and communities through consistent dialogue and sharing of decision-making and implementation responsibilities.

A wide range of actions are proposed to strengthen coral reef management and monitoring:

Pressures

1. Climate change – take strong national stance (with SIDS) on climate issues internationally, and adaptation/low carbon fuels locally.
2. Small-scale fishing – increase training, legislation and sustainability measures, and enforce bans on destructive gears (dynamite and poisons).
3. Sedimentation, urban and agricultural runoff – improve soil conservation, agricultural and urban development plans to minimize soil erosion and pollution runoff.
4. Beach excavation – sand harvesting should be stopped, as it exacerbates the problem of erosion and runoff, resulting in sedimentation of reefs.

Responses

5. Marine Protected Area network – conduct participatory implementation and develop capacity required for effective co-management of the new national network of MPAs to ensure MPA effectiveness in protecting reefs from current and future threats.
6. Community-led efforts – facilitate community-based management of marine resources and identify synergies between community and government efforts.
7. Mohéli National Park - the change from an MPA to an island management system offers opportunities to greatly enhance the links between terrestrial and marine stakeholders, livelihoods and impacts
8. Strengthen both government and non-government institutions to play complementary and mutually supportive roles in protecting coral reefs.

Monitoring

9. Capacity building is needed to increase the number of personnel and level of expertise.
10. Training is needed in diving, survey methodology, identification of coral, fish, and invertebrates, and data management and analysis. A recommended avenue is involvement of the University of Comores as a potential provider of personnel and long-term data storage.

11. Funding is needed to mainstream monitoring activities, and could be acquired through fundraising and/or lobbying with relevant programmes, such as the National Protected Area Network.

The 2016 meeting of the National Coral Reef Task Force included discussion of the urgent need for awareness raising for both the public and decision makers, including providing recommendations on strategies for coral reef conservation. Interpretation of survey findings, dissemination and availability of information, and inclusion in management and legislative decision making are equally important. These activities require outreach to decision makers and managers, and a forum for results dissemination is recommended.

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2.2 Kenya

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2.2.1 Summary

Kenya has rich and diverse coral reefs of great importance, both ecologically and socio-economically; as major fishing grounds, tourist attractions and coastal protection. Numerous patches of reefs and extensive fringing reef are located along about two-thirds of Kenya's coastline. These reefs have been under threats from a variety of stressors including overexploitation, nutrient pollution, use of destructive fishing methods and more recently, their sustainability is being put at risk by global climate change. Long-term monitoring has been pursued by Kenyan institutions since 1998/99, to follow the trends and status of corals and fish populations at a country level. In this report, reef data sets of corals and fish were compiled from different data providers/institutions and and developed into a national reef database to allow extensive evaluation of reef status.

Currently, Kenyan coral reefs have an average hard coral cover of 18%, with fleshy algae at 34%, across a range of healthy and degraded reefs. Fully protected reef lagoons have higher hard coral cover (15-40%), focal fish species abundance (>100 indiv./ha) and less algal cover (<20%), while open access (fished) reefs have low hard coral cover (<8%), lower focal fish abundance (<40 indiv./ha), high algal turf cover (>40%), and high coral rubble cover (>10%). Recovery of Kenya reefs from the 1998 coral bleaching event was slow, with cover remaining at 8-10% from 1999 to 2003, following which cover increased slowly to today's level. Recovery was slightly better in no-take MPAs, followed by partially protected reserves and community-conserved areas, and least in unprotected areas. Fish abundances show a similar pattern, being highest in no-take areas and lowest in unprotected areas, but with high levels of variation among sites.

Given the socio-economic and ecological values of coral reefs, the development of an improved system for coral reef networking and data exchange among different partners in the country and at regional level is urgently needed as a first step towards development of cohesive policy and to achieve effective and sustainable use of reef biodiversity.

2.2.2 Introduction

Kenya's coral reefs cover an area of approximately 639 km^2, and can be differentiated into two regions: the southern reef is an almost continuous fringing reef system from Malindi south to Vanga bordering Tanzania; the northern reefs are discontinuous patchy and fore reef slopes from Lamu to the border with Somalia, along the barrier islands of the Bajuni

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Acknowledgements: *Data from Kiunga MNR and Lamu were collected by CORDIO, WWF and KWS. Data from Malindi and Watamu was based on joint surveys conducted by KWS and KMFRI. Data from Mombasa reefs which include fully protected and reserves areas were obtained from KWS. Data from Diani- Chale were on previous monitoring programme to support artisanal fisheries in the area by CORDIO. Data from Kisite and Shimoni were obtained from KMFRI and KWS joint surveys under the World Bank KCDP project. East Africa Wildlife Services provided reef data based on community areas.*

Archipelago (fig. 2.2.1). In between, a stretch of 100 – 150 km is devoid of coral reefs due to the discharge of freshwater and sediments from two major rivers; the Tana and Athi-Sabaki Rivers (Obura 2001; Visram et al. 2009). The size, extent and diversity of coral reefs decrease northward, with the southern reefs having higher reef coral diversity linked to the center of biodiversity south of Kenya (Obura 2001; Visram et al 2007). Latest surveys by Obura (2012) show this pattern, with 239 species in southern reefs, 203 in Lamu and 177 in Kiunga in the north.

Coral reefs are among the best-known marine habitats in Kenya, mainly because they provide myriad ecological goods and services such as for fisheries and tourism, to millions of coastal people. However, because they are found in benign environments along the coast, they are the most heavily used and impacted marine ecosystem by a variety of human activities including over exploitation, destructive fishing practices, habitat degradation, uncontrolled development, and nutrient pollution from sewage disposal. Since 1998 climate-change associated coral bleaching events have been on the increase and pose a significant threat, over and above the many local threats affecting coral reefs in Kenya.

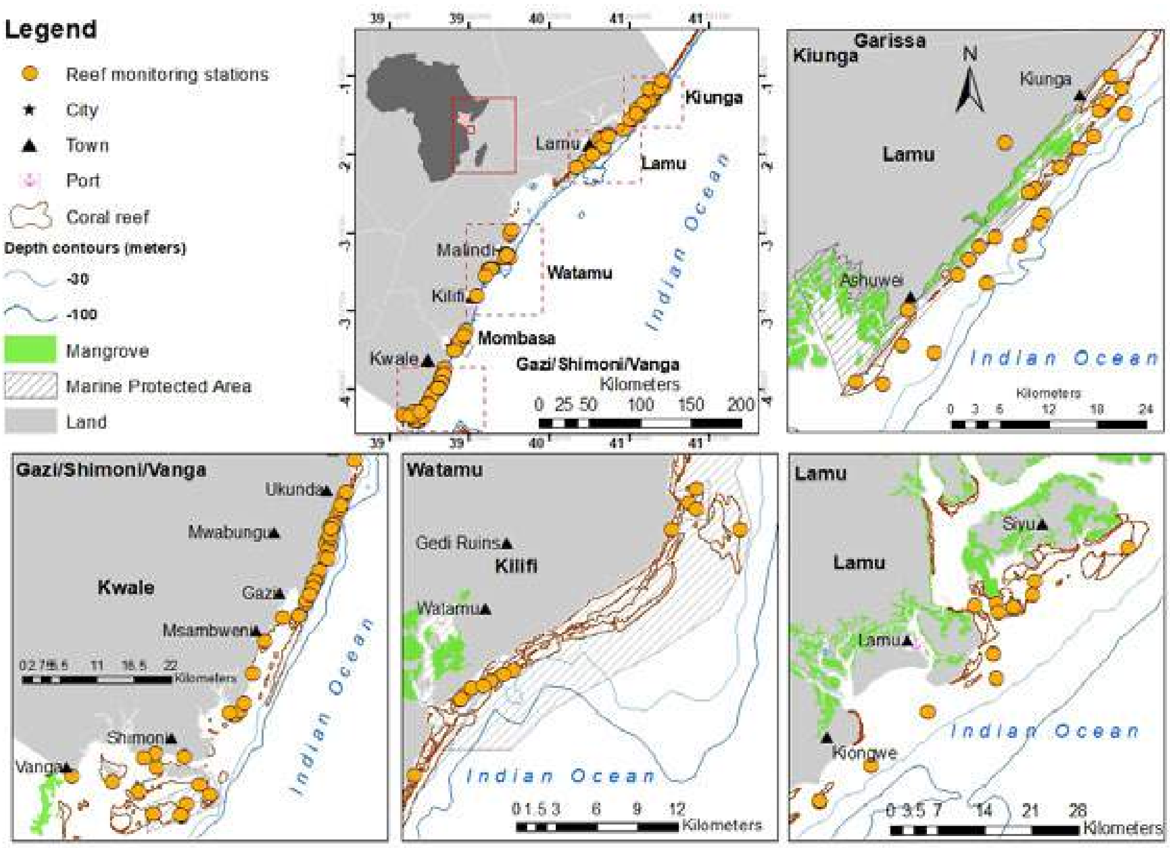

Figure 2.2.1 Kenya's coral reefs and monitoring stations for which data was included in this study

2.2.3 Status and trends

In 1998, reefs along the entire coast of Kenya suffered widespread bleaching and mortality of corals that reduced hard coral cover to almost 8% (fig. 2.2.2a). Coral cover remained low from 1999-2003 (< 10%), followed by a slow recovery to 25% by 2013. The drop in 2014 and 2015, and high peak in 2016 may be due to different sites sampled, as no mortality event occurred at that time. Fleshy algae followed a complementary pattern, rising to >70% in 2000-2002 after the mortality of corals, then declining slowly to <20% in 2014-2015 (fig. 2.2.2b).

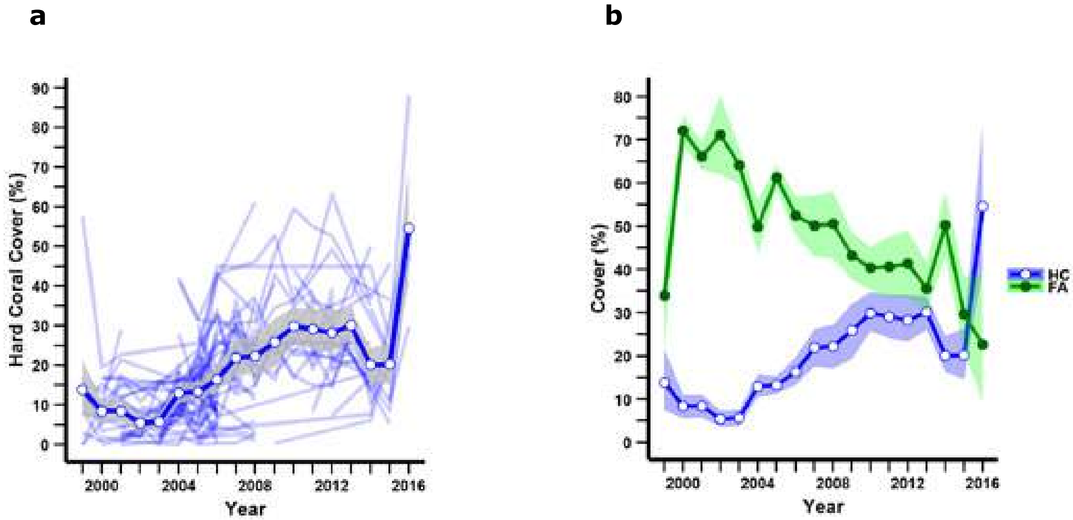

Figure 2.2.2: a) Trend in hard coral cover on Kenyan reefs (national mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines); b) Trend in mean hard coral cover (blue line, open circles) and fleshy algae (green line, closed circles) in Kenya (coloured shaded areas represent 95% confidence limits of the mean).

Hard coral cover was highest in fully protected areas and Community Conservation Areas (CCAs, see description in 'Responses' section), at levels of >27%, 31%, respectively) (fig. 2.2.3). Open access reefs had consistently the lowest hard coral cover (<14%) and highest algal turf (>38%).

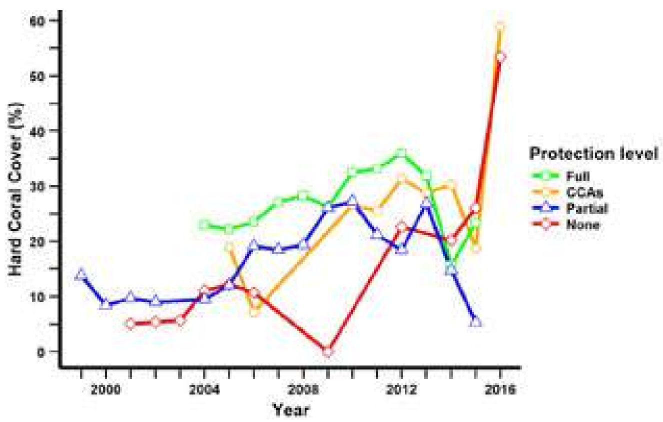

Figure 2.2.3 Comparison of hard coral cover among four management regimes with different levels of protection in Kenya from 1999-2016. (CCA- Community Conservation Areas, in which protection is at partial levels)

All fish families showed high variation in abundance among sites, with the abundance of some commercially important fish (such as the Acanthuridae, Lethrinidae, Lutjanidae, and Haemulidae) being relatively higher (> 500 indiv/ha). The Serranidae and Mullidae, and herbivorous fish such as the Scaridae, Siganidae and Labridae were found at lower abundances.

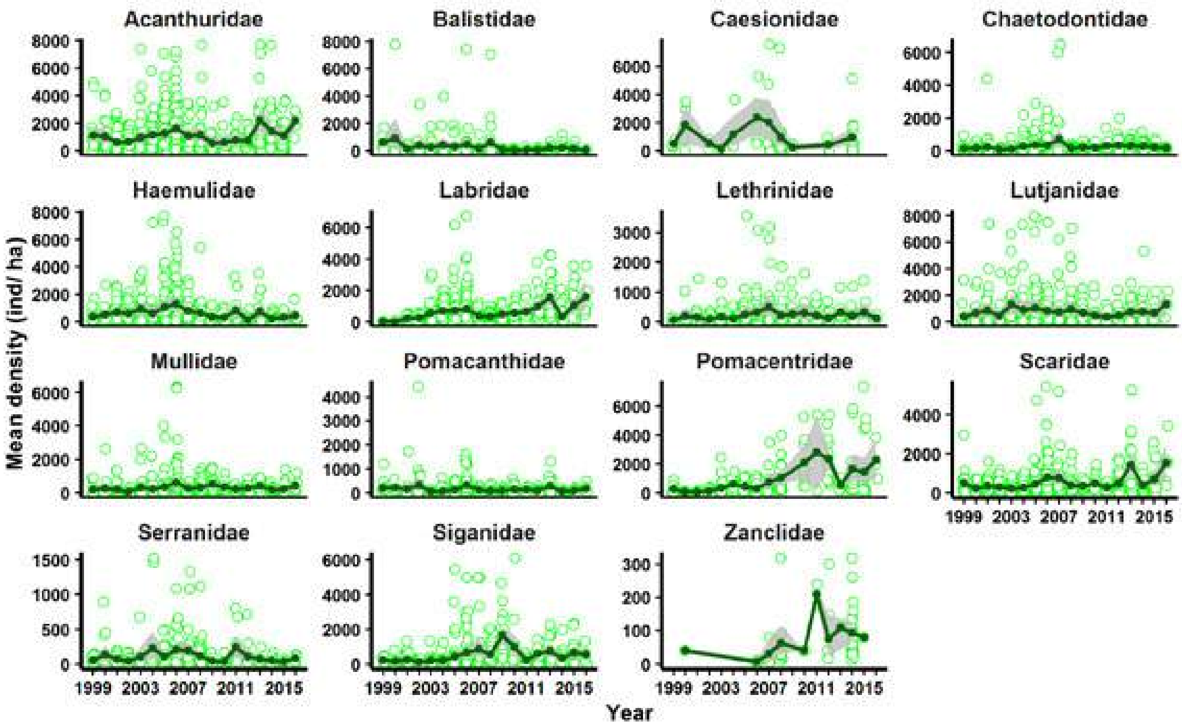

Figure 2.2.4 National averages of abundance for 15 fish families on coral reefs in Kenya between 1999 and 2015. Circles represent surveyed sites and shaded areas represent the 95% confidence limits of the mean.

Fish abundance varied across protection regimes, with no-take MPAs showing highest abundance, followed by reserves (with partial protection) and community conservation areas (fig. 2.2.5), though error bars show high variation within each of these categories over time. This difference is most likely attributable to protection status from fishing, with fully protected areas having the highest abundance of commercially important (Lethrinids, Haemulids, and Lutjanids) and herbivorous (Scarids, Acanthurids and Siganids) fish than reserves and CCAs, both of which have only partial levels of protection. Community-based MPAs have higher fish abundance (64 per ha) than unprotected areas, suggesting that they can be a valuable spatial management tool alongside the national protected area system.

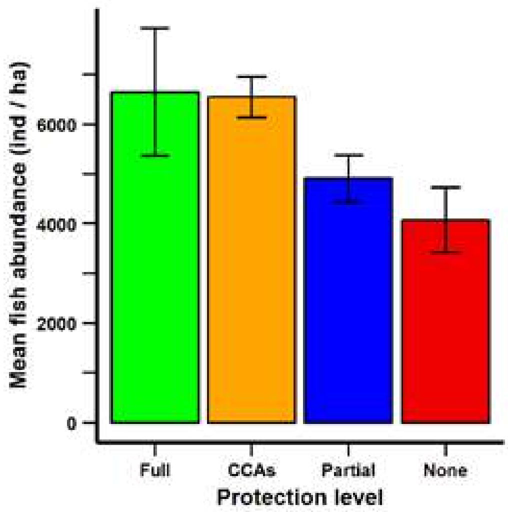

Figure 2.2.5 Comparison of fish abundance (mean and standard deviation) based on annual averages among four management regimes with different levels of protection in Kenya from 1999-2016. (CCA- Community Conservation Areas, in which protection is at partial levels)

2.2.4 Coral bleaching 2016

The severity of coral bleaching in 2016 differed among locations but overall was relatively low, with less than 10% of reefs showing high or extreme bleaching, and only 10% of reefs showing moderate mortality (of 10-50%). Malindi and Shimoni reefs had the highest number of colonies bleached and recently dead, with highest levels of bleaching in the susceptible coral genera *Acropora* and *Pocillopora*, which dominate coral communities in these protected areas.

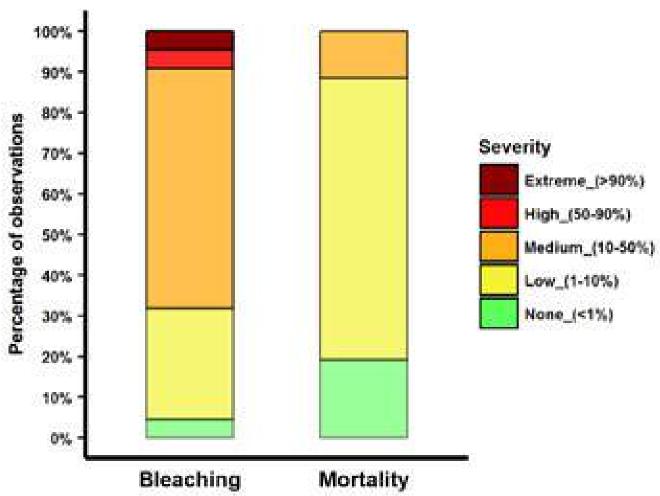

Figure 2.2.6 Observations of coral bleaching (n=22) and associated mortality (n=26) collected in Kenya in 2016. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site.

Comparing the 2016 event with past bleaching events, it was not as severe as in 1998, when 50-90% loss of corals was estimated along most parts of the Kenyan coast. Other milder bleaching events have been noted in 1987 and 1994 (McClanahan et al 2001), and more recently in 2002, 2005 and 2010.

2.2.5 Drivers and pressures

Reef fisheries - the Kenyan artisanal fishery is estimated to support between 8,000 to 10,000 fishers (Kaunda-Arara 2003; Ochiewo et al. 2004), predominantly utilising traditional dugout canoes in shallow lagoons of fringing reefs. The number of fishers has increased over the years due to other drivers (below), over-exploitation of targeted resources has occurred leading to declines in individual catches, such as of serranids (groupers), lutjanids and other scavengers, and rabbitfish, a local favourite. The number of fishers has increased dramatically, with 15-20 fishers/km^2 recorded in unprotected areas, double the 10 fishers/km^2 threshold calculated to maintain Maximum Sustainable Yield (MSY) (McClanahan 1992; Obura 2002; Alidina 2005)

Population - currently, the coastal population is estimated at 3.3 million people, with an annual growth rate of 3.7% (GOK, 2009; Mangi et al. 2007). This is compounded by migration from inland to coastal areas, attracted by employment in maritime trade, fisheries, agriculture, mining and tourism (UNEP/FAO/PAP/CDA 2000; McClanahan et al. 2005). The increase in the coastal population has not only increased exploitation pressure on coral reef resources, but also increased competition for access resulting in ecological degradation of the coral reefs and fisheries resources.

Poverty - According to the Human development report 2005, 42% of the Kenyan population lives below the national poverty line (Mangi et al. 2007), and this is likely higher at the coast. Many artisanal fishers earn about Ksh. 201-280 (US$3-4) per day, and retain some of the fish catch to take home as food (McClanahan and Mangi, 2001; Mangi et al. 2007). These low economic returns have contributed to emergence of destructive fishing practices, including beach seine nets and spear gun fishing; methods that are cheap to make or use, but highly destructive to reef habitats and fishery resources (Obura, 2002). Tourism - the tourism industry is the second in importance for the country's economy, with Marine Protected Areas providing direct income through entrance fees. The development of tourist hotels and resorts has attracted many tourists, with a record of 800,000 visitors in 1997. However, due to political instability, tourist numbers declined to about 20%, with hotel occupancy dropping to 5-10% of capacity (Obura 2001; Mangi et al 2007). The reduced tourism industry led to high job losses, with many turning to fishing in order to sustain their families.

Climatic Change - the impacts of warmer temperatures on coral bleaching on coral reefs in Kenya are well documented (McClanahan et al 2005; Obura 2005). Coral reefs along the entire Kenyan coast suffered unprecedented coral bleaching and mortality during the first half of 1998 (Obura 2001), with coral cover declining from 40% to less than 15% (Obura 2002; McClanahan et al 2002). Mortality was higher in marine parks than on unprotected reefs, though this may be an artefact of the latter being in more severe conditions already, and less attractive for tourism-oriented parks. As noted in the section on coral bleaching, the multiple minor bleaching events may have contributed to the slow recovery of reefs since the 1998 mass event.

2.2.6 Timeline

1968	Kenya established its first marine protected areas and reserve (MPA), Malindi and Watamu.
1978-1986	Designation of Kenya's other four parks, with reserve buffers around them – Kisite/Mpunguti, Kiunga and Mombasa.
1974	First reports of sea urchin (Echinometra mathaei) infestations in Diani reefs as an indicator of overexploitation and reef degradation
1995	Diani Marine Reserve gazetted, but opposition from fishers prevented it becoming established.
1997/98	Kenya's first major mass-bleaching event
2001	National ban on the use of speargun and beach seine nets for fishing
2002	Minor bleaching event.
2002	Major Harmful Algal Bloom (HAB) reported in Kiunga, with high fish mortality and disease in corals - Montipora, Astreopora and Echinopora; Similar coral disease outbreak reported in Mombasa NP.
2002	First reports of an outbeak of the sea urchin Tripneustes gratilla in seagrass beds in Diani-Chale, with outbreaks over the next 3-4 years noted in Mombasa/Nyali, Watamu and Malindi.
2003-2004	Crown of thorns seastars outbreaks and removal from Mombasa NMP
2004	Indian Ocean Tsunami of 26 December 2004. Impacts in Kenya limited to erosion of some beaches (north), beached boats, some overturned plate corals, and one death
2005	Mild Bleaching event, mortality limited to susceptible species; Pocillopora spp.
2006	The Kuruwitu Community Managed Area designated as Kenya's first LMMA.
2010	Second major bleaching of corals, less severe than 1998 with 17.5% corals bleached.
2012	First community-based coral reef restoration project started in Wasini conservation area.
2013	Kenya receives its first Oceanographic research vessel (RV Mtafiti), donated by VLIZ.
2015	Sand harvesting on outer reef slope in Diani, north coast of Kenya.
2016	Third widespread coral bleaching event.

2.2.7 Responses

Legislation and policies - Kenya has a wide variety of national coastal and marine environmental legislation that goes back several decades to the 1960s and before, that provide a strong legal base for management of marine and coastal resources (Obura 2001). This includes Parliamentary Acts on Fisheries Management (Cap 378, Laws of Kenya), Wildlife Conservation and Management (Cap 372, Laws of Kenya), the Coastal Development (Act no. 20 of 1990, Laws of Kenya), and the Environment Management and Coordination Act (EMCA, 1999). The Fisheries Act has recently been updated (2016). A challenge is to reduce the fragmentation among different institutions and their mandates that affect coral reefs, with the recent Integrated Coastal Zone Management (ICZM) Action Plan and Coral Reef and Seagrass Strategy providing ways to bridge the gaps. A number of policy processes have also been undertaken to improve protection of coral reefs and associated ecosystems:

- The first steps in ICZM were undertaken in 1992, and continued with an ICZM Policy and Plans developed from 2010 to present.
- The National Biodiversity Strategy and Action plan (NBSAP, 2000)
- The first Status of the Coast Report (2008), produced as a baseline for management.

- A National Coral Reef Task Force was developed in 2009 under the Regional Coral Reef Task Force (CRTF) of the Nairobi Convention.
- A Coral Reef and Seagrass Ecosystems Conservation Strategy Plan (2014) was launched for 2015-2019.

Marine Protected Areas (MPAs) - Historically, management of coral reefs in Kenya has been the domain of central government, with a network of 4 marine parks (fully protected) and 6 marine reserves (partially protected, allowing traditional fishing) under the management of Kenya Wildlife Service (KWS).

Fisheries – in areas not managed by KWS, fishing has grown relatively unregulated and unmanaged. Some specific prohibitions exist, such as against spearguns and beach seines, and buffer zones to keep trawlers a certain distance from shore. However, their implementation has been variable over time, with both spearguns and beach seines being among the most popular fishing gears.

Community Conservation Areas (CCAs) - in recent years, coastal fishing communities have embraced the concept of community-based conservation and established 12 demarcated CCAs (the local term for Locally Managed Marine Areas, LMMAs), to enhance sustainable fisheries and other livelihood options such as eco-tourism (Mwaura and Murage 2013). In Kenya, these initiatives are typically undertaken in a co-management framework and are strongly emphasized in recent government policies and regulations, though under authority of fisheries rather than conservation legislation (Samoilys et al. 2011; Obura 2013). However, their effectiveness is not fully demonstrated as the benefits are not yet as clear as those implemented by the government (Mwaura and Murage 2013).

2.2.8 Discussion and recommendations

Monitoring the status of reefs (i.e., in terms of coral cover, key fish species and sea urchins) and understanding their drivers has great relevance for resource managers and policy-makers seeking to protect ecosystem services generated by coral reefs (Graham et al 2013; Jouffray et al. 2015).

The current condition of coral reefs in Kenya varies according to the relative influence of different drivers, including climate change, degree of protection from human disturbances and the intensity of fisheries resource extraction. Bleaching events, particularly the 1998 event that resulted in 50-90% loss of coral cover are a growing concern. However, recovery of reefs has been reported mainly in Marine parks and reserves in southern Kenya than in northern reefs (Obura 2002). Recovery after bleaching is mediated by local ecological factors, so reducing local anthropogenic stressors such as destructive fishing practices and sewage disposal helps to reinforce these ecological recovery factors, and thus increase the resilience of these reefs (Obura 2005).

In the face of increasing direct human impacts and predicted climate-change bleaching events, there is an urgent need to anticipate and prevent undesirable regime shifts and, conversely, to reverse shifts in already degraded reef systems. Such challenges require a better understanding of the primary human and natural drivers that undermine reef ecological status and fishery resources in order to plan for effective conservation and management of coral reefs.

Based on the results of this study, we recommend the following actions to reduce the threats to coral reefs.

1. Encourage community-based protection of coral reefs in partnership with government fisheries department by enhancing legislative mechanisms for their long-term sustainability
2. Reduce use of destructive fishing gears through interventions that reduce effort, such as through development of viable alternative livelihoods
3. Adopt conservation strategies that promote the restoration of degraded reefs
4. Promote long-term monitoring of coral reefs and bleaching events to raise awareness on impacts and management issues to the public, resource users and others.
5. Promote awareness on existing laws and regulations governing management and conservation of coral reefs to stakeholders.
6. Strengthen existing local, regional and international networks for improved consultations and active engagement on conservation and management of coral reefs.
7. Promote awareness of existing laws and regulations governing management and conservation of coral reefs to stakeholders.
8. Engage reef users (boat operators, fishers, hoteliers, resource managers, policy-makers, public) in research and monitoring forums in order to raise awareness and attitude change towards corals/and or reefs.

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2.3 Madagascar

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2.3.1 Summary

The monitoring of the state of coral reefs in Madagascar, which began in 1998, shows that there has been a decline in coral cover for the whole country from about 50% to 30% presently. The period 2004-2005 was a decisive turning point because it was during this period that there were continuous cyclones which caused havoc at several reef sites, even changing their geomorphology by transforming flats colonized by corals into sandy areas smothered by sedimentation. The degradation of reefs nationally is exacerbated by global warming that causes coral bleaching. Mortality due to severe coral bleaching has caused noticeable declines in coral in 1998 and 2004, and most recently in 2016.

To counter this decline in coral reef health, the Malagasy government has pledged to increase the area of marine protected areas by threefold. Currently, there are 18 marine protected areas totaling 1,216,637 hectares, managed by various bodies working in the field of the environment. In addition, there are 149 Local Managed Marine Areas covering 11,770,000 hectares that are scattered across Madagascar. Finally, there are various laws and regulations that regulate and control the exploitation of reef marine resources in ways that do not destructively affect reefs.

2.3.2 Introduction

Situated in the south West Indian Ocean, Madagascar is one of the biggest islands of the world with 587,045 km^2 of terrestrial surface. The Malagasy coastline is over 5600 km long and shelters one of the most important coral reef areas in the western Indian Ocean with 3450 km of coral reefs, comprising 1130 km of fringing reef, 502 km of barrier reef, 557 km of coral banks and 1711 km of immerged reef (Cook 2012). The surface area is estimated at more than 2000 km^2.

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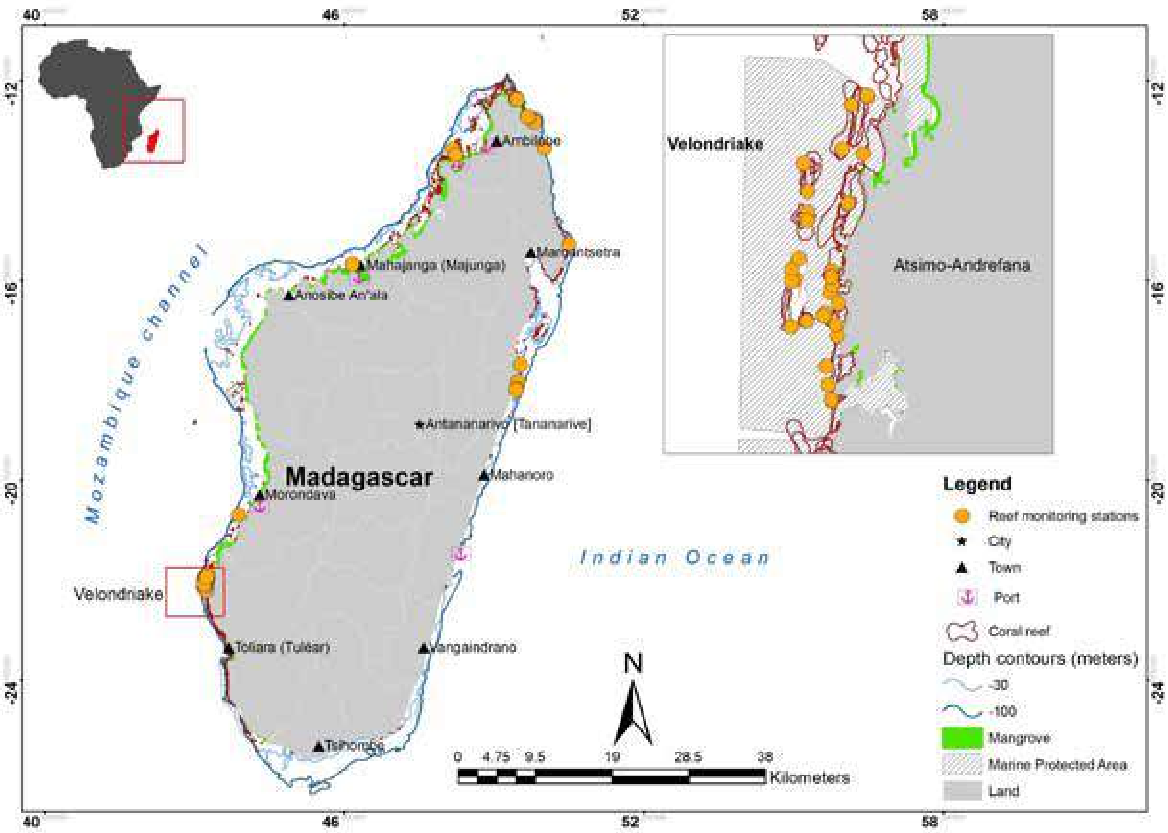

Figure 2.3.1. Madagascar's coral reefs and monitoring stations for which data was included in this study

2.3.3 Status and trends

Live coral cover in Madagascar has shown a gradual decrease from 1998 to present, from an average of 50% to 30% (fig. 2.3.2a). This is a significant 20% regression in about 20 years, with more or less significant peaks of change every four or five years, which could be the isolated consequences of coral bleaching phenomena. After each major bleaching event there is a slight decrease in coral cover. More precisely, there is a fall after 1998, another after 2002 and another after 2012. The results of post-bleaching monitoring in 2017, are expected to confirm the impacts of the year-round phenomenon in 2016, which was one of the most important coral bleaching events of our time. The effect of sedimentation is demonstrated clearly on the submerged reef flat of Antrema, where benthic cover is poor. This is due to terrigenous discharge from the Betsiboka River. Sedimentation was particularly important in 2004-2005, when Madagascar experienced many strong cyclones, contributing to the decline of reefs that year.

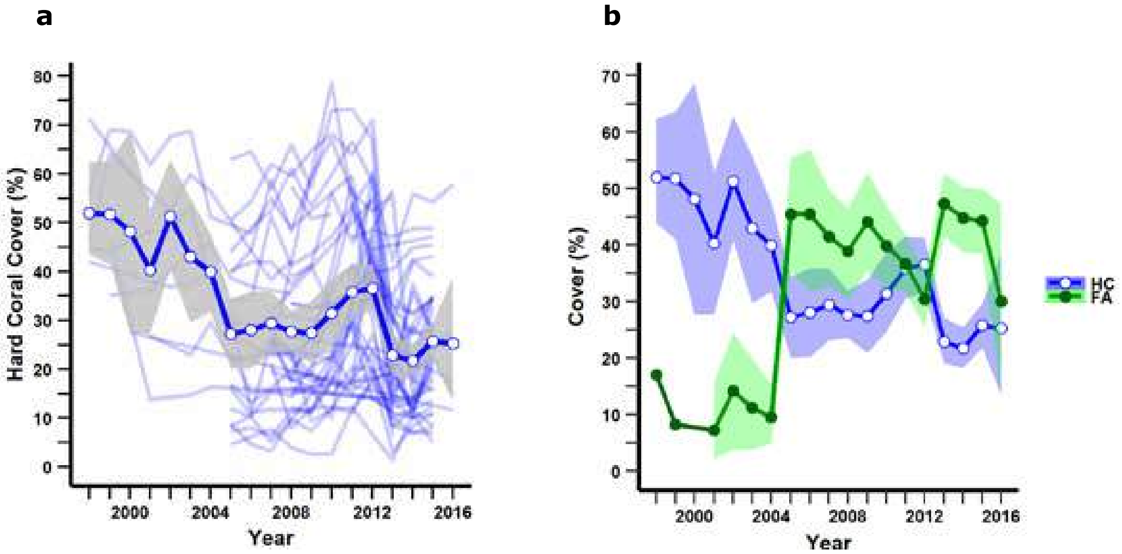

Figure 2.3.2. a) Trend in hard coral cover on Madagascar reefs (national mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines)); b) Trend in mean hard coral cover (blue line, open circles) and macro algae (green line, closed circles) in Madagascar (coloured shaded areas represents 95% confidence limits of the mean)

The inversion between changes in coral cover and that of algae is very clear (fig. 2.3.2b). It is important to mention that this algae does not include the red algae at the reef flat that are correlated with good health of a reef, but rather the brown algae favored by terrigenous sedimentation, and invasive algae favored by the increase in water temperature. The decline in coral cover and disintegration of skeletons or sedimentation creates soft substrates favoring the development of opportunistic algae and other ruderal species.

Fish densities are presented from 2008 to 2016 (fig. 2.3.3). Some families showed evidence of a decrease in density (Haemuidae, Scaridae, Chaetodontidae, Balisitidae, Lutjanidae, Lethrinidae), others were more or less stationary (Acanthuridae, Caesionidae, Mullidae) while the Siganidae and Serranidae showed an increase. The increase in serranids is somewhat surprising, as this group is among the most exploited. The fact that they occupy very varied biotopes including coral and non-coral dominated habitats could perhaps explain why the decline in coral cover does not appear to have influenced their population levels. The abundance of carnivorous coral fish appears to have decreased. Several ecological studies have already shown that there is a significant positive correlation between abundance of coral fish and the diversity and benthos coral cover (Luckhurst and Lukhurst 1978). William (1986) showed that coral degradation can affect some species of fish, mainly those that feed on polyps or use corals as habitat.

The overall decline of many coral reefs in Madagascar is related to land-use activities and fisheries. However there are still reef sites, although quite rare, that still have good coral cover and fish populations. It should also be noted that initiatives to create marine protected areas have begun to bear fruit as newly protected sites are beginning to regenerate, for example Tanikely reef (Nosy Be) where there is an increase in coral cover, and Nosy-Faho, on the east coast, where protection is provided by its remoteness and difficulties to access it.

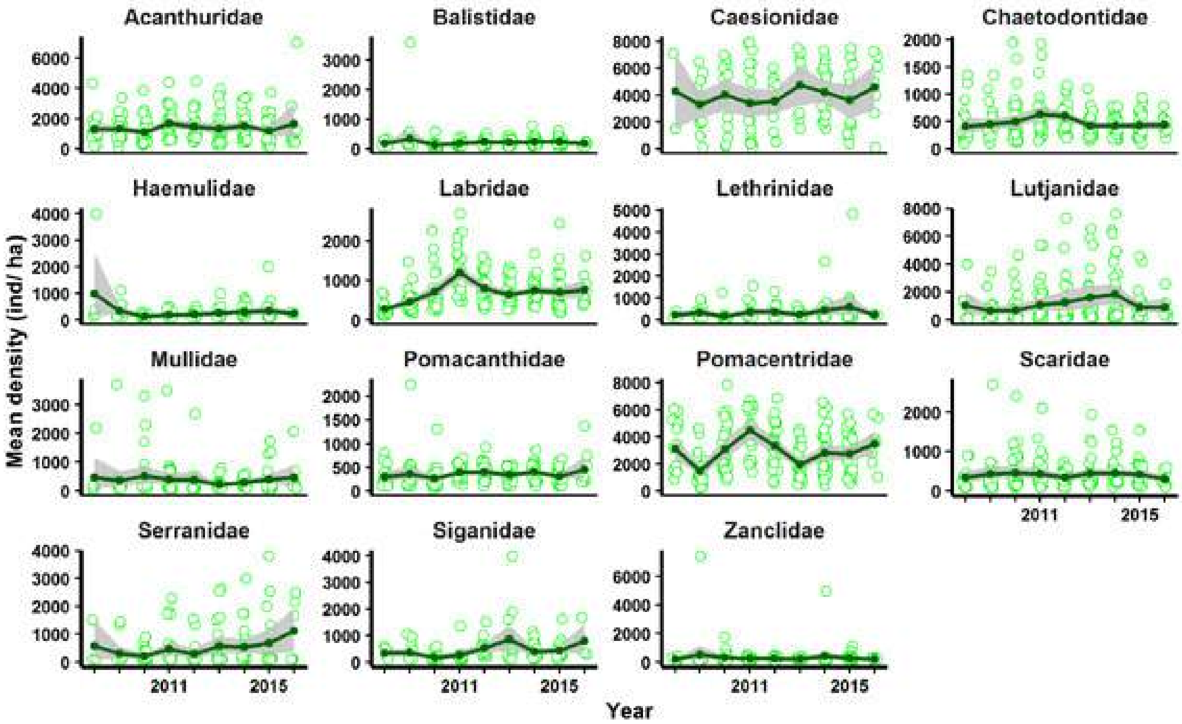

Figure 2.3.3. National averages of fish abundance for 15 fish families on coral reefs in Madagascar (circles represent surveyed sites and shaded areas represent the 95% confidence limits).

2.3.4 Coral bleaching 2016

Coral bleaching in 2016 was widespread, affecting all the reef sites on this large island. Almost 30% of reefs surveyed showed 50% bleaching or greater, but sampling of sites after the bleaching event was limited (fig. 2.3.4).

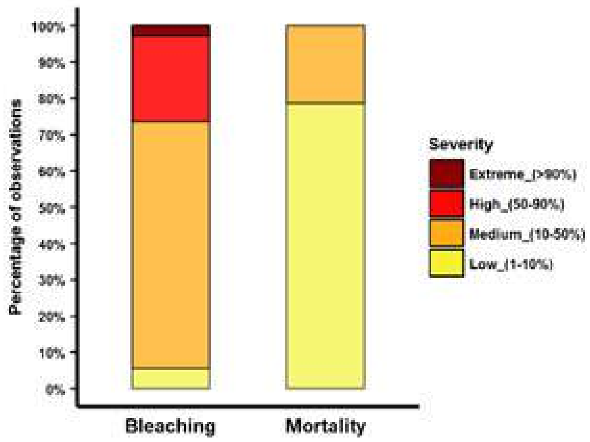

Figure 2.3.4 Breakdown of observations of coral bleaching (n=72) and associated mortality (n=28) collected in Madagascar in 2016. Categories represent the severity of bleaching/ mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site. The bleaching period was from January-May, and mortality from May-September.

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Precise data were collected at three sites in the Northwest: Fascène bay, a big bay in the north of Nosy-Be Island, and on two reef zones in Dzamandjar one of the long term monitoring sites started in 1997. Surveys were undertaken in May 2016. Bleaching varied among genera. Surveys at Dzamandjar showed different levels of bleaching on the fore reef and back reef. On the fore reef (fig. 2.3.5a), some genera were 100% bleached, while three genera *Acanthastrea, Cyphastrea* and *Gardineroseris* remained normal. On the back reef (fig. 2.3.5b), five genera (*Acropora, Pavona, Echinopora, Goniopora* and *Montipora*) were 100% bleached while one genus, *Acanthastrea*, was unaffected. At Fascene Bay, 50% of colonies were bleaching and 15% dead (fig. 2.3.6a), with Acropora showing 50% incidence of mortality (fig. 2.3.6b).

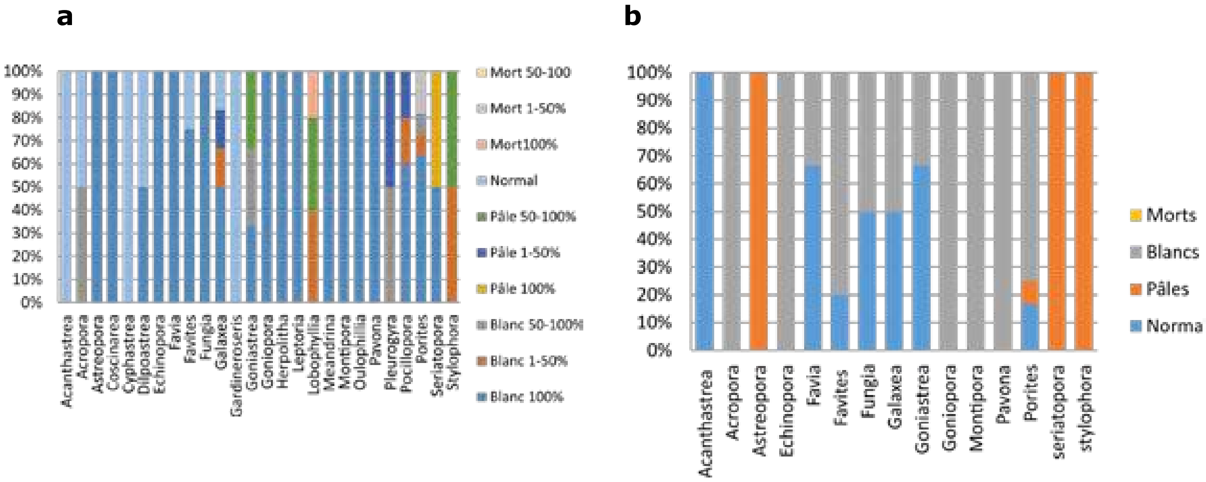

Figure 2.3.5. Status of coral bleaching 2016 in Dzamandjar (back reef), north-west of Madagascar - a) back reef, b) fore reef.

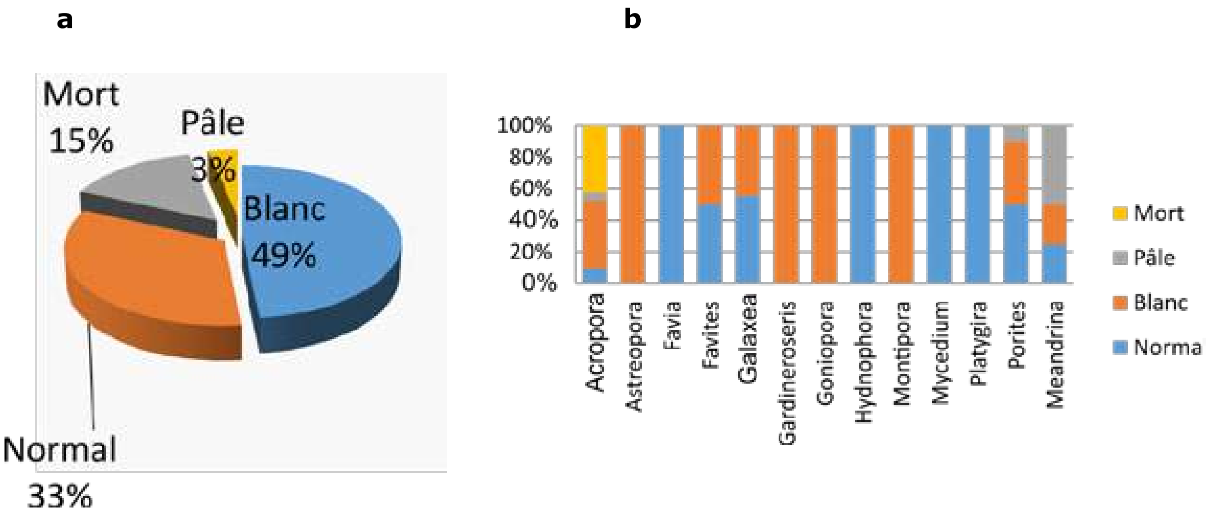

Figure 2.3.6. Status of coral bleaching 2016 in Fascène Bay, north-west of Madagascar - a) by number of colonies, and b) by genera.

2.3.5 Drivers and pressures

Threats affecting the coral reefs in Madagascar are quite similar the situation in other countries with coral reefs. There are anthropogenic factors such as marine pollution, coral extraction, and mechanical degradation of corals through trampling due to fishing by walking or poorly managed tourism. Sedimentation has already been mentioned in the interpretation of the results. It is due to both anthropogenic factors as a result of deforestation, which favors coastal erosion, but also to cyclones whose impacts on reefs in terms of sedimentation are very important. All these vulnerability factors are exacerbated by climate change, which is a cross-cutting theme that encompasses ecological, socio-economic and even political issues. The notion of adapting to climate change in the natural resources exploitation system in general, and marine reef resources in particular, is a major issue that must be central in planning for coral reef conservation.

In Madagascar, the value of marine resources has not kept up with changes in the economy and market practices. It still remains as it was a hundred years ago, where raw fish are bought and sold locally, with no value-addition to transform them into more valuable products. For a fisherman, if he wants to increase his income, and he is obliged to do so, he must increase how much he catches. However, resources are becoming scarcer due to excessive pressure and the decrease in the productivity of natural ecosystems.

We are concerned that under current conditions Malagasy fishers cannot rise out of poverty with the limited resources available. What is needed are innovation, product transformations, and economic transformation – which require political will. Faced with climate change, if the state does not assist peasants and fishermen to become the actors of an economic transformation, they will be obliged always to draw on already-depleted natural resources. Herein lies the most important threat to Madagascar's natural ecosystems, of which coral reefs are one example.

2.3.6 Timeline

It is not obvious to generalize for all Madagascar periods or events that have happened and that generate structural changes in the coral reefs. Coral bleaching events that are fairly regular and repetitive seem to be the most influential phenomenon in Madagascar's coral cover. These are the cases of the 1998, 2002 and 2016 bleaching events that marked the coral reefs of Madagascar through the degradation and mortality that they caused. In addition, there are cyclonic events such as cyclones Gafilo and Josie that have structurally changed some reefs like that of Antrema or Nosy-Faho reef flat (Toamasina, east coast). There is also the almost complete transformation of the Great Reef of Toliara, where the reef flat formerly covered with corals has become a sandy-muddy detrital flat without a single coral colony. The reef of Nosy-Vato, on the side of Toliara Bay completely disappeared and became a sand bank. These comprehensive changes have taken place in the space of about 20 years.

Nevertheless, important events related to coral reefs in Madagascar include:

1997	International seminar on the relation between humans and coral reefs in Nosy-Be, that created the regional coral reef network for the IOC member states
1998	First major bleaching event
2004-2005	Cyclonic event with negative impact on coral cover
2016	Second major bleaching event

2.3.7 Responses

Area-based protection for coral reefs has had a long history in Madagascar. To date, there are 18 MPAs (fig. 2.3.7) totaling 1,216,637 ha managed by Madagascar National Park, WWF, WCS, Blue Ventures, Service d'Appui à la Gestion de l'Environnement. Recently, Locally Managed Marine Areas have become a popular instrument, now numbering 149 LMMAs covering 11,770,000 ha. Communities and stakeholders active in the LMMAs jointly created the MiHARI network, a national network for LMMA support and capacity building. The number of beneficiary peoples for these initiatives has been estimated at over 148,000.

In 2015, the President of Madagascar declared in Sydney, during the World Parks Congress, the intention of Madagascar to increase the area of marine protected areas in the country by 3 times. This engagement will significantly enhance coral reef preservation as most marine protected areas have a strong focus on coral reefs.

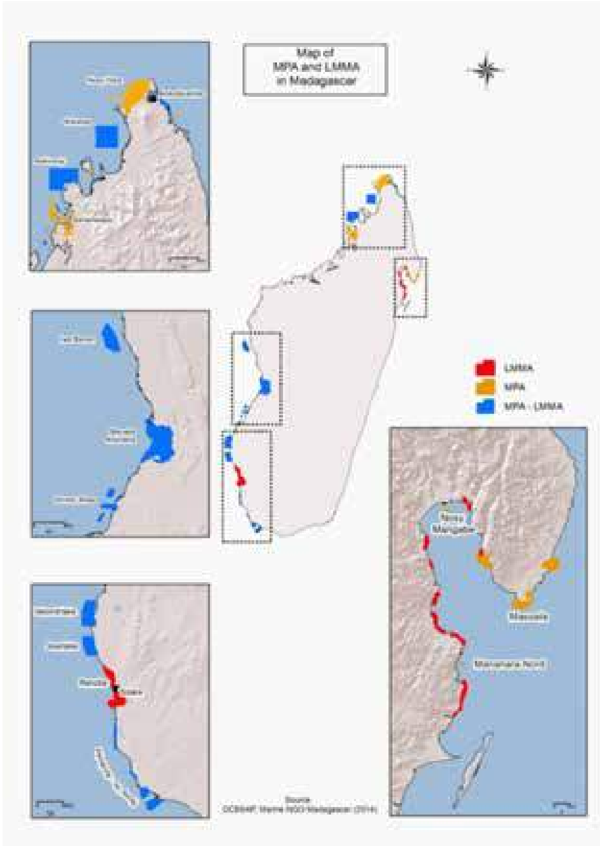

Figure 2.3.7- Location of Marine Protected Areas (MPAs) and Locally Managed Marine Areas (LMMAs) in Madagascar

A number of policy actions have also been initiated relevant to coral reefs. The national committee of Integrated Coastal Zone Management was created in 2010, under which a sub-committee for coral reefs. In 2016, a State Secretariat in charge of the sea and marine resources was established with a broad mandate over Madagascar's ocean domain. The last 5 years have seen the redynamisation of the coral reef network, and validation of the regional reef network charter. Sensitive marine resources have been protected by specific legislation against exploitation - for black corals (2013) and holothurians (2016)

2.3.8 Conclusion

Madagascar's coral reefs have shown a relatively rapid and significant decline in coral cover from 50% to 30% in the last 20 years, losing 20% of cover, or around 1% per year. At this point, therefore, only 60% of the known coral cover of Madagascar has been left since 1998. the long term future of Madagascar's reefs is therefore uncertain, and particulary as the rate of degradation is expected to accelerate in coming years, with the direct or indirect effects of climate change. Of course, the degradation is not linear and many factors could influence this evolution, but it helps the decision-makers to reflect on the future of our coral reefs.

Our recommendation concerning the future of coral reefs in Madagascar goes far beyond the limit of ecology because it is no longer sufficient to focus only on traditional threats such as pollution, destructive fisheries, deforestation, etc. These can be managed because they are generated by local human activities. With the advent of climate change, it will no longer be enough to create marine protected areas. There is now a pressing need for assistance and support to increase awareness and training to increase the adaptability and resilience of Madagascar's public to the consequences of current and future changes.

2.3.9 References

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Williams DMcB (1986) Temporal variation in the structure of reef slope fish community (central great barrier reef): short term effect of *Acanthasterplanciinfestation*. Mar Biol Prog Ser 28: 157-164.

2.4 Mauritius

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2.4.1 Summary

The Republic of Mauritius consists of several outlying islands all located in the south-western part of the Indian Ocean. For its two main islands, Mauritius and Rodrigues, long-term coral reef monitoring has been on-going since the late 90's and there are currently 38 and 13 monitoring stations in Mauritius and Rodrigues respectively. On Mauritius Island, long-term monitoring of coral reefs shows an overall decline in live coral cover at both backreef and forereef sites from close to 50% in 2002 to around 20% eight years later. This decline can be attributed to frequent bleaching events which have been increasing in intensity and severity. In Rodrigues, coral reefs seem to have undergone little change over the past few years, remaining at around 40%. In 2016, mild to moderate bleaching was observed in several lagoon and off-lagoon sites around Mauritius Island however post-bleaching surveys reported recovery of most bleached corals. Sites where coral cover has improved has been attributed to greater control of activities within conservation zones supported by strong legislation and enhanced enforcement, such as in Blue Bay Marine Park. Examples of other responses to pressures include the establishment of an Integrated Coastal Zone Management framework including the establishment of a National Coral Reef Network/Task Force, and the implementation of national projects including coral reef restoration and coral reef research programmes.

2.4.2 Introduction

The Republic of Mauritius, located in the south-western part of the Indian Ocean (Map 1), consists of the main island Mauritius (1,865 km²) and several outlying islands namely: Rodrigues (108 km²), St. Brandon or Cargados Carajos Archipelago (1.3 km²), Agaléga (~21 km²), Tromelin (~0.8 km²), and the Chagos Archipelago (~56 km²) which includes the Diego Garcia atoll. With a total land area of 2,040 km², total length of coastline of

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496 km and 16,840 km² of territorial sea, Mauritius holds jurisdiction over an Exclusive Economic Zone (EEZ) of about ~1.9 million km². It also jointly manages, with the Seychelles an extended Continental Shelf of 396,000 km² in the Mascarene region.

Coral reef monitoring in Mauritius has developed independently across the different islands (fig. 2.4.1). In 1996, the Albion Fisheries Research Centre (AFRC) initiated an island-wide long term permanent monitoring of coral reef ecosystems at 21 selected sites on the main island, including shore, backreef and forereef sites. The monitoring programme includes collection of data on coral and benthic cover, fish and invertebrate biodiversity and crown of thorns (COTs) starfish prevalence at study sites. Of the 248 stations surveyed, 62 have been established as permanent monitoring stations but with only 38 (33 in lagoons and 5 off-shore) being regularly monitored over time. Monitoring on Rodrigues island started in 1999 with 13 being regularly monitored over time. Individual surveys have been conducted on St. Brandons and Agalega islands, and to date the Republic of Mauritius has not yet been able to carry out coral reef surveys in Tromelin Island and the Chagos Archipelago.

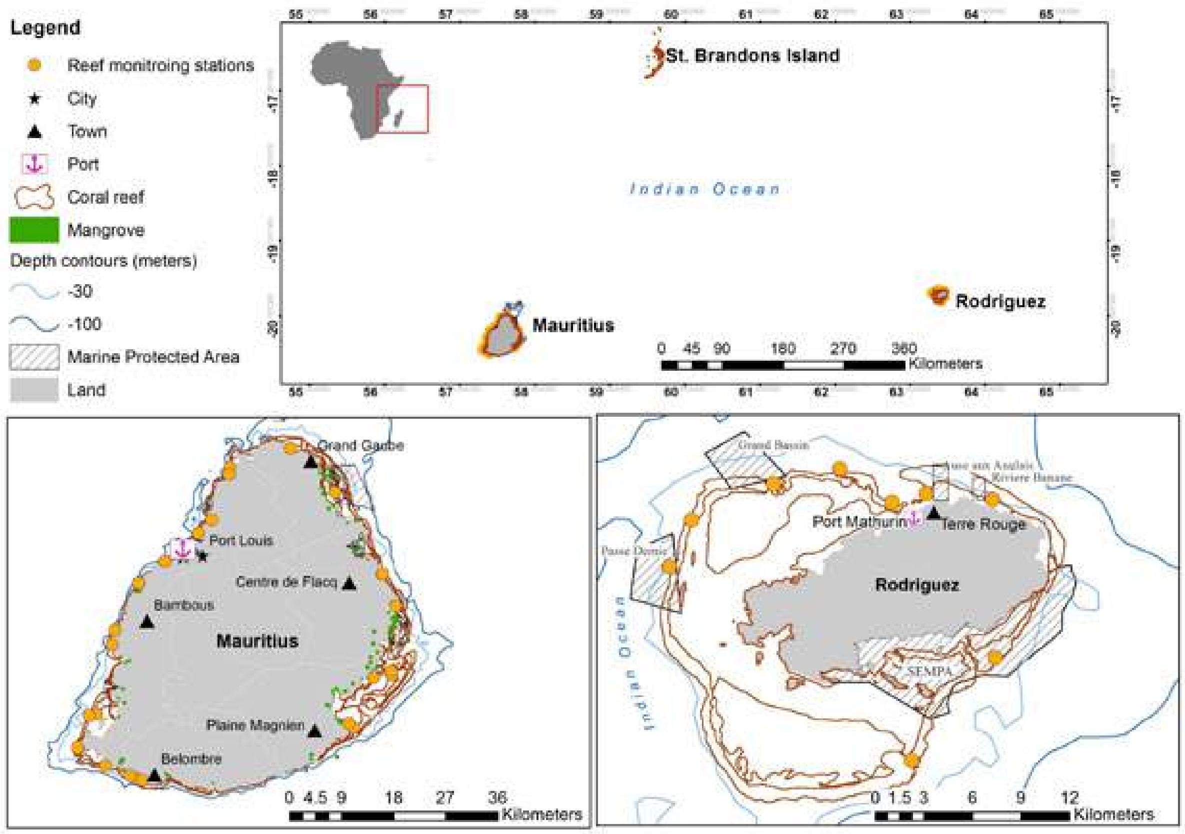


Figure 2.4.1 Main islands of the Republic of Mauritius, and the coral reefs and monitoring stations on Mauritius and Rodrigues for which data was included in this study

2.4.3 Status and trends

From 2002 to 2010 a progressive decline in coral cover is shown on coral reefs on Mauritius Island (fig. 2.4.2a), though cover at individual sites varied widely, from <10 % to 80%. In 2011 a significant break in the monitoring record occurred, with monitoring at many sites being stopped, and new sites being started. The jump in coral cover in 2011 is likely an artefact of this, following which a continuing decline in coral cover is shown from 2011 to 2014. By contrast, Rodrigues shows a progressive increase in coral cover over the monitoring period, from 20-40% in early years to 50% in 2014.

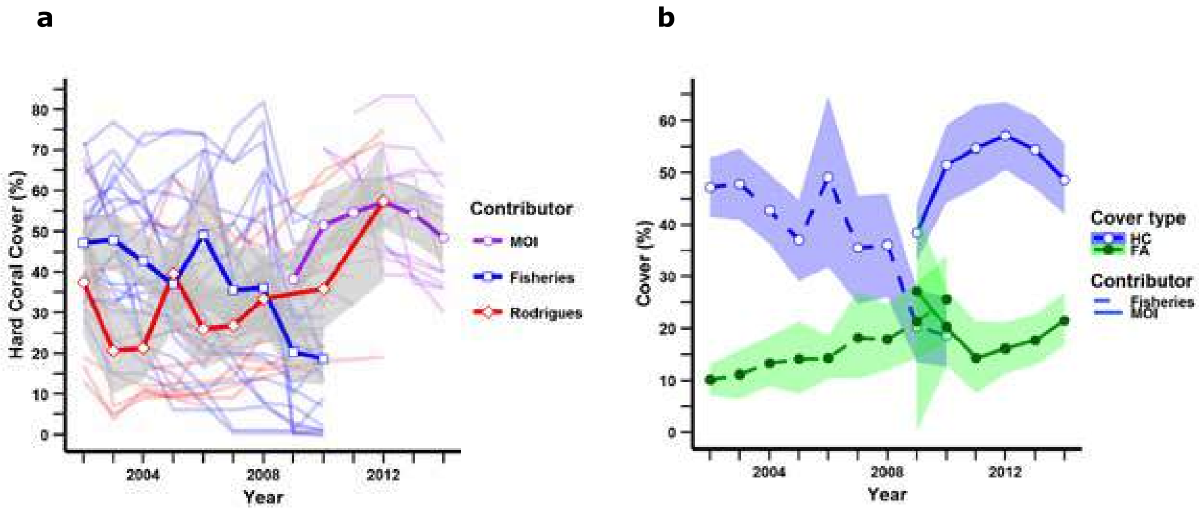


Figure 2.4.2. a) Trend in hard coral cover in the Republic of Mauritius Island from two sources on Mauritius Island (MOI and Fisheries) and from Rodrigues Island (mean (thick line), 95% confidence interval (grey shaded area), individual monitoring stations (light lines). b) From Mauritius Island alone, trend in mean hard coral cover (blue line, open circles) and fleshy algae (green line, closed circles) (coloured shaded areas represents 95% confidence interval of the mean). MOI- Mauritius Oceanography Institute; Fisheries - Albion Fisheries Research Centre.

Complementary patterns are shown in the cover of fleshy algae on Mauritius Island, which increases progressively form 2002 to 2010 and from 2011 to 2014 (fig. 2.4.2b). The decrease in fleshy algae from 2010 to 2011, compensatory to the jump in coral cover is nevertheless much less. Comparing reef zones on Mauritius Island, back-reef stations showed the overall decline from ~49% in 2002 to ~18% in 2010 (fig. 2.4.3a). Fore reef and shore reef monitoring sites showed the same decline from 2002 to 2010 but were discontinued, and not monitored from 2011 onwards. Going against this trend, reefs in the Blue Bay Marine Park showed a gradual increase in live coral cover after the 2009 coral bleaching event, reaching about 40% of the total substrate cover.

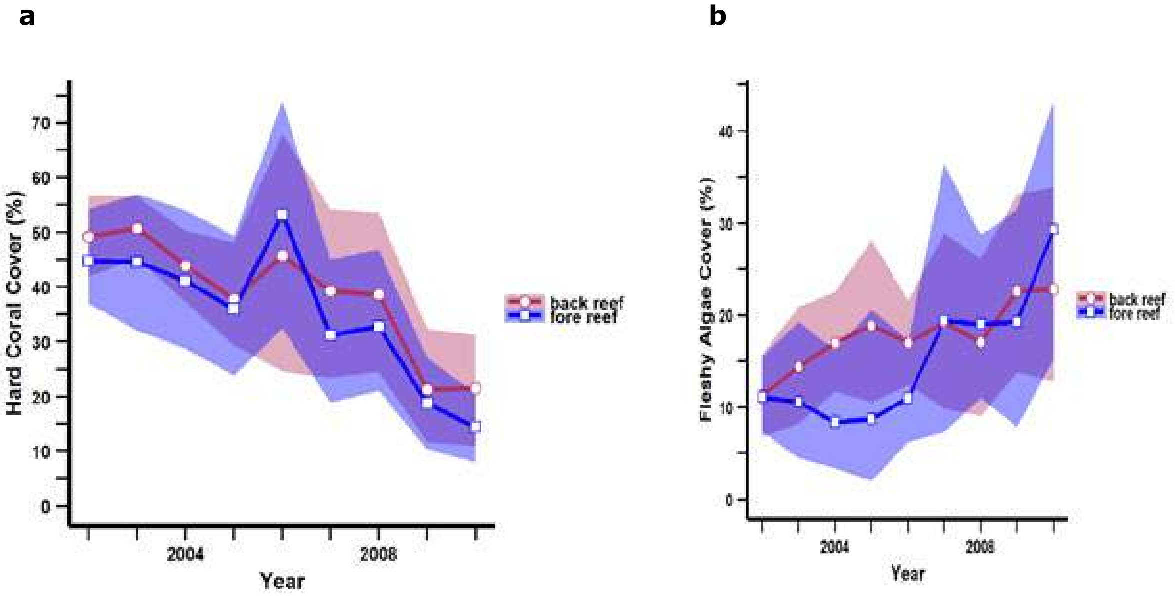


Figure 2.4.3 Comparison of mean percent cover of (a) live corals (b) fleshy algae for Mauritius Island separated by fore reef and back reef zones with 95% confidence limits (using only Albion Fisheries Research Centre data)

Coral reefs of Rodrigues have undergone little change from 2002 to 2010, but discontinuity in monitoring sites in 2012 resulted in the maximum % live coral cover recorded of >50% (Fig. 2.4.2a). The % live coral cover on the reef slopes has been consistently higher than that of the back reefs, at 50% and 20% in 2012, respectively (fig. 2.4.4), likely due to storm damage reducing cover on the shallow reef flats (Lynch et al. 2003).

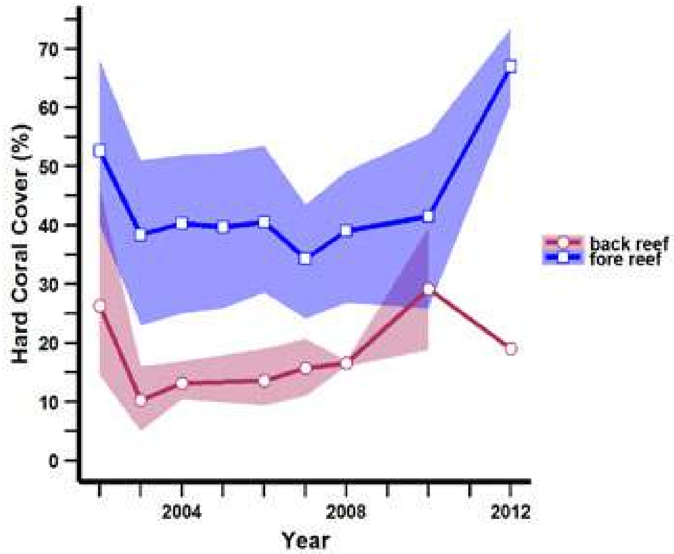
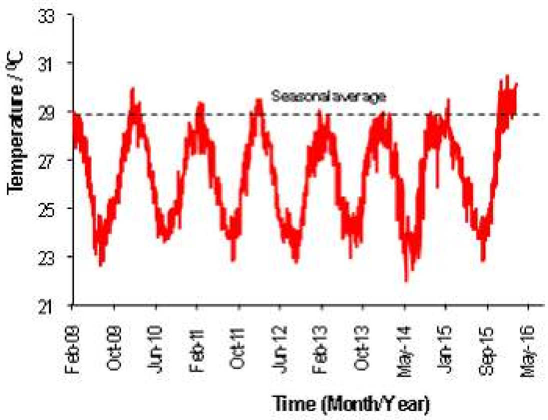


Figure 2.4.4 Mean percent cover of live corals on Rodrigues Island separated by fore reef and back reef zones (shaded areas represent 95% confidence limits of the mean)

The decline in coral cover on Mauritius Island is strongly attributed to frequent bleaching events recorded in 1998, 2003, 2004 and 2009 with increasing intensities and severities, further exacerbated by persistent land-based activities (fishing, coastal development, water pollution, algal proliferation, sedimentation among others). Moreover, the invasion of crown of thorns and coral diseases have also been recorded, thus contributing to the reef degradation. The recovery of live coral cover in Blue Bay might potentially be due to increased larval settlement and coral recruitment, complemented by the implementation of the Blue Bay Marine Park Management Plan, with greater control of activities in the strict conservation zone supported by strong legislation and enhanced enforcement.

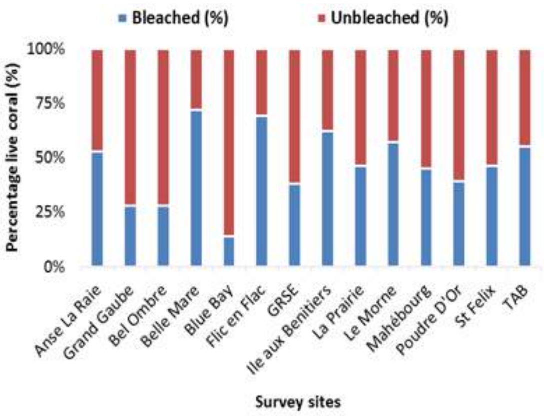
2.2.4 Coral bleaching 2016

During the early months of 2016, *in-situ* sea-water temperature in the nearshore waters of Mauritius peaked above the seasonal average (29^{0}C) (Fig. 2.4.5a) causing mild to severe bleaching in several lagoon and off-lagoon sites around the island (Fig. 2.4.5b). Overall, bleaching was widespread but at mild to moderate levels, with 40-50% of the island's live coral cover partially or totally bleached (Fig. 2.4.5c). A qualitative survey of over 14,000 colonies showed that 42% of the live corals were partially bleached. Among the sites surveyed, Belle Mare, Flic en Flac and Ile aux Benitiers were the most affected with more than 65% of their live corals having partially bleached. By contrast, Blue Bay, Bel Ombre and Mon Choisy were the least affected sites, with less than 15% bleaching (fig. 2.4.5d). Among genera, *Acropora* (>80%) was the most affected, in particular the species *A. muricata* (>85%), *A. cytherea* (>70%) and *A. selago* (>60%). Post-bleaching surveys at several affected sites (i.e. Anse la raie, Belle Mare, Grand Gaube) have reported recovery of partially bleached corals, with low cases of coral mortality.



a) Mean daily daytime temperature (^{0}C) recorded by in-situ loggers at Grande Rivière Sud-Est (GRSE) (depth: <2.5m) from Feb-09 to Mar-16 (MOI Newsletter 1-2, 2016).

b) Locations where bleaching surveys were undertaken in 2016.



c) Mean percent bleached and unbleached corals recorded during quantitative surveys at selected reefs sites around Mauritius (MOI Newsletter 1-2, 2016).

d) Levels of bleaching recorded at surveyed sites (in lagoons & off-lagoon) around Mauritius

Figure 2.4.5. Composite figure on bleaching observations in Mauritius, 2016. Data compiled on bleaching records from MOI & AFRC qualitative surveys).

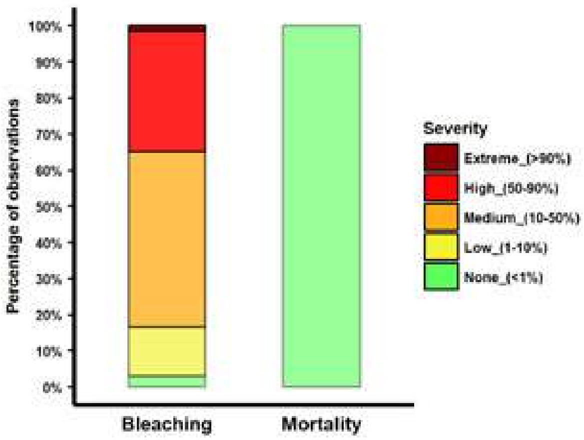


Figure 2.4.6 Observations of coral bleaching (n=66) and associated mortality (n=1) collected in 2016 for Mauritius Republic. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site. Only 1 site reported coral mortality estimates between May and September.

The bleaching event impacted the AFRC coral farming project at Blue Bay Marine Park, started in 2014. About 45% of the coral fragments had survived since the project started and were ready for transplantation, and then in March showed partial bleaching. Gradual recovery following the bleaching event has occurred.

2.4.5 Drivers and pressures

The reefs of Mauritius are under significant pressure from a combination of natural and human induced impacts. The major threats contributing to the current on-going reef degradation are:

- Global warming, increased sea/ocean water temperatures and increased frequencies and severity of El Niño events.
- Persistent increased in fresh water runoffs, reduced salinity, eutrophication (nutrient enrichment), increased sedimentation, erosion and pollution (marine pollution and pollution from inland activities), due to agricultural inputs, coastal development, deforestation, urbanisation and industrialisation.
- Increased fishing pressure: over-fishing, illegal fishing and destructive/bad fishing practices (i.e. trampling over corals, anchor damage, seasonal seine net fishing in Mauritius).
- Increased recreational activities inside lagoons.
- Ocean acidification.
- Cyclones and storm surges.
- Coral diseases (i.e. microbes including pathogens, white band diseases, Turpios sponge).
- Predator outbreaks (i.e. Crown of thorns, *Acanthaster planci*, corallivorous snails *Drupella sp.*).

2.4.6 Timeline

		Impacts on:	
Year	**Event**	**Mauritius**	**Rodrigues**
1998	Severe coral bleaching event (loss of more than 10% of live coral cover in Mauritius).	✓	✓
1999	Intense cyclone Davina.	✓	
2001	Mild bleaching event	✓	✓
2002	Very intense tropical cyclone Dina.	✓	
2002	Mild bleaching event	✓	✓
2003	Intense Tropical Cyclone Kalunde. Sporadic coral bleaching event (National Ocean science Forum, NOSF 2003)	✓	✓
2004	Crown of thorn starfish (COTs) outbreak reported at certain sites.	✓	
2005	Mild bleaching event	✓	✓
2007	Tropical cyclone Gamede.	✓	
2009	Coral bleaching in some lagoons around Mauritius, including algal blooms resulting in coral and fish mortality (Source: AFRC) Selective bleaching of massive Porites in some lagoons of Mauritius (MOI)	✓ ✓	
2012	Mild bleaching event	✓	✓
2013	Flash flood events mainly affecting the northern region of Mauritius.	✓	
2015	Intense cyclone Bansi.		✓
2015	Flash flood events mainly affecting the southern region of Mauritius.	✓	
2016	El Nino 2016: Coral bleaching event (40-50% bleaching recorded)	✓	✓

2.4.7 Responses

Reefs of the Republic of Mauritius are of prime importance and for the past years, a lot of effort has been put into implementation of management measures for their protection. In order to reduce pressure in the lagoon, the Ministry has formulated and is implementing several regulations, policies and management measures to better protect and conserve the marine biodiversity while promoting sustainable utilisation of marine resources. Apart from the proclamation of Marine Parks, Fishing Reserves and delimitation of other no-take zones, application of certain laws, legislation and guidelines by the Government of Mauritius as well as implementation of successful national projects accompanied by proper sensitisation programmes, are significantly contributing to conservation of coral reefs locally.

The demarcation of areas under special management is a core strategy used by the government. Mauritius has proclaimed 8 MPAs that include 6 fishing reserves and 2 marine parks and the Marine Protected Areas Regulations are prescribed in the Fisheries and Marine Resources Act 2007 (see fig. 2.4.1). Blue Bay Marine Park (3.53 km^2) was proclaimed in 1997 and declared a Marine Park in June 2000 under the Fisheries and Marine Resources Act 1998. In 2008, it acquired the status of a Ramsar Site. Since July 2016, its Visitors Centre is fully operational and actively contributes to the Sensitisation/ Public Awareness Programme on the importance and conservation of the marine ecosystem. In Rodrigues, 4 Marine Reserves and a multiple-use Marine Protected Area in the south-east of Rodrigues (SEMPA) have been gazetted in 2007 and 2009 respectively. Several offshore islets are classified as Nature Reserves (7 out of 49 islets surrounding Mauritius) and National Parks (8 out of 49 islets surrounding Mauritius).

The application of policies, guidelines, laws and legislation has touched on many threats to coral reefs, and in laws spanning management of the coastal zone, environmental protection, fisheries, tourism, planning, and maritime/oil spill contingency plans. Activities have included: reduction of coastal/lagoonal fishery by encouraging artisanal fishermen to use off-lagoon Fish Aggregating Devices (FAD), banning of sand mining/coral sand extraction from the lagoon (2001), prohibitions on coral and shell collecting, a moratorium on sea-cucumber exploitation (2008), application of Environment Impact Assessment guidelines for regulated coastal development, zonation of lagoons for different sea-related activities, octopus and seine net fishing periodical closures and gear buy-back,.

Implementation of an Integrated Coastal Zone Management (ICZM) framework started with an establishment of an ICZM Division within the Department of Ministry of Environment in 2002. Under this, several sub committees were established, including one on Coral Reefs, under which a National Coral Reef Network (NCRN)/Task Force has coordinated coral reef activities. The ICZM Sub-Committee on Coral Reef includes representatives from concerned Ministries, National Coast Guard, University of Mauritius, Tourism Sector, Wastewater Management Authority, Reef Conservation, Mauritius Marine Conservation Society (MMCS), Indian Ocean Commission, and Dive Centres among others.

Some key activities by the National Coral Reef Network in 2015/2016 include a field training at Belle Mare on the harmonisation of the methodology for coral reef monitoring and data collection on substrate cover and associated biodiversity (December 2015), and a three half-day workshop on Coral Diseases Identification and Monitoring (May 2016).

The government of Mauritius is also exploring new techniques and technologies for coral reef restoration. Projects include one on coral farming for small scale rehabilitation (by MOI and AFRC, initiated in 2008), with test sites on both Mauritius and Rodrigues. A second project to enhance coral recruitment involved collection of fertilised coral eggs during a coral spawning event at one site, and transferring those to the lagoon at Blue Bay Marine Park, to enhance settlement. These projects may also eventually contribute to conservation of locally threatened coral species through maintenance of a brood stock on-land thus retaining overall coral diversity

Finally, to increase awareness about the importance of coral reefs, governmental institutions as well as NGOs are involved in sensitisation campaigns targeting the public. A major component of this was the establishment of the Blue Bay Marine Park Visitors Centre (fully operational since July 2016), plus a number of activities such as interviews, public talks, distribution of pamphlets, field guides and posters, public events, implementation of community-based projects, guided visits to coral reef sites and training of eco-guides.

2.4.8 Recommendations

As a small island developing state (SIDS), Mauritius is continuously exposed to natural and anthropogenic impacts contributing to persistent reef degradation. It is therefore imperative to continue monitoring reef health through on-going field data collection, compilation and analysis, for informed decision making to enhanced reef management measures. A broad range of priorities have been identified and reported in the National Report on coral reefs (2016) on which this chapter is based. Limited data is available on the health status of coral reefs at the outer islands of Mauritius. There is therefore an urgent need to characterise marine biodiversity at these islands.

Due to inadequate studies on local reefs, limited data availability at some sites, irregular timeline for data collection and lack of long-term monitoring, it is very difficult to compare data at different sites in time. There is therefore an urgent need for:

1. Harmonisation and standardisation of methods/protocols for field data collection for survey targets.
2. Undertaking further multi-disciplinary studies on coral diseases, coral larvae recruitment sedimentation in lagoons, impacts of bleaching events, physical studies on salinity, pH and ocean acidification, phytoplankton & zooplankton distribution and abundance, regular sea water quality monitoring and invasive and exotic marine species.

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2.5 Mozambique

Author: *Erwan Sola[1]*

2.5.1 Summary

Coral reef monitoring at the national level started in Mozambique in 1999, but irregular funding and support has resulted in patchy coverage of data across the years, and loss of early data. Nevertheless, the spread of monitoring sites in recent years, and summary data from early years enables an overall trend in reef health to be discerned. Coral cover has declined progressively across the country, from a mean of 30-60% in 1999 to about 20-30% today, under pressure from mass bleaching events, flooding from terrestrial runoff from cyclones and heavy fishing. The global coral bleaching event in 2016 impacted reefs in both the north and south of Mozambique with half the observed reefs showing medium or higher levels of bleaching (>10%), though final mortality was observed to be low (< 10%). Synchronous spawning of *Acropora* coral species in the Quirimbas archipelago is a unique feature for the Western Indian Ocean, and may have important effects on recovery of reefs following mass mortality. Significant investment in coral reef monitoring is needed for Mozambique in coming years, given the importance of its reefs nationally and at regional levels, and the growing threat and opportunity of offshore natural gas extraction.

2.5.2 Introduction

In 1998, the first initiative to establish a coral reef monitoring Programme in Mozambique was the result of a joint effort from UGC (Unidade de Gestão Costeira), IIP (Instituto de Investigação Pesqueira) and UEM (Universidade Eduardo Mondlane). The Mozambique Coral Reef Monitoring Programme (MCRMP) was launched in 1998 under MICOA (Ministry of Environment), with funding support and technical assistance of Sida's CORDIO (Coral Reef Degradation in the Indian Ocean). Motivated in part by the need to assess damage incurred by the global mass bleaching events of 1998, objectives of the initiative were to establish a network of long-term monitoring sites, use the programme to inform coral reef management at a national level, and build national capacity (Motta et al. 2002). Consistent monitoring ended in 2002/2003 due to financial and institutional reasons, and since then monitoring has been ad hoc, based on projects and individual studies. Monitoring in Mozambique is thus characterized by low frequency sampling at sparse locations.

The northern part of Mozambique is characterised by extensive coral formations fringing the coastline and the extensive island systems in the Quirimbas and Primeiras/Segundas island groups (Motta et al. 2002). This section forms a part of the high-diversity core region identified for the Western Indian Ocean (Obura 2012). The southern half of Mozambique is a high-energy coast with rocky outcrops covered by a non-accreting coral reef veneer (Ramsay 1994, 1996), which continues towards the southernmost distribution of corals in South Africa (Boshoff 1981). The central section, with numerous major river outlets and associated mangroves, is devoid of coral reefs.

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Acknowledgements: *Data presented in this chapter are exctracted from the publications and reports listed in the reference or kindly contributed by Isabel da Silva and Marcos Pereira*

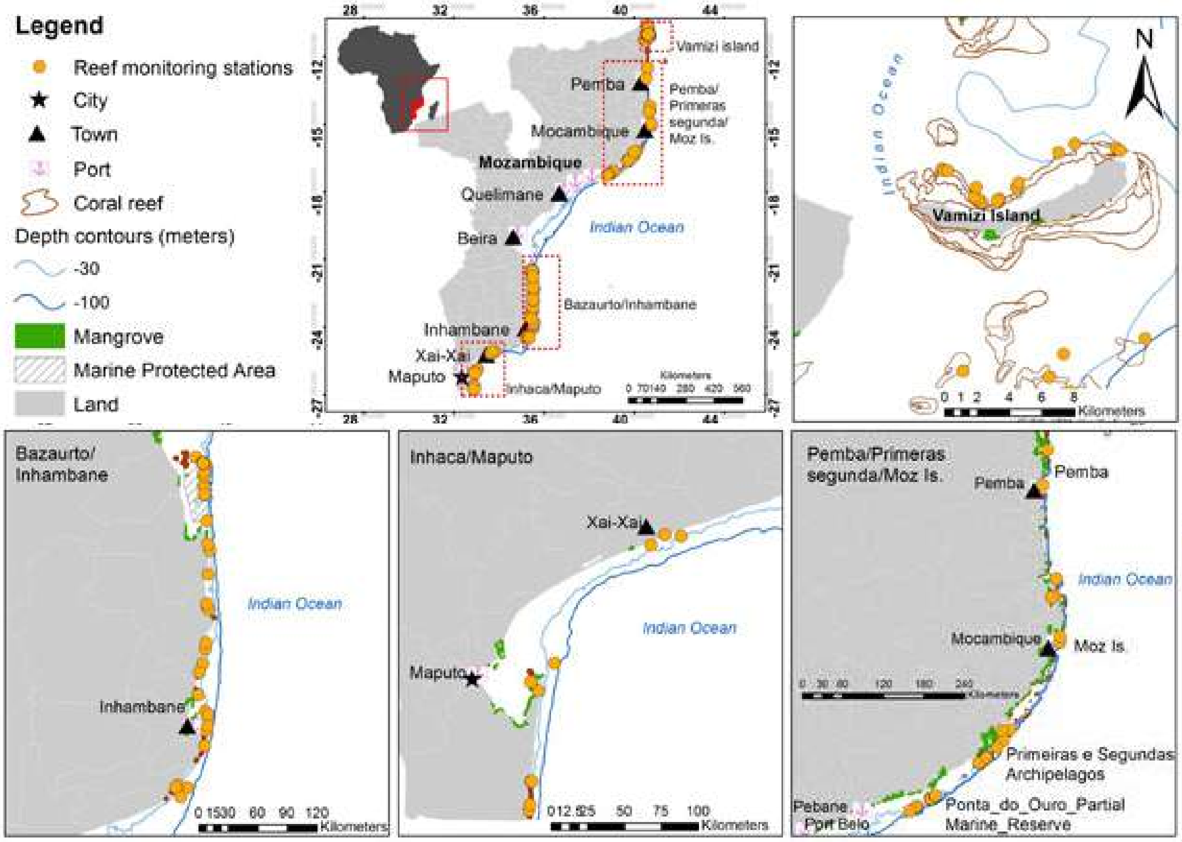

Figure 2.5.1 Republic of Mozambique's coral reefs and monitoring stations for which data was included in this study

2.5.3 Status and trends

Data on coral cover retrieved from earlier reports shows cover of 30-60% prior to 2000, and progressive decline since then (fig. 2.5.2). Due to very little continuity in monitoring over the full time period only broad patterns can be inferred, suggesting coral cover decline over the last two decades. Conversely, fleshy algal cover has remained relatively low, apart from a single record in 2003. The high fleshy algal cover in 2015 is from surveys in the southern reefs of Inhambane Province, which naturally have high fleshy algal cover.

From the literature and isolated studies, coral reefs in northern Mozambique have remained healthy and vibrant, in spite of variable impact of bleaching events, and high fishing pressure in some locations (Samoilys et al. 2015, Davidson et al. 2006), but impacts are accumulating, and the downward trend is clear (fig. 2.5.2).

Fish data is even more scarce for Mozambique than is benthic data, with only 5 years of data collected in 2003, 2005, 2011, 2014 and 2015 – and in general these have not been from the same sites, except for recent monitoring in Palma district in the north. Given the paucity of data, no interpretation is made, but fig. 2.5.3 is presented for future reference.

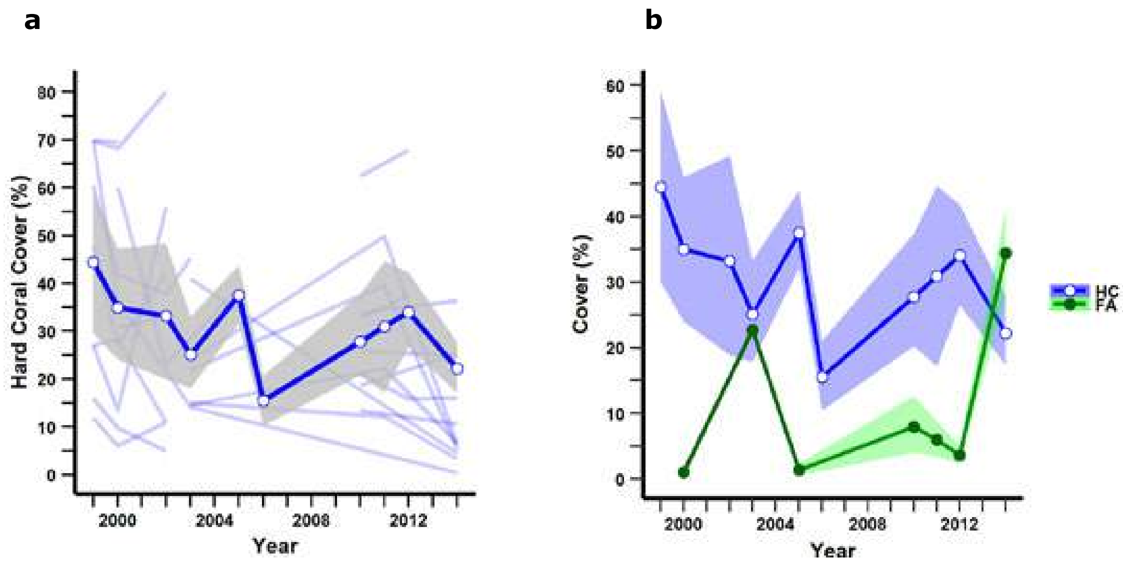

Figure 2.5.2. a) Trend in hard coral cover on Mozambique reefs (mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines)); b) Trend in mean hard coral cover (blue line, open circles) and fleshy algae (green line, closed circles) in Mozambique (coloured shaded areas represent 95% confidence interval of the mean)

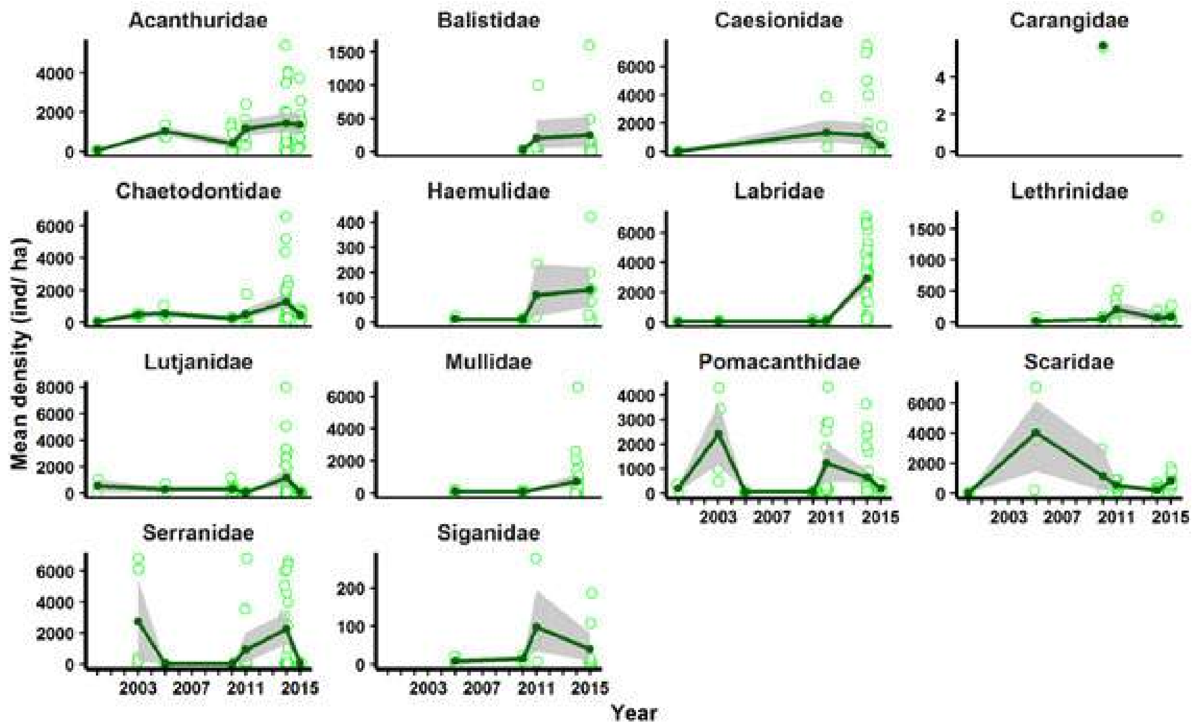

Figure 2.5.3: National averages of abundance for 14 fish families on coral reefs in Mozambique between 2000 and 2015. Circles represent surveyed sites and shaded areas represent the 95% confidence limits of the mean.

2.5.4 Coral bleaching 2016

The first signs of coral bleaching were visible in March 2016 in Bazaruto Island, in southern Mozambique. The highest level of bleaching nationally was reported in this area, at Santa Carolina Island, though in general the southern region was less affected by bleaching than the north. Some reefs in the north, such as Nuarro and Pemba, showed no signs of bleaching at all. At Vamizi Island, in the far north, bleaching was low for most sites surveyed, except in the shallow part of the lagoon where bleaching was stronger (at a site also prone to high sedimentation). In general, the more tropical reefs in the north, with the highest diversity and abundance of corals (e.g. Nuarro and Vamizi) were less strongly impacted by bleaching, perhaps due to the proximity to the shelf-break and deep canyons bringing in cooler water from depth, offering some protection from high temperature anomalies.

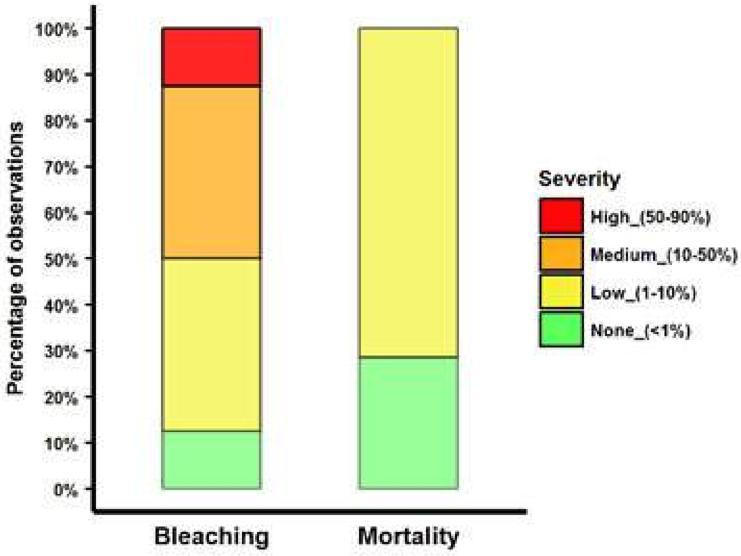

Figure 2.5.4. Observations of coral bleaching (n=16) and associated mortality (n=7) collected in Mozambique in 2016. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site.

2.5.5 Mass-spawning of corals at Vamizi island

Dynamics of coral reproduction are poorly known for East Africa, with indications of low synchrony in lower latitudes with spawning spread between October and April in Kenya (Mangubhai and Harrison 2008) and a stronger peak of spawning in January at higher latitudes in South Africa (Kruger and Schleyer 1998). Patterns of high reproductive synchrony among *Acropora* species have been documented at Vamizi Island, in northern Mozambique (Sola et al. 2016). This results in an annual mass-spawning event, with the synchronous release of gametes by numerous species of *Acropora*, and likely other taxa, on 1-3 nights per year around September. Massive spawn-slicks are visible at the surface in the following days and larval recruitment also peaks following these events (Sola et al 2015). Local hydrodynamics are likely to promote the local retention of the larval production, to the reefs of Vamizi and adjacent islands, so they benefit from this high annual reproductive input. This is thought to contribute to the high resilience of those reefs and is of major importance in the context of the future offshore mining for natural gas in the area. Synchronous spawning of corals has only been confirmed for Vamizi, but is likely to occur in other Islands of the northern Quirimbas Archipelagos, and as far north as the Songosongo Islands in Tanzania, where similar spawn-slicks have been observed from aerial flights at the same time as spawning occurs in Vamizi (D. Obura pers. comm.).

From a management perspective, synchronous spawning presents both a hope for the future of these soon to be impacted coral reefs (high reproductive success and recruitment), but also a challenge, as care must be taken to avoid disrupting it, with potentially severe consequences on the reproductive success of corals.

Figure 2.5.5. Closeup of Acropora sp. Branch during release of egg bundles during mass spawning, and slicks of egg and sperm on Vamizi island beach the morning after spawning.

2.5.6 Drivers and pressures

In the last two decades, damage from ENSO-induced bleaching events, and the recovery from this damage has varied widely between reef areas, with no clear relation to latitude. In addition, local drivers of coral reef decline exist, increasing the vulnerability of corals reefs in Mozambique. Historically, coastal development in Mozambique has been limited and did not pose direct pressure on coral reefs, as these were usually situated in more remote and under-populated areas. Destructive fishing methods also are not a main concern. Although damage from anchoring traditional fishing dhow can be noticed in heavily fished areas, such as Pemba or Palma (pers. obs.)

Increasing population along the coastline, whether from influx of refugees from the civil war (1976-1994) or for economic opportunities in recent years, has led to increasing pressure on coastal resources. Along with the harvesting of food from the intertidal environment, artisanal coral reef fisheries are the first source of protein for coastal communities, so increasing demand also places added pressure on the coral ecosystems. As coastal populations keep growing, and in the absence of a strong legislative framework based on sound scientific information and enforcement capacity, the negative effects of uncontrolled fisheries on coral reefs are among the principal pressures to the reefs of Mozambique.

The exploration of offshore natural gas in Inhambane Province (southern Mozambique) already places pressure on the reefs of that area, and future projects countrywide will increase this pressure both in the south and north. New projects include: the proposed construction of a deep water harbour at Ponta Techobanine (reef removal, dredging, increased ship-traffic, reduced water quality); the development of Nacala's harbour for exporting coal extracted in Tête (increased ship-traffic, pollution from coal-dust, dredging); and offshore gas mining in the Quirimbas archipelago and in the Primeira e Segundas islands (drilling, shipping, construction of an underwater pipeline and Liquified Natural Gas plant).

The 1999-2000 floods led to increased influx of freshwater and mud in the Xai-Xai lagoon and a large mortality of corals in 2000. With global climate changes, local climatic anomalies could also become stronger, more frequent and less predictable with possible implication for coral reefs as well.

2.5.7 Timeline

1976-1994	Civil War; migration to the coast leading to increased fishing pressure
1998	Global mass-bleaching event
2000	Heavy rain and floods impacting the Xai-xai lagoon
2000s	Offshore Gas Mining in Inhambane Province.
2002	Bazaruto National Park gazetted, the first major coral reef national park in Mozambique.
2004	Global mass-bleaching event
2005	Quirimbas National Park gazetted, second government national park with marine focus
2012	Primeiras-Segundas National Park gazetted, the largest marine area under protection.
2012	Massive offshore natural gas fields in Palma district, within the Qurimbas Archipelagos (Mozambique Area 1 in the Rovuma Basin; 130 Tcf), transition from exploration to exploitation phases expected in 2022.
2016	Global mass-bleaching event

2.5.8 Responses

Mozambique has gazetted several large marine protected areas focused around coral reefs, all in areas with high and growing pressure from surrounding fishing communities, and with high potential for nature-based tourism (see Timeline).

In addition, the importance of fishing at both commercial and subsistence/artisanal levels has long been the focus of the National Fisheries Institute (IIP) and its National Institute for the Development of Small-Scale Fisheries (IPDDE). In parallel with other countries of the region, the government has promoted co-management with fishing communities, through community fishing councils (CCPs). These have rresponsibilities for management and monitoring of fisheries, and where supported by partners, some have designated reserves where fishing is restricted, such as at Vamizi Islands.

Capacity building in marine and fishery sciences has been a focus at the national level, with establishment of higher education courses in marine biology, initially at the University of Edouardo Mondlane (UEM) in Maputo, and recently at, for example, UnilLurio, in Pemba. The marine station at Inhaca Island, in the Inhaca marine park (Africa's first marine protected area) was a leading research and capacity building station when it was established, and is recently being revived with support from Sweden (Sida).

2.5.9 Discussion

The Mozambique reef network failed to establish a consistent time series of data for reef status along the coast, and data that was collected consistently from 1999-2004 has been lost. This makes difficult any analysis of the evolution of reef condition in Mozambique over time. Fortunately, with the addition of ad hoc and project surveys since then, spatial coverage of sites is good, with monitoring stations across the whole latitudinal range of the country. This enables a general trend to be observed, of general decline of coral cover. Monitoring has been sufficient to reveal some level of impact of the 2016 global coral bleaching event at all locations, but also some signs of recovery from previous bleaching events, at variable levels among sites.

2.5.10 Recommendations

A framework for coordination of coral reef monitoring needs to be re-established at the national level. A key lesson from the early 2000s is that it should include participants from government and non-government sectors that have an interest in reef health and monitoring data at the locations where they are invested in, and that support is needed to secure data in a centralized form to provide backups in case of institutional and personnel changes. Capacity building needs to be maintained to cope with personnel changes, including in-water data collection as well as overseeing reporting and data management at larger scales.

In addition, the following can be done …

1. Promote/improve community fishery organizations (CCPs);
2. Promote privately managed sanctuaries;
3. Prepare management strategies and plans for offshore natural gas mining operations, such as in the Quirimbas Archipelago;
4. Improve legal frameworks for enforcement;
5. Raise awareness and strengthen environmental education for coastal populations;
6. Invest in capacity building and improved research at national and provincial levels through the continued effort of higher education in marine biology and related areas.
7. Tackle issues of increasing coastal population through improved social development and family planning.

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2.6 Reunion (France)

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2.6.1 Summary

Reunion Island has a poorly developed reef system, with 25 km of fringing reef on the west coast of the island. Evidence of reef degradation led to the establishment of a coral reef monitoring programme in 1998, with stations spread among the 4 main reef areas along the coast. Monitoring is focused on spatial and temporal changes in the benthic and fish communities using methods recommended by the GCRMN.

In the majority of stations, the dominant temporal change is a chronic increase in the cover of algae, including turf and fleshy algae, and algal growth on dead coral, and a decline in live coral. On some fore reef sites, the increase in algae is associated with a decline in coral diversity, and a shift in the composition of coral genera to ones with lower diversity (Galaxea, Porites, Astreopora and soft corals).

This shift in the benthic community structure to greater algal abundance has repercussions on the fish, with the principal change being a shift in trophic dominance to greater abundance of herbivores. Further, the very low abundance and biomass of carnivorous and piscivorous fish is indicative of excessive pressure from fishing.

Management responses have increased and diversified over the last ten years, and include: establishment of regulations for direct and indirect uses, improved water-treatment on land to reduce pollution, control of fishing effort, and environmental education. The Marine Natural Reserve of Reunion, created in 2007 and covering 80% of the reefs of the island, is the principal management tool for coral reefs, and undertakes research, sensitization of users and surveillance. Initial improvements in reef health as a result of the reserve are visible some 7 years after its initial establishment, though full recovery, if at all possible, is likely to need several decades.

2.6.2 Introduction

Reunion is the western-most island of the Mascarene Archipelago, situated at 700 km east of Madagascar and north of the tropic of Capricorn. With an area of 2512 km², the island is made up of 2 volcanoes: le Piton des Neiges (3069 m) which is inactive and highly eroded, and Piton de la Fournaise (2631 m), which is active with ongoing eruptions and flows on the south-east border of the island. The varied terrain and micro-climates of the island create a high diversity of terretrial habitats and species.

The island has been a French ‘departement’ since 1946 and has experienced a half century of social, economic and political turmoil. Total population has grown 4 times from 227,000 in 1976 to 845,000 in 2014 due to improved medical facilities and high birth rates, and

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recently, high immigration from Europe and the Indian Ocean. Population density is high, at 333 inhabitants/km^2 (INSEE, 2012).

Marine habitats include rocky and sandy facies, with still poorly-known biological communities. The youth of the island (800,000 years), evidenced by ongiong creation of the island and lava flows on the southeast coast, mean that coral reefs are poorly developed, with the main reef development on the west of the island. Here, the fringing reef has a total length of 25 km, or 12% of the island perimeter, and an area of 12 km^2 (IUCN, 2013). Reef structures in Reunion are divided into coral communities growing directly on the volcanic rock, reef platforms where the reef flat extends from the shoreline, and fringing reefs (the most mature reefs on the island). The fringing reef, estimated at an age of 10,000 years (Montaggioni 1978) is divided into four complexes: Saint-Gilles/ la Saline, Saint-Leu, Etang-Salé and Saint-Pierre. Seagrass beds are rare, and mangroves are totally absent.

Long term monitoring of Reunion's coral reefs was started in 1998, at 14 stations of which 7 are on the reef flat and 7 on the fore reef, and spread across the 4 reef complexes. Ten of the stations are located within the Réserve Naturelle Marine de la Réunion (RNMR) (fig. 1). Monitoring is done at an 'expert' level, focused on benthos and fish populations, the latter on 49 focal species across 8 families. A Reef Netork has been established in la Reunion, with additional monitoring and observations being conducted for multiple purposes, and including citizen science, for example in the "Sentinelles du récif" programme.

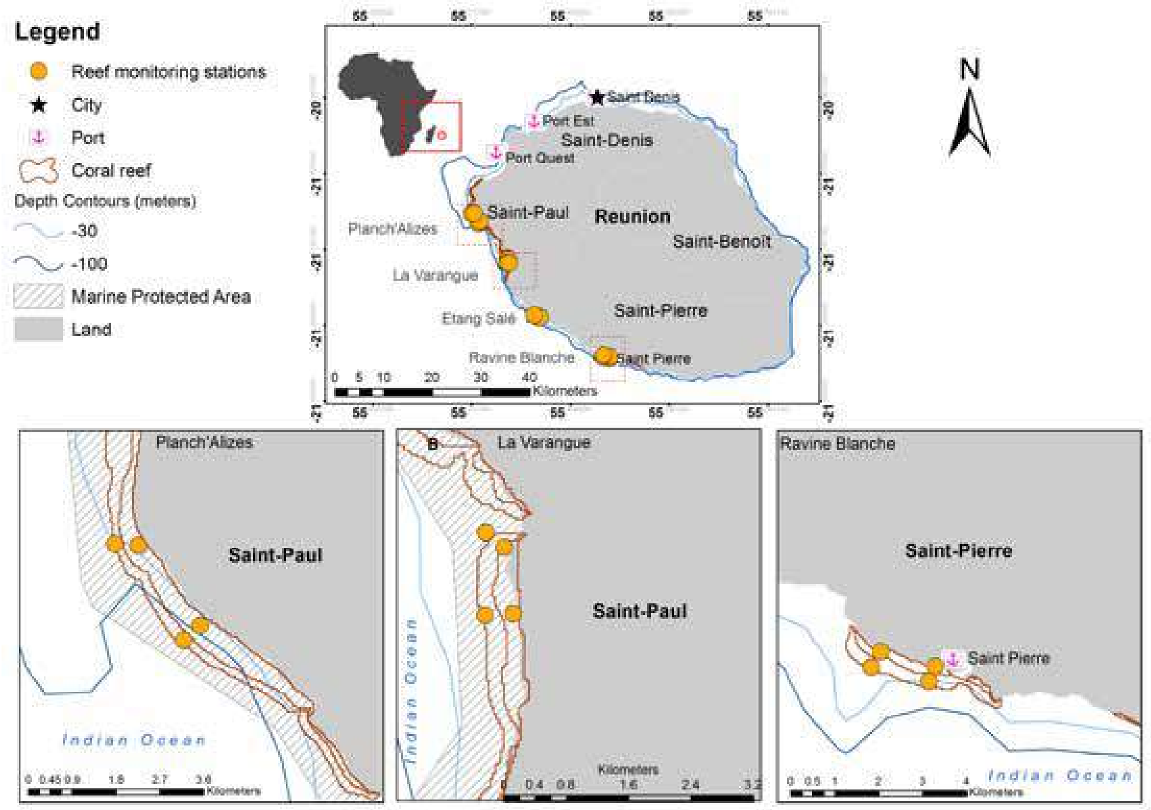

Fig 2.6.1 Reunion's coral reefs and monitoring stations for which data was included in this study

NATIONAL CHAPTERS

2.6.3 Status and trends

Hard coral cover in Reunion has ben stable since 1998, averaging 40-45% (fig. 2.6.2). By contrast, a major and chronic increase has occurred in the algal community (fleshy algae, turf algae and algae growing on dead corals), which have increased from < 20% to 40-50% over the same period. This has occurred across most sites around the island, with the exception of those at Saint-Pierre and Saint-Leu (station La Corne), which have shown a more stable coral community over time (Bigot 2008).

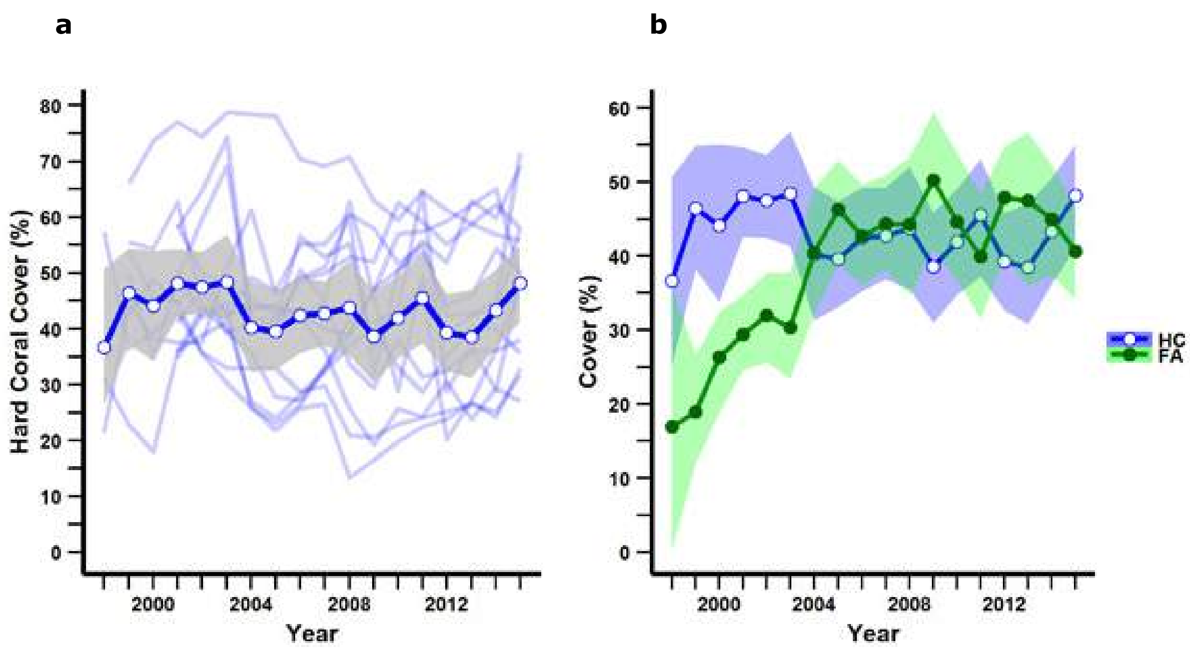

Figure 2.6.2. a) Trend in hard coral cover at 14 monitoring stations in Reunion from 1998-2015 (mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines)); b) Trend in mean hard coral cover (blue line, open circles) and fleshy algae (green line, closed circles) in Reunion from 1998-2015 (coloured shaded areas represents 95% confidence limits of the mean)

Variation is high among sites and reef sectors, varying between 8% and 80% (from 2015 surveys). The healthiest fore reef sites are in the St. Pierre sector in the south, while the most degraded are in the southern part of the Saint-Gilles/La Saline reef complex. The healthiest reef flat sites are in the lagoon of St. Pierre (Alizé Plage, Ravine blanche) with coral cover of 65%, while the most degraded reef flats are in the Saint Leu sector with coral cover of 40%.

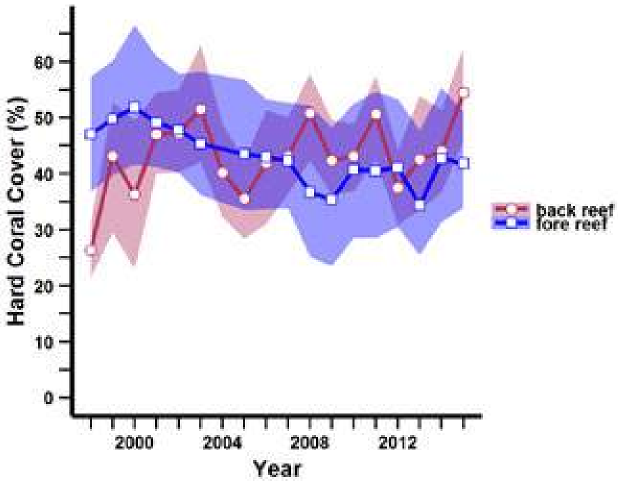

Figure 2.6.3 Comparison of mean percent cover of hard coral in Reunion at fore reef (blue line, open squares) and back reef (purple line, open circles) zones with 95% confidence limits (coloured shaded areas)

Investigation of the evolution in composition of the coral communities from 1998-2008 (Bigot 2008) showed that the upsurge in algal cover is associated with certain factors:

- In certain cases, the algae represent early successional stages, with opportunistic species responding to the availability of new space after environmental disturbances. This is not associated with general loss of species diversity, and was observed on the reef flat stations of Saint-Gilles, Saint-Leu, Etang-Salé and the fore reef stations of Saint-Leu and Etang-Salé. Nevertheless, this could represent an early stage in a longer term loss in biological diversity.
- In other cases, the increase in algae is associated with a shift in coral community structure, for example where hard coral communities dominated by *Galaxea*, *Porites* and *Astreopora* are replaced by the soft corals *Sinularia* and *Sarcophyton*. This is occurring on the fore reefs at Saint-Gilles/La Saline (Planch' Alizé, Toboggan) and Saint-Leu and is more of a concern, as it reflects a shift in community dominance and structure and a more significant loss in biodiversity and associated species.

These trends were reconfirmed in 2014 in the Marine Reserve (Bigot et al. 2016) where further loss of coral diversity (from 10 to 17% on average) was documented across the entire fore reef sectors of Saint-Gilles / La Saline and Saint-Leu.

Fish community structure in la Reunion is strongly determined by reef geo-morphology over short term changes such as seasonal factors or disturbances such as cyclones (Chabanet 1994, Letourneur et al. 2008). Trends in the abundance of the eight families monitored are shown in fig. 2.6.4.

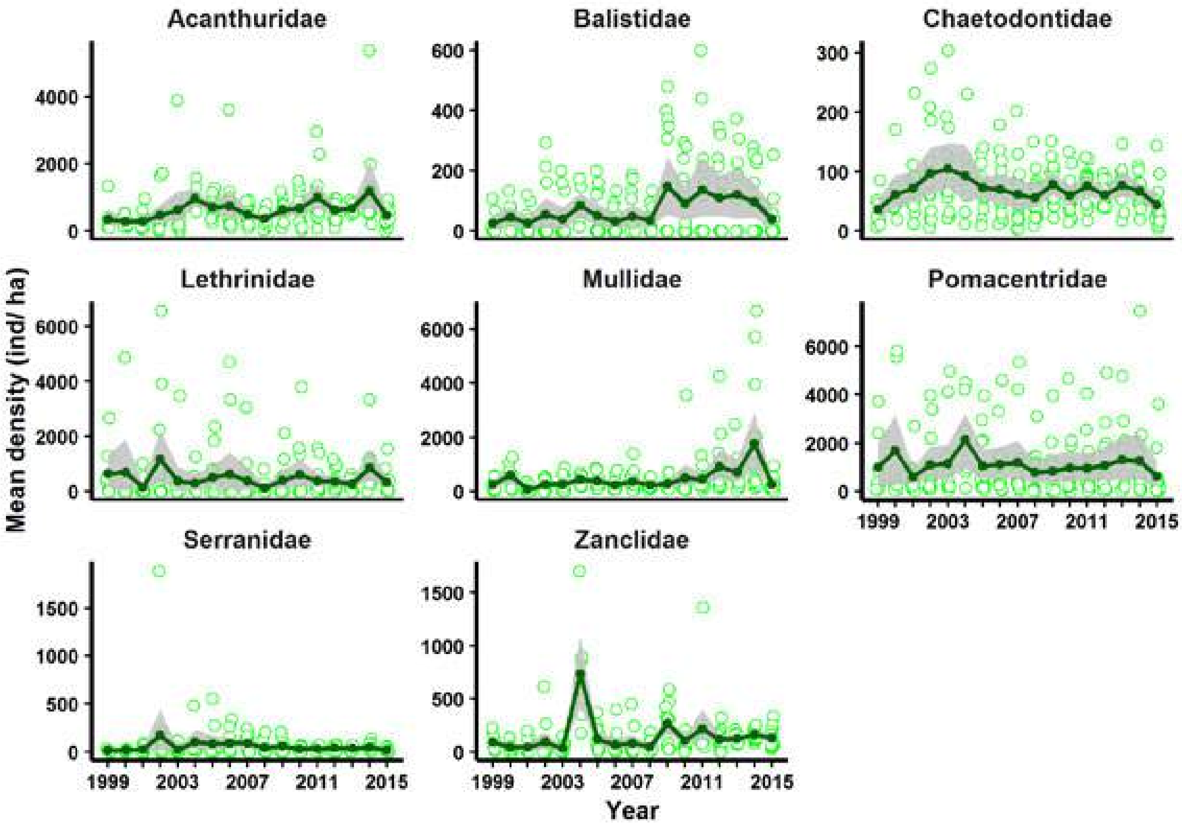

Figure 2.6.4. National averages of abundance for 8 fish families on coral reefs in Reunion from 1998-2015. Circles represent surveyed sites and shaded areas represent the 95% confidence intervals

Reef flat communities are strongly dominated by omnivorous and herbivorous fish, principally the Pomacentridae, by species associated with the dominant cover of branching *Acropora* (e.g. *Chromis, Dascyllus*) or with algal colonization of dead branches (e.g. *Stegastes*) (fig. 2.6.5a). Fore reefs are strongly dominated by herbivores in the family Acanthuridae, while top predators and piscivores, such as in the Serranidae, are extremely low in abundance. Analysis of changes in fish community structure from 1998-2008 found that the decline in hard coral cover and increase in fleshy algae is responsible for decreasing structure in fish assemblages, due to changes in biotic processes such as fish recruitment. The decline in fish community structure is associated with a decrease in species richness and modification in trophic structure, with certain herbivore species (Acanthuridae) and opportunists such as the damselfish (*Stegastes*) benefiting from the increase in algal abundance (fig. 2.6.5b).

a **b**

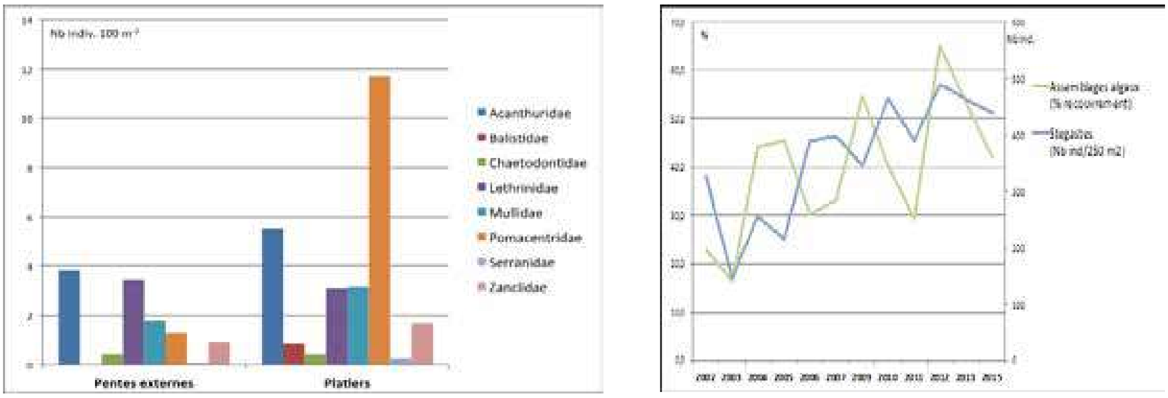

Figure 2.6.5. a) Mean density in 2015 of fish functional groups at fore reef and reef flat sites in 2015 (RNMR 2015); b) evolution of fleshy algal cover and Stegastes density from 2002 to 2015 on the reef flat site La Varangu, in Saint-Leu (RNMR 2015).

Several indicators point to overexploitation of reef resources by local fisheries in Reunion. These include: the low abundance of carnivores and piscivores (Tessier 2005), the small size of commercial species at the establishment of the marine reserve (Bruggemann et *al.* 2008), and the mean biomass of the total fish fauna in Reunion is between 200 and 400 kg/ha, which corresponds to 10-30% of the fish biomass of unfished reefs across the Western Indian Ocean (McClanahan et *al.* 2007), and 5-10% of the biomass of reefs totally isolated from direct human impacts (Chabanet et *al.* 2015).

2.6.4 Coral Bleaching 2016

The first signs of bleaching in the Reunion were observed toward the end of February 2016, and the bleaching intensified to reach its peak in April 2016. The data analysis of temperatures from NOAA/NESDIS clearly showed the link between this phenomenon and the positive irregularities of water temperatures (fig. 2.6.6).

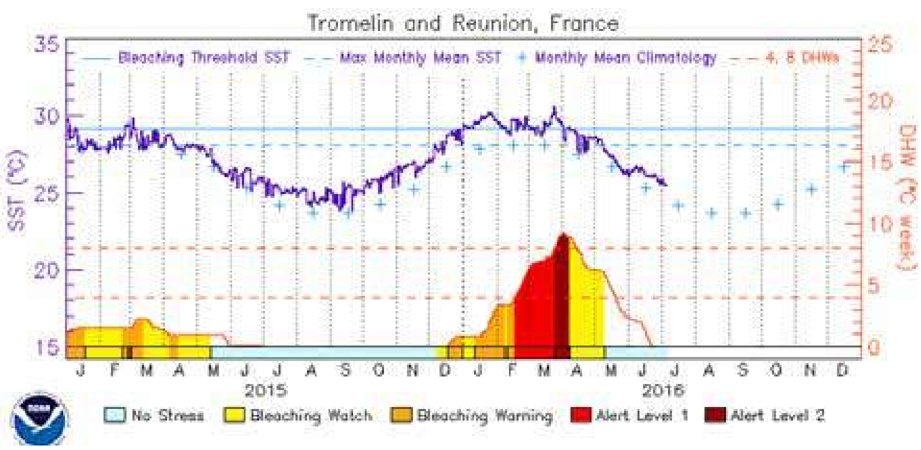

Figure 2.6.6 Sea Surface Temperature, temperature anomaly and DHW (Degree Heating Week). NOAA/NESDIS, 2016

To study the breadth of the impact of this phenomenon, and within the framework of the BECOMING project (Blanchissement Corallien des territoires français de l'océan Indien), 69 stations were sampled from Saint-Gilles to Saint-Pierre, with 26 stations on the external slope and 43 on the reef flat. Both the basic and intermediary level methods from the IOC coral bleaching monitoring manual (IOC, 2016) were carried out, and data presented are from the basic level data collection.

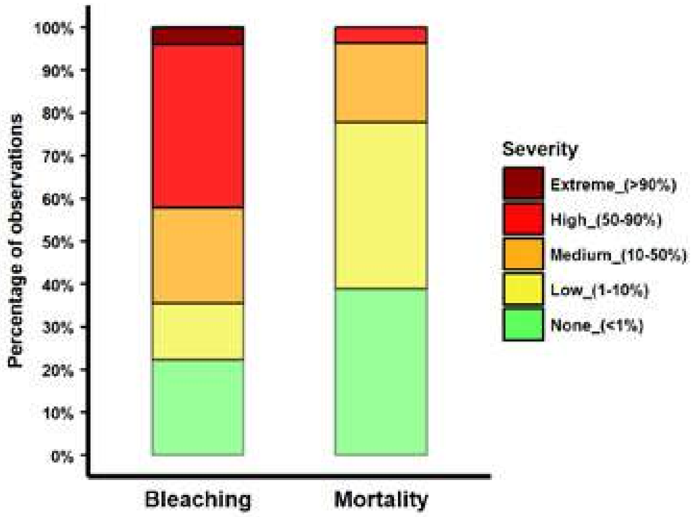

Figure 2.6.7 Observations of coral bleaching (n=76) and associated mortality (n=54) collected in 2016. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site.

Observations in April 2016 (during the peak) allow us to classify this episode as intermediary in the regional context, with about 45% of bleached colonies on the external slope and 35% on the reef flat. The most affected reef-flat was in Saint-Leu with an average of 60% of the colonies bleached, but 3 stations in St Gilles had 90% of the colonies bleached on their reef flats. The other reef flats had a lower prevalence and more homogenous rate of about 30%. On the external slope, the most affected areas were Saint-Leu and Saint Gilles with an average of 65% and 50% of the colonies bleached respectively, with some reef slopes in St Leu experiencing over 80% of colonies bleached. Overall, more than 40% of stations in Reunion had over 50% of their coral bleached (fig. 2.6.7).

Reunion had experienced previous episodes of bleaching in 2004, 2005 and 2009, with the most severe event in 2004 when an average of 37% of the coral cover was bleached (Nicet et *al.*, 2004).

The most affected of the abundant genres on reef flats were Acropora (white) and Montipora with Pocillopora, Pavona and Porites less affected by bleaching. On the reef slopes, Acropora (white), Millepora, Montipora (pale), Porites (pale) and Platygyra (pale) were the most affected, and Pocillopora were less affected.

The monitoring follow up done at the end of June/beginning July 2016 to evaluate the coral mortality as a result of bleaching showed a substantial recovery in bleached coral. Only 5% of sites experienced high coral mortality, with almost 80% of sites experiencing less than 10% mortality of coral cover (fig. 2.6.7).

2.6.5 Drivers and pressures

The coral reefs of Reunion are highly vulnerable, due to their low development level and proximity to the beach at the interface between the island watersheds and the ocean. Located on the most settled and altered shores of the island, they experience a full range of human threats:

- Coastal development: construction on land has augmented considerably the direct runoff of water during heavy rains, with terrestrial material being flushed into the reefs and lagoon. Regular rains result in strong turbidity events. For example, in February 2012 (Cauvin, 2012) and in 2016 at Etang Salé, 'rivers of mud' resulted in high turbidity in reef waters over several weeks resulting in high mortality of lagoon corals (up to 80% in some places). In other locations, coastal erosion and loss of beaches emphasizes the problem of a changing coastline (Troadec 2003).
- Water quality: discharge from treatment plants, overflow of collection basins and general groundwater flow, and discharge of pollutants (e.g. heavy metals, hydrocarbons, pesticides) represent into the sea a strong pressure due to the topography of the island and rapid transfer of water down-slope. In addition, due to ocean waters around Reunion being low in nutrients, the effect of nutrients washed into the sea is significant, resulting in eutrophication of reef waters.
- Resource extraction (fishing): demersal reef fisheries are artisanal in nature, but overexploitation has been documented since the 1980s, resulting in collapse in food chains and reduction in the number of fishers. Fish Aggregating Devices have been installed since 1988 transorming the fishery into an open ocean pelagic one, however pressure on reef fish has remained high due to increased recreational fishing, speargun fishing and gleaning in shallow waters. Though essentially recreational activities, they have come to represent a significant source of subsistence (David & Mirault, 2003) for low-income communities, and high demand for seafood.
- Other activities on the reef that are non-extractive have nevertheless had a growing impact due to the shallow waters of the reef flat and lagoon (1.5 m maximum), for example with trampling and physical damage.

In parallel with these human pressures, cyclones and tropical depressions are regular phenomena on Reunion, and significantly impact coral communities. The ocean swell and waves associated with cyclones and depressions, as well as physical damage in the shallows and on vulnerable corals, cause significant declines in coral cover. Massive rainfall associated with cyclones affects the reefs both through lowering surface salinities, and massive runoff and sedimentation from land. A signature example was cyclone Firinga in 1989, when the reef flat at Saint-Leu and the fore reefs adjacent to ravines that carry massive surface flows from the island, were almost totally destroyed, and overall 18% of coral cover was affected around the island (Naïm 1989).

Large swells from the south can also impact coral communities, such as in May 2007, when *Acropora* colonies on the fore reefs of Saint-Gilles, Saint Leu and l'Etang Salé were significantly impacted. Low sea level anomalies are also experienced, with a strong one in July/August 2015 (Mouquet et *al.*, 2015) that resulted in high mortality of exposed coral colonies. Finally, high sea temperature anomalies linked to El Niño episodes, result in regular bleaching and sometimes significant mortality of corals. The most recent, in 2016, is still being studied.

2.6.6 Timeline

1970's	First scientific studies on Reunion coral reefs
1980's	First sightings of reef degradation and marine resources overexploitation
1988	Installation of the first fish aggregating devices
1989	Very high coral mortality after Hurricane Firinga
1997	Creation of the Reunion Marine Park Association, to protect coral reefs
1998	Mass coral bleaching event recorded in SWIO, causing moderate degradation on Reunion reefs
1998	Set-up of Reunion Coral Reef Monitoring Network to monitor coral reefs
2002	Hurricane Dina expected to cause a massive reef fishes mortality
2007	Setting up of the Marine Nature Reserve of Reunion Island
2015	Implementation of the DCE coral reef survey
2015	Massive reef flat mortality due to tide anomaly (regional currents)
2016	Mass coral bleaching event recorded in SWIO, causing moderate degradation on Reunion reefs

2.6.7 Responses

The belated understanding that coral reefs were degrading, faced with antagonism from user groups, resulted in a slow implementation of marine protection in Reunion (Conand et al. 2002). The first steps included a three-month ban on spear fishing throughout the island and regulation of all onshore fishing methods, staring in 1976.

The Marine Park of Reunion, targeting management of coral reefs, was created in 1997. After a long series of consultations, it was transformed into the Marine Natural Reserve of Reunion in February 2007 (with a length of 45 km along the coastline, and area of 35 km^2), and its management was assigned to a "Public Interest Group". It includes three protection zones: a general use zone (45%), an area of reinforced protection (50%) where extraction is banned with certain exceptions, and an area under full protection (5% of the area) where only permitted research and monitoring are allowed. Eight per cent of Reunion's coral reef area is in the reserve. An island-wide reef network is articulated around the consultative group for the reserve, with 44 members from four different groups (government, local authorities, users and scientists). Management and protection of corals is specified under a management plan (currently from 2013-2017), which includes actions around knowledge, awareness and enforcement.

Water quality is a significant issue in Reunion, with a framework for action under the European Union directive on water (the 'DCE', of 23 October 2000). This includes state obligations to conserve and restore water bodies, including surface, underground and coastal waters. With respect to the sea, this includes maintaining healthy ecological functioning of coastal and reef systems, with specific targets and reference points for regular assessment. A water management plan for Reunion (2012-2018) assures implementation of the DCE, with multiple projects addressing watershed issues and rehabilitation of water works being implemented under local authorities. The increasing development on land and high vulnerablity of coastal systems requires, nevertheless, additional actions, including: improvements in storage reservoirs, improved compliance of small scale treatment plants, reducing erosion and pollution from rainwater runoff, and improvements in water treatment and purification methods.

Surveillance of coastal fisheries is done regularly by rangers of the Marine Reserve and other authorities, to reduce illegal fishing on the reefs. In 2015, 85 incidents were reported by the Reserve. Actions to develop and consolidate fishing activities in non-reefal waters are implemented by relevant authorities, including: promotion of deep demersal and pelagic fisheries, support of coastal infrastructure (including Fish Aggregating Devices, artificial reefs), implementation of protection zones (the Reserve, and the fishery reserve of Sainte Rose) targeting resource replenishment and habitat protection, fishery monitoring and actions to assure sustainability of fisheries. Priorities for the coming years include integration and reinforcement of informal fisheries and diversification of opportunities, such as through tourism based on fishing with local fishermen.

2.6.8 Discussion

The coral reefs of Reunion, due to their small size, proximity to the coast, and the level of urbanization in upstream watersheds, are extremely fragile. Monitoring over the last 18 years of the health of Reunion reefs shows increasing impacts and reduced health of the benthic communities across the whole island. While rapid recovery of early-succession coral communities after climate-related bleaching impacts is in evidence, the chronic decline in water quality, directly related to coastal development focused on the west coast of the island, has considerable impact on communities (Naïm et al., 2013). This is shown in the gradual increase in benthic algae and decrease in hard coral cover, and a shift in coral communities from *Acropora* to hard and soft coral genera that are more opportunistic and stress resistant. This has occurred on both reef flat and fore reef zones. Fish populations are affected by modification of their habitat, which, on top of overexploitation by fisheries, results in disequilibrium in the trophic structure with a predominance of herbivores and decline in carnivores. These results are clear for the monitoring sites, selected as representative for the entire west coast of the island, and are indicative of general degradation all around Reunion.

The responses to this situation by the authorities have intensified and diversified in the last decade. These include regulation of direct and indirect uses, improved water treatment, reorientation of fisheries, raising awareness on the environment, and improved management of coastal and marine areas with the establishment of the Marine Reserve. Increasingly, it has become important for the monitoring network to demonstrate the effectiveness of management actions for a healthy reef, in order to change actions if needed, and to legitimize management (such as the marine reserve) in the eyes of decision-makers, politicians and marine users.

In view of future increases in i) anthropogenic pressures on coral reefs related to increasing population and urbanization in watersheds, and ii) climate change impacts, the strengthening of monitoring systems and improvement in their production of robust indicators of the state of coral reefs, are top priorities for the coming decade.

Box 1 – 7 years of monitoring the 'reserve effect' of the Marine Natural Reserve of Reunion

The effect of the reserve was monitored for the benthos (hard and soft corals and algae) and fish on the reefs of St Gilles, La Saline and Saint-Leu. A comparative analysis of the spatio-temporal evolution of populations was conducted from 2006 to 2015.

- **For fish,** the reserve effect was visible in all sanctuary zones (5% of the overall reserve) and was statistically significant for fore reefs of La Saline and Saint-Leu. Biomass increased by 67% from the start of the reserve, the proportion of biomass normally taken by fisheries increased by 78%, and the biomass of commercially targeted species increased 900%. Species richness also increased. Total fish biomass was measured at 264 ±31 kg/ha on reef flats, and 635 ±63 kg/ha on fore reef slopes. The increase in biomass on fore reefs was due to an increase in key fishery species such as groupers.
- **For the benthos,** alomost all fore reef stations at La Saline and Saint-Leu presented a decrease in diversity of corals (of 18 to 40 %), both inside and outside the sanctuaries. The rapidity of this decline, over only the last 3 years, is very worrying from an environmental point of view. In the St Gilles/La Saline and St Leu sectors the decline in hard corals is complemented by an increase in algal turfs, in both reef flat and fore reef zones. An increase in live coral cover was, however, noted in the sanctuary of la Saline on the fore reef, though overall cover remains relatively low (18%).

The encouraging results within the sanctuaries emphasize their value. However, restoration of fish populations takes several decades, requiring regular monitoring to adjust management measures if and when these become necessary.

Box 2 – the coral indicator 'DCE'

In the EU water directive, to evaluate the health of coral reef water masses, a workhop was held in 2012 to adapt the indicator "benthic hard substrates" for the fringing coral reefs of Reunion. This was undertaken under the umbrella of the national working group. The indicator is calculated from multiple components, to reflect: improvements in the quality of the water mass (based on coral indicators including the proportion of Acropora, cover of encrusting coralline algae), or alterations in the type of water mass (based on cover of algae or soft corals). Different weights are used in combining sub-indices into the global index, and the interpretation of the overall index is made based on a matrix of reference values determined by local experts.

Box 3 – the 'BD récif – a new database for archiving coral reef data.

The project 'Base de Données Récifs-pilote Océan Indien (BDROI)' has developed a database (BD récif) for coral reef ecosystems to ensure security and interoperability of data, and to allow evolution of the system over time. It supersedes 'COREMO 3', which was developed for Reunion and other French islands in the Indian Ocean. BD récif will centralize data from monitoring programmes, impact studies and research projects, among others. In parallel, it addresses different national requirements for data systems, and synthesizing data for management. Initially under development for the Indian Ocean, the database will be deployed in all French territories with coral reefs, and to other countries through regional cooperation projects.

Box 4 – innovative new technologies for coral reef monitoring

Since 2009, several projects have enabled the acquisition and analysis of hypersectral images of coral reefs in Reunion and islands in the Mozambique Channel. These have enabled the development of analytical methods for high resolution (to 40 cm) mapping and analysis of reefs, including bathymetry, bottom cover identification, areal cover calculations, health assessments, etc). The project HYSCORES aims to consolidate these approaches to provide indicators of coral health to evaluate the potential for operational outputs from innovative techniques established under the DCE programme.

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2.7 Seychelles

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2.7.1 Summary

Coral reefs in the Seychelles continue to be impacted by a number of pressures, including mass coral bleaching events. The 1998 mass coral bleaching event had devastating effects on reefs throughout the islands, reducing coral cover to between 3 and 5% after which it returned slowly to pre-bleaching levels by 2015. The lag and then progressive recovery were mainly driven by fast growing Acropora corals which went from 1% cover in 2005 to 22% in 2015, when for the first time it surpassed mean non-Acropora coral cover since 1998. By 2013 coral cover at sites within protected areas surpassed that in unprotected areas. In the outer islands, coral reef monitoring has been more haphazard, with high heterogeneity in mean coral cover ranging between 4 and 95%.

Black-spined sea urchins on the reefs of the inner islands have increased between 2005 and 2015, predominantly on granitic and unprotected reefs. The density of fish on coral reefs in the Seychelles' inner islands remained relatively stable between 2005 and 2015 with mean relative abundance of 3,400 fish ha^{-1}. The butterfly fish (Chaetodontidae) is the only fish family showing a clear trend having increased in density by nearly 5 times within 11 years, correlated with the recovery of the coral community.

Despite these positive trends observed between 1998 and 2015, recovery of coral reefs in the Seychelles was abruptly termintaed in the first half of 2016 by another large-scale mass coral bleaching event resulting from the persistence of high seawater temperature. Most corals showed signs of bleaching during the peak of the event and at some sites mortality in excess of 90% was recorded. Post-bleaching assessments indicate that even though a large percentage of corals bleached and died, the effect of the 2016 event was not as severe as in 1998. Pockets of resilience have been found where corals appear untouched despite the fact that other corals around them have bleached and died.

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Acknowledgements: *The authors would like to thank their affiliated organisations and the multiple partner organisations that have supported the various coral reef monitoring and research programmes over the years. In alphabetical orders the organisations are: Aldabra Marine Programme, Alphonse Island Lodge, CORDIO, Denis Island Lodge, Department of Parks and Wildlife (Australia), Desroches Island Development Ltd, Desroches Island Lodge, Global Environment Facility, Global Vision International, Government of Seychelles, Green Islands Foundation, Indian Ocean Commission, Island Conservation Society, Islands Development Company, James Cook University (Australia), Marine Conservation Society Seychelles, Ministry of Environment, Energy and Climate Change, M/Y Pangaea, Nature Seychelles, North Island Luxury Private Resort, Seychelles Fishing Authority, Seychelles Islands Foundation, Seychelles National Parks Authority, Silhouette Hilton LaBriz Resort & Spa, University of Hawaii (USA), University of Lancaster (UK) and University of Newcastle upon Tyne (UK). The data presented in this report remains the property of the organisations and individuals who collected them.*

2.7.2 Introduction

The Seychelles islands lie in the middle of the Western Indian Ocean (fig. 2.7.1). The country has a small land mass (445 km²) but a large Exclusive Economic Zone (EEZ; 1.3 million km²) and a population of about 91,400 people. The Seychelles' economy is dependent on tourism and fisheries. While most of the fisheries income originates from industrial tuna fishing, small-scale demersal fisheries are important culturally and for food security. A substantial portion of the catch is taken in near-shore coral reef associated habitats. Coral reef habitats are also important for tourism as a substantial proportion of visitors to the Seychelles takes part in marine-related eco-tourism activities such as snorkelling and diving.

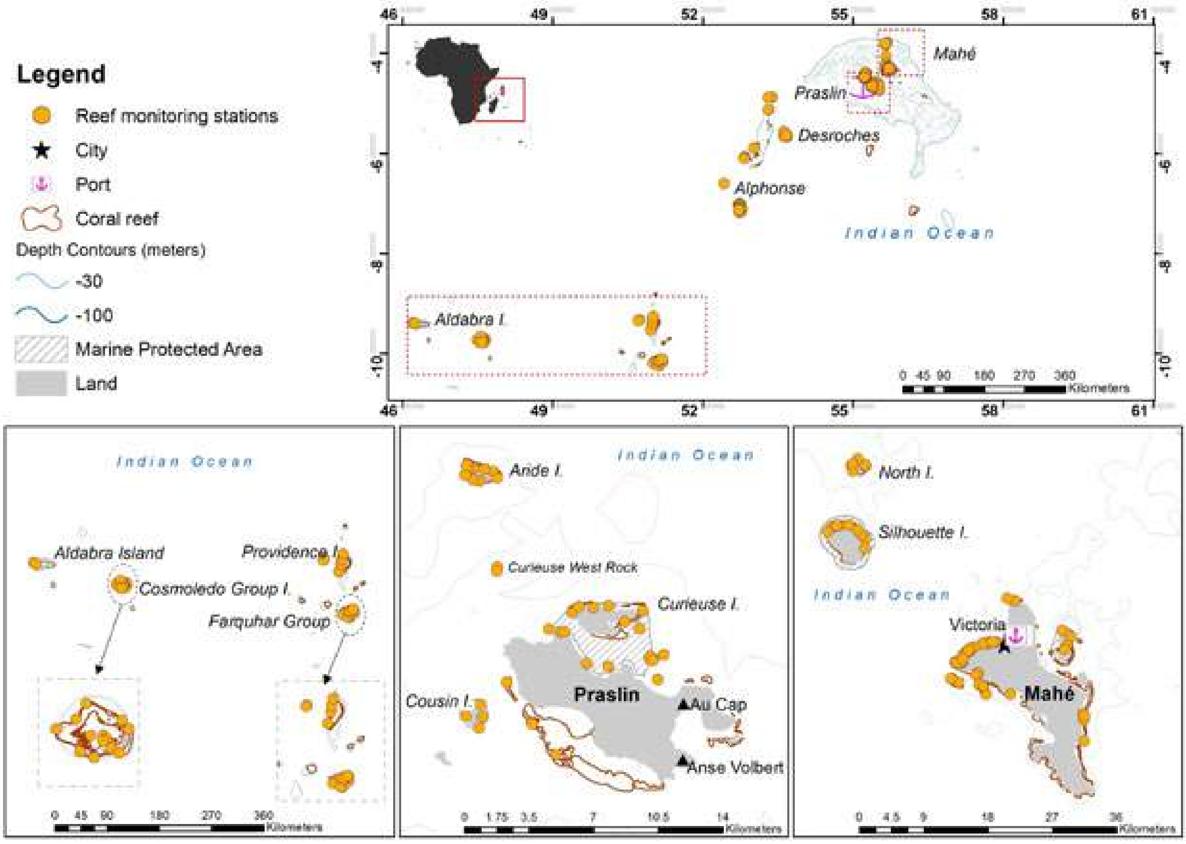

Figure 2.7.1. Seychelles islands' coral reefs and monitoring stations for which data were included in this study

Coral reefs cover an area of approximately 1,690 km² (Spalding et al., 2006), with most reef areas located in the outer islands. The 1998 mass coral bleaching event had devastating effects on the reefs of the Seychelles and reduced coral cover at many sites to less than 5% (Turner et al., 2000; Graham et al., 2008). The reefs in the inner islands were the hardest hit with many of them having undergone a widespread phase-shift from a coral-dominated to a rubble and algal dominated state (Graham et al., 2006). Recent studies in the inner islands have shown that certain demographic bottlenecks are hindering the recovery of coral reefs by limiting the survival of coral recruits (Chong-Seng et al., 2014).

At present, coral reef monitoring is being undertaken on at least 50 sites in the Inner islands at various frequencies ranging from annual to once every 4 years. In the outer islands, a coral reef monitoring programme has been running in the Aldabra UNESCO World Heritage Site since 1999, but surveys are done at irregular intervals. In the other outer islands, coral reef monitoring is done haphazardly due to their inaccessibility. Multiple organisations are involved in coral reef monitoring, including NGOs, volunteer programmes, government and international universities. There is no centralised coordination of monitoring and no centralised database for archiving of monitoring data.

2.7.3 Status and trends

It took 17 years after the mass coral bleaching event of 1998 for hard coral cover on the Seychelles' inner islands to return to pre-bleaching levels of 42%, in 2015 (fig. 2.7.2a). Initial recovery from the bleaching event was slow and coral cover fluctuated between 3 and 5% for the first 4 years. In 2003, the reefs started a slow recovery trajectory, regaining about 2 percentage points of live coral cover each year. This trajectory was maintained over the years despite multiple small mass bleaching events during this period.

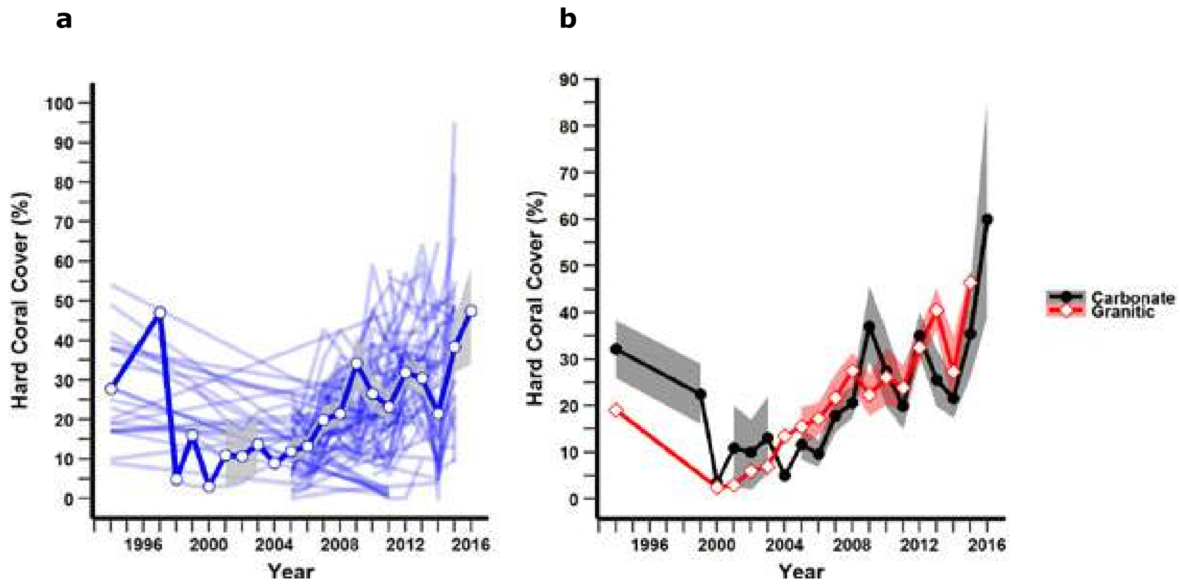

Figure 2.7.2: a) Trend in hard coral cover on Seychelles islands' reefs (national mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines)); b) Comparison of hard coral cover among carbonate (black line, closed circles) and granitic reefs (red line, open diamonds), (coloured shaded areas represent 95% confidence limits of the mean).

Carbonate and granitic reefs had about the same level of hard coral cover when regular reef monitoring started in 2000. During recovery, granitic reefs fared slightly better than carbonate reefs and recorded higher average coral cover in most years (fig. 2.7.2b). The higher rate of recovery on granitic reefs has in the past been attributed to a phase-shift on many carbonate reefs, due to competition with macroalgae or physical damage to corals by mobile rubble. Nevertheless, by the end of the data series carbonate reefs were showing similar overall cover to granitic reefs.

The initial phase of recovery was dominated by coral genera other than *Acropora*, in 2005 making up 12% of reef cover compared to 1% for *Acropora*. As time passed *Acropora* recovery has accelerated, reaching 22% in 2015, when for the first time it surpassed mean non-Acropora coral cover. Between 2005 and 2012, sites located in protected areas had similar levels of live coral cover as those found at unprotected locations. However, by 2013 coral cover within protected areas exceeded that in unprotected areas by a margin of about 10% (fig. 2.7.3a). On average the abundance of macro-algae has remained relatively low (1.2%) at monitoring sites between 2005 and 2015 (fig. 2.7.3b). However, other sites in the inner islands are reported to have undergone a phase-shift from coral to macro-algae domination (see Graham et al., 2015).

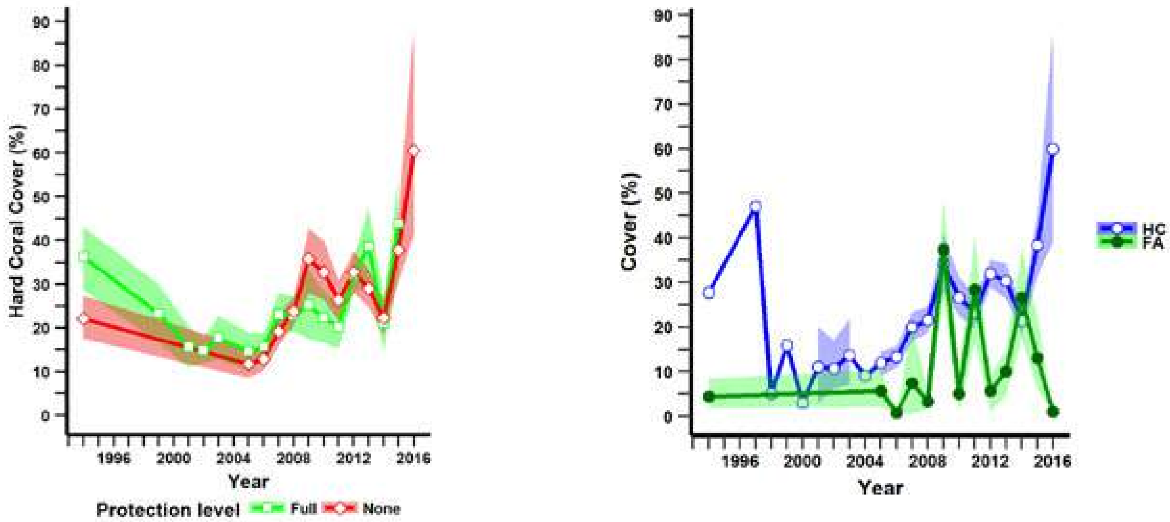

Figure 2.7.3: a) hard coral cover on protected and unprotected reefs, and b) fleshy algae and hard coral cover trends in the Seychelles inner islands.

Mean hard coral cover on the reefs of Aldabra in 2015 was around 30% on the shallow reefs and around 18% on the deeper reefs. A gradual increase in hard coral cover has been recorded over time for the shallow reefs whereas deeper reefs have remained fairly consistent. This is consistent with data collected as part of the reef mapping project undertaken in 2012 which recorded higher mean coral cover on shallower transects than deeper ones. However there was high level of heterogeneity in coral cover on the reefs of Aldabra with sites ranging between 2 to 44% (Chong-Seng, 2015). Data collected during the mapping survey indicates that there are sites where hard coral cover in excess of 80% exists (Haupt et al., 2015).

In the other outer islands coral reef monitoring has been done opportunistically and available data and trends are summarised in Table 2.7.1.

Table 2.7.1: Mean hard coral cover at sites monitored in the Seychelles outer islands.

Island	Year (No sites Monitored)	Mean Hard Coral Cover	Trend
African Banks	2013 (2)	10%	Unknown
Alphonse	2009 (30)	43%	Unknown
Boudeuse	2013 (3)	27%	Unknown
Cosmoledo	2002 (5), 2014 (15)	Generally < 5% (2002), 6 – 29% (2014)	Increasing
Desroches	2008 (7), 2012 (2), 2014 (4), 2015 (9)	15-95% (2015)	Unknown
Etoile	2013 (2)	4%	Unknown
Farquhar	2009 (33), 2014 (13)	17% (2009),16.8% (2014)	Stable
Providence	2016 (3)	54%	Unknown
Remire	2013 (2)	20%	Unknown
St. Pierre	2016 (2)	38%	

The density of coral recruits (corals < 5 cm diameter) has gradually increased on the reefs of the inner islands, between 2005 and 2015 (fig. 2.7.4). Mean recruit density across all reef types was 13.0±0.14 m^{-2} in 2015, from 44 genera in 14 families. In general, granitic reefs had higher recruitment than carbonate reefs (fig. 2.7.4). Initially (2005 – 2007) *Pocillopora* dominated recruitment, giving way to *Acropora* in 2008, which continues today. The same increasing trend in recruit density has also been observed at Aldabra.

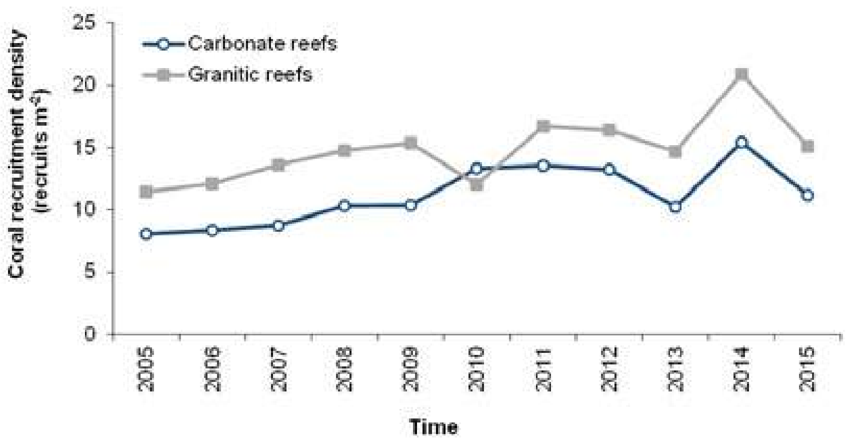

Figure 2.7.4. Comparison of temporal trend in the density of coral recruits (< xx cm diameter) on granitic and carbonate reefs in the Seychelles inner islands between 2005 and 2015.

The density of black-spined sea urchins has increased on both granitic and carbonate reefs of the inner islands between 2005 and 2015, mostly of short-spined sea urchins (*Echinothrix spp.*). Conversely, the density of long-spined sea urchins (*Diadema spp.*) has remained more or less stable over the years. Sea urchin density has also remained higher in unprotected areas over protected areas.

The density of fish on coral reefs on the northwest shores of Mahé Island has remained relatively stable between 2005 and 2015 with mean relative abundance of 3,400 fish ha^{-1}. The butterfly fish (Chaetodontidae) is the only family showing a clear long-term change with an increase in density of nearly 5 times (fig. 2.7.5). This is correlated with the increase in live hard coral cover over the same period. Densities of the other families have remained more or less constant. Overall density of fish on carbonate and granitic reefs did not differ substantially but there was more variability on carbonate compared to granitic reefs. A long-term decrease in overall fish density on reefs within protected areas is apparent, whereas reefs in unprotected areas appear to be showing signs of a slow but long-term increase in density. Fish biomass was not analysed as part of this report. It is however known that biomass may be a more reliable indicator of the effects of fishing or habitat changes than fish density, with higher biomass of targeted species having been recorded in protected areas than in unprotected sites (Graham et al., 2007).

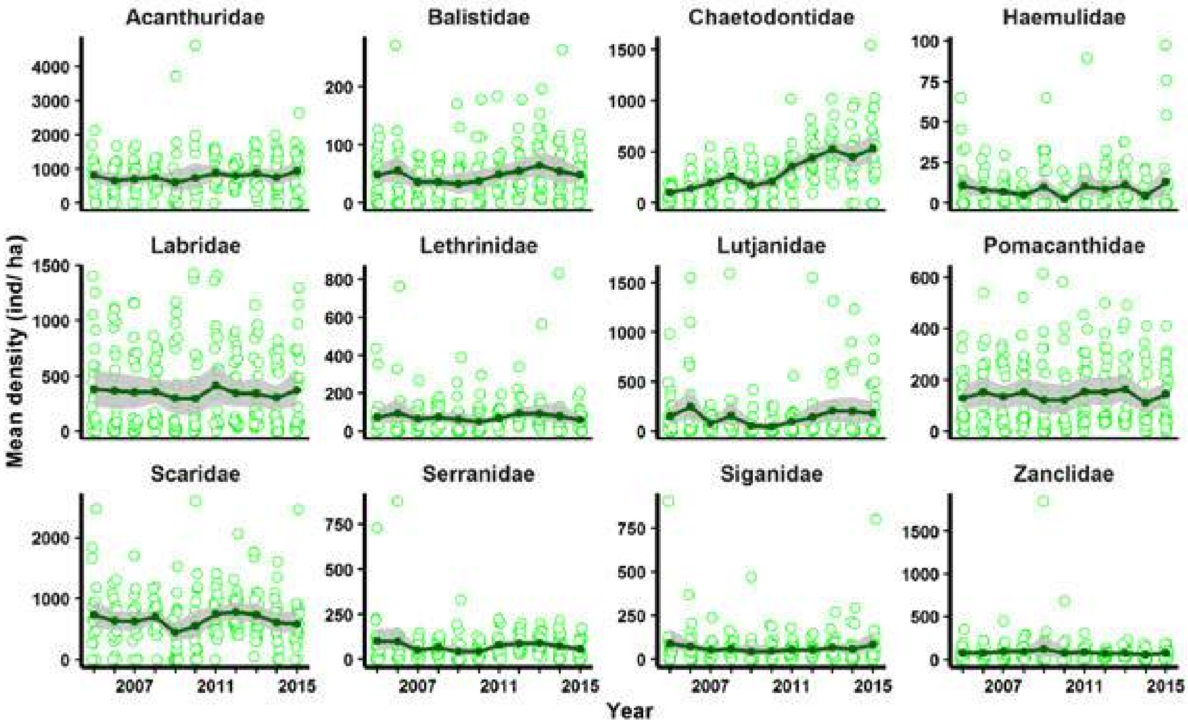

Figure 2.7.5. Averages of fish abundance for 12 fish families on coral reefs in the Seychelles inner islands between 2005 and 2015. Open circles represent surveyed sites and shaded areas represent the 95% confidence limits.

Surveys of coral reef associated fish at Aldabra in 2015 recorded 332 species from 46 families and mean fish biomass of 4,800 kg ha-1 (Friedlander et al., 2015). Total fish biomass in the Aldabra Group was 94% higher than areas open to fishing in the northern Seychelles and 88% higher than in some no no-take reserves in the inner islands. Differences in top predators were even more striking, with biomass 98% higher in the Aldabra Group compared to areas open to fishing around the granitic islands and 96% higher than in no-take reserves. Surveys undertaken at Farquhar in 2009 found similar high levels of fish biomass (3,200 kg ha^{-1}), indicative of a relatively intact reef fish assemblage (Friedlander et al., 2014): high dominance of large groupers, snappers and jacks, and the frequent encounters of large Napoleon wrasse (*Cheilinus undulatus*) and Bumphead parrotfish (*Bolbometopon muricatum*), which are listed as endangered and vulnerable, respectively, by IUCN.

2.7.4 Coral bleaching 2016

The first signs of bleaching were observed in the south of the archipelago at Aldabra in early January 2016, where 23 genera were found to be affected to different degrees. Full bleaching developed a few weeks later, peaking at 60-99% of all corals being affected (Chong-Seng, 2016). Surveys during peak bleaching estimated mortality to be in the region of 14%, and only 13% of corals were recorded as healthy. Post-bleaching assessment recorded an overall drop of 50% in hard coral cover (Burt, A. *pers. comm.*)

From Aldabra, the event quickly made its way northwards. By the end of March bleaching was observed around the island of Providence and St. Pierre, where it was reported to be mild with 20% of corals showing signs of stress. By early April, bleaching was being reported from the island of Alphonse and Desroches in the Amirantes. The reef on the west side of Alphonse was found to be severely affected with 70-80% of the corals showing signs of bleaching. Mortality was highest in the genera *Acropora* and *Pocillopora*. However, the eastern side of the same island was reported to be almost untouched with < 15% of hard corals showing signs of stress. At Desroches Island, temperature was found to steadily increase from around 28.5 to 30.4 °C from October 2015 to March 2016 (Bluemel, 2016).

In the Seychelles inner islands, the first observations of coral bleaching were made during mid-March with reports coming from multiple locations throughout the island group. On the northeast coast of Mahé, the genera *Pocillopora* and *Acropora* showed first signs of bleaching at all depths. In subsequent weeks all hard coral genera, as well as other benthic organisms such as soft corals, corallimorphs and zooanthids were affected, across all sites visited. Areas with a high cover of branching, tabulate, digitate and submassive corals, such as on carbonate reefs, were affected more severely than sites with higher coverage of encrusting corals, typically granitic reefs. Coral mortality was first observed in *Pocillopora* and in branching/tabulate *Acropora* colonies, estimated at 50% in some shallow areas of Baie Ternay, by the beginning of May. The worst affected genera were *Acropora, Leptoseris, Pocillopora, Lobophyllia, Porites, Fungia, Diploastrea, Echinopora* and *Physogyra*.

By early August 2016 some corals were still showing signs of bleaching despite sea temperatures having returned to normal for over 2 months. Overall, while >60% of sites in the Seychelles were reported with high or extreme bleaching (i.e. 50 - 100% bleaching), about 30% were reported with high or extreme mortality (fig. 2.7.6). Post-bleaching assessments around the island of Praslin indicated that even though most corals that bleached died as a result, the 2016 event was not as severe as in 1998. Pockets of resilience have been found where corals appear untouched, surrounded by other corals that did bleach and die.

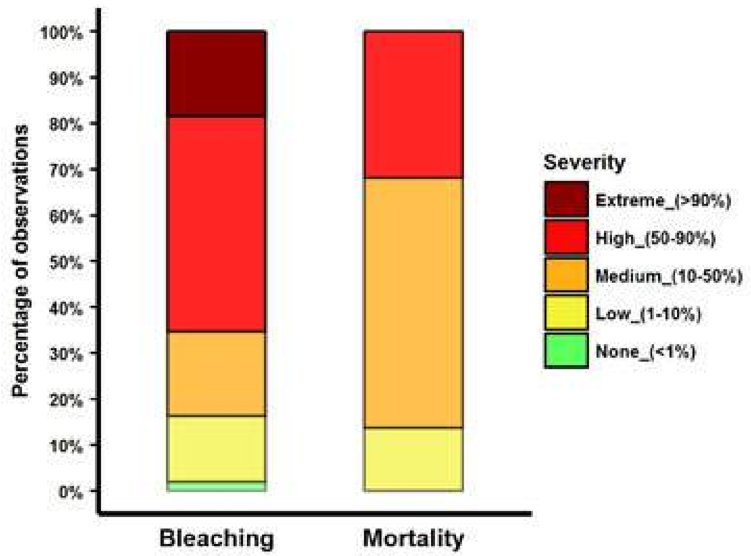

Figure 2.7.6. Observations of coral bleaching (n=49) and associated mortality (n=22) collected in Seychelles in 2016. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead as a result of bleaching at a site.

2.7.5 Drivers and pressures

Mass coral bleaching due to thermal stress remains the greatest driver of coral reef degradation in the Seychelles. In 1998, the mass coral bleaching event severely reduced live hard coral cover on the reefs throughout the islands (Goreau et al., 2000; Ahamada et al., 2004; Graham et al., 2006), with coral reefs within the inner islands being the hardest hit (Teleki and Spencer, 2000; Turner et al., 2000). By the end of 2015, seventeen years after the event, mean live hard coral cover on the reefs in the inner islands had bounced back close to pre-bleaching level. However, many sites were found to have undergone a widespread phase-shift from a coral-dominated to a rubble and algal dominated state (Graham et al., 2015). This shift from coral to macroalgal dominance might have also been helped with high inputs of nutrients (Graham et al., 2015), which may largely be of anthropogenic origin. In 2016, coral reefs throughout the Seychelles succumbed to the effect of another mass coral bleaching event. It has been predicted that the frequency and severity of mass coral bleaching events will increase in the near future as a result of climate change. This period might be too short for corals to adapt and each successive recovery might not reach pre-1998 bleaching level and might cause long-term reduction in coral cover.

In early 2014, the Seychelles inner island experienced a Crown of Thorns (COTS; *Acanthaster planci*) explosion which persisted well into 2016. The outbreak was mostly concentrated along the northwest coast of Mahé Island, with some reports from Praslin. The outbreak died down after the passing of the mass coral bleaching event in 2016. Other plague organisms such as black-spined sea urchins (*Diadema spp.* and *Echinotrix spp.*) are also impacting recovery of coral reefs at certain locations where they occur in high densities and indiscriminately graze on small coral recruits. However, as herbivores, urchins may also be important in the recovery process.
Various coral diseases have been recorded on the reefs of the Seychelles. A "black

disease" caused by the sponge called *Terpios hoshinota* has been reported in the Aldabra World Heritage Site (SIF, 2014). A survey of the reefs within the Aride Special Nature Reserve found no evidence of coral diseases (Talma et al., 2015). In October 2015, an extensive harmful algal bloom (HAB) occurred on a large part of the Mahé Plateau and was responsible for deaths of thousands of coral reef associated fishes that were found washed up on beaches throughout the inner islands. Corals in certain areas were also found to become pale during the event but no large scale coral death was reported. The phytoplankton *Cochlodinium polykrikoides* was identified as the main species responsible for the algal bloom. This species is known to be toxic and has been previously associated with fish deaths.

Overfishing of demersal reef fishes remains an important pressure on coral reefs of the Seychelles. Loss of herbivores has been linked to the dominance of macro-algae at certain sites that were previously dominated by corals. A recent study from the inner islands has shown that reef recovery seems to be promoted in areas where the densities of herbivorous fishes were relatively high (Graham et al., 2015).

One of the largest anthropogenic impacts on coral reefs have been through large-scale dredging and land reclamation activities which have been undertaken on the main island Mahé to meet the ever-growing need for flat land. This started with the reclamation of Port Victoria and accelerated in the late 1960s with the construction of the airport and continued into the late 1990s. A total of about 8 km^2 of reef and mangrove has been lost. This was associated with excessive sedimentation which persists decades after the construction. These fine sediments are easily re-suspended and end up on coral reefs where they limit coral growth and recruitment. In the high granitic islands erosion of laterite soil from the steep slopes ends up on the reef, especially after periods of heavy rain.

2.7.6 Timeline

1965	Start of land reclamation on Mahé to construct Seychelles International Airport
1973	Ste Anne Marine National Park declared the first MPA in the Seychelles
1982	Aldabra became a UNESCO World Heritage Site
1997	Set-up of Seychelles National Coral Reef Network (SNCRN) to monitor coral reefs
1997	Outbreak of Crown of Thorns starfish aloSng the North West Coast of Mahe Island
1998	Mass coral bleaching event causing widespread death of corals throughout the Seychelles archipelago
1998	Start of Phase 3 of land reclamation on Mahé East Coast and Praslin
2003	Start of Implementation of SEYMEMP Project
2004	Indian Ocean tsunami
2008	Small coral bleaching event in the inner islands
2013	Start of coral reef restoration project on in Cousin Special Nature Reserve
2014	Outbreak of Crown of Thorns starfish
2015	Mass algal bloom on Mahé Plateau causing wide-spread death of coral reef fishes
2016	Mass coral bleaching event recorded throughout the Seychelles islands

2.7.7 Responses

There is still no policy framework in the Seychelles for the conservation of coral reefs at the national level. The Marine National Parks and Nature Reserves are the only places where coral reefs and corals are fully protected through the National Parks and Nature Conservancy Act. A Biodiversity Bill is presently being drafted and it is expected that it will strengthen the legal basis for coral reef conservation. The development of a National Coral Reef Strategy and Action Plan (NCRSAP) has also been recommended (Nevill, 2017).

Strategic responses to promote coral reef conservation have been mostly through the debt-swap for nature initiative. As part of this initiative, US$ 30 million of Seychelles debt to the Paris Club is being forgiven in exchange for the country to set aside 15% of its Exclusive Economic Zone (EEZ) as No Take Reserves, while putting a further 15% under active management. Through this initiative, the Marine Protected Area network in the outer islands will also be greatly increased.

More active responses are also being implemented through efforts to rehabilitate degraded reefs. There are at least 3 coral reef restoration initiatives currently under implementation. As part of these initiatives, bleaching resistant corals are being grown in nurseries and used to rehabilitate degraded reef sites that are showing little sign of natural recovery.

Phase shift from coral to macroalgal dominated state documented at some reef sites may be fuelled by nutrient input from terrestrial sources. In order to limit the amount of nutrient input into the marine environment, a plan to connect more households to a centralised sewage treatment system continues, discouraging the use of septic tanks and soakaway pits. In the Marine National Parks and Special Nature Reserves mooring buoys are being installed at certain locations to prevent boat users from dropping their anchor as means of reducing physical damages to coral reefs.

In 2015, a management plan was drafted for the demersal fishery operating over the Mahé Plateau through extensive public consultation. For the first time in the history of Seychelles it was agreed that effort in the demersal fishery should be controlled by introducing limits on the number of fish traps being used, control of rabbitfish spawning aggregation fishery, minimum size limits for certain key species, and recreational bag (catch) limits. It is anticipated that these measures might help to reduce catch but not to the extent required for stocks to rebuild. More stringent measures, such as controlling the total amount of effort in the fishery have been called for.

Targeted research on coral reefs is also being encouraged. Coral reef monitoring continues to be undertaken at many sites within both the inner and outer islands and local organisations are being encouraged to network and share information about the reef sites under their management. There are plans to increase the number of monitoring sites especially on the east coast of Mahé, where the number of sites monitored is comparatively low.

An atlas of shallow marine ecosystems around Praslin and its satellite islands is presently being produced along with a valuation of ecosystem services provided by shallow marine habitats. It is anticipated that greater availability of information about reef and other marine ecosystems around these islands will strengthen environmental decision making. At the same time, Seychelles continues to put a lot of effort on raising public awareness of environmental issues including those concerned with coral reefs.

2.7.8 Discussion

It has taken much longer for the coral reefs of the Seychelles inner islands to recover from the impact of the 1998 mass coral bleaching event compared to other countries in the region. The slow recovery is thought to be due to there being very few corals left after 1998 to seed recolonisation, as mortality occurred even down to depths of 30 m. The mid-oceanic location of the islands isolates them from coral larvae coming from other locations in the region. Monitoring in the inner islands initially showed that granitic reefs were recovering better than carbonate reefs. A number of factors could be responsible for the higher rate of recovery of granitic reefs, including enhanced sediment shedding ability, low suitability of the rock for macro-algae and lower impact of grazing and water movement on the denser granitic rock. Nevertheless, recovery on carbonate reefs by 2015 equalled that on granitic reefs.

In 2015, the cover of *Acropora* on the inner islands exceeded that of other genera combined for the first time since the 1998 bleaching event. The dominance of Acropora is encouraging since it regrows the fastest, and provides the most structural complexity that creates the micro-habitats used by other reef associated species such as fish, crabs and shells.

The positive effect of the MPAs is apparent in two ways. Since 2012, reefs in protected areas have shown higher coral cover than unprotected reef sites. Second, the density of black-spined sea urchins is 50% lower in MPAs compared to unprotected sites. However, the positive effects of MPA are not apparent in reef fish communities as there appears to be a slow reduction in overall fish densities on protected sites and a reverse trend on unprotected sites. Fish density may not capture what is happening on the reefs of the inner islands and size or biomass may be a better indicator of management success.

The recovery in reef health over the last 17 years since the 1998 mass coral bleaching event was quickly reversed in the first half of 2016 when another mass coral bleaching event was recorded. In the outer islands, bleaching was extensive but it appears that mortality was not very high. In the inner islands, a high level of mortality was reported. However, mortality was highly variable among sites with some sites losing the vast majority of their coral cover while at others coral cover was reduced by 50%. Post-bleaching assessments are needed to quantify the full impact of the bleaching event on live hard coral cover. Interestingly, mortality in 2016 was not as high as 1998 event (Turner et al., 2000) despite the fact that the 2016 El Niño was longer lasting and more extensive than the 1997-1998 episode (JPL, 2016).

Surveys around the island of Praslin found what appear to be several pockets of resilience where corals were not affected by the mass bleaching event. For example, at the Baie Ste Anne jetty a large stand of *Acropora* bleached but only a small portion died. At Chauve Souris, within the Curieuse Marine National Park there is an area in about 3 m of water where corals looked healthy during the bleaching event, where corals in nearby areas bleached and died. It is expected that these pockets of resilience will help provide more beaching resistant larvae that will colonise the reefs of the inner islands and that the next generation of coral communities may be more adapted to high water temperatures. As there are more live corals left on the reef this time around it is expected that recovery will be faster than from the 1998 event.

2.7.9 Recommendations

In order to strengthen the conservation of coral reefs in the Seychelles it is important that a number of measures are implemented at various levels:

1. A clear policy for the conservation of coral reefs is drafted and discussed with all stakeholders concerned. This policy should form the basis for integration of coral reef conservation in the Biodiversity Act which is presently being drafted and in the revision of the Environment Protection Act and the National Parks and Nature Conservancy Act thereby strengthening the legal basis for conservation of coral reefs.
2. A national plan of action for the conservation of coral reefs and associated ecosystems should be drafted and implemented in line with the Seychelles Sustainable Development Strategy (SSDS) and the National Biodiversity Strategy and Action Plan (NBSAP). The action plan should have clear reporting mechanisms and include elements on: reducing man-made pressures, managing Crown of Thorns outbreaks, rehabilitation of impacted sites, coral reef monitoring, strengthening and financing the Seychelles National Coral Reef Network (SNCRN), capacity building, and empowering engagement of non-government entities, such as NGOs and CBOs
3. The SNCRN prepares a national status of coral reefs report at least once every 2 years, ensuring distribution and reaching the highest level of government.
4. The production of other tools such as marine habitat maps and economic valuation of marine ecosystem services are encouraged and supported by coral reef related national initiatives.
5. A system is put in place to share metadata on coral reefs in the Seychelles. This will make it easier to share information among organisations and will foster greater collaboration.
6. Targeted research on coral reef ecology, especially on factors enhancing or delaying the recovery of coral reefs from large-scale impacts should be encouraged along with active collaboration among organisations (government, NGOs, CBOs, academia) at the local and international level.

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2.8 South Africa

Author: *Sean Porter*

2.8.1 Summary

South Africa has a relatively small area (~40km²) of coral reef located in the extreme north-eastern part of the coast. These reefs are marginal and non-accretive, yet the coral communities are rich in diversity, and dominated by soft corals. Long-term monitoring since 1993 has shown a decline in soft coral cover of almost 1% per annum, and a gradual decrease in water temperature. The reason for the decline in soft coral cover remains unclear and may not be representative of the entire reef system. By contrast, hard coral cover rose slightly from 1993 to 2008, and since then has been relatively stable at just under 20% cover. Coral bleaching has occurred, including in the 2016 global bleaching event, but with no recorded mortality of corals.

Since the reefs' discovery in 1970, there has been a good history of sound conservation management, as their biodiversity value and tourism potential was realised early on. All reefs fall within two national protected areas, which in 2000 were given World Heritage status, and declared part of the marine component of the iSimangaliso Wetland Park World Heritage Site. The day-to-day conservation management is effectively undertaken by Ezemvelo KZN Wildlife in consultation with the Wetland Park Authority.

Due to the reefs remoteness from industry, and the protected area status of the land adjacent to them and the ocean around them, pressures and threats are generally minimal, and predominantly from recreational fishing (for pelagic fish only) and SCUBA dive tourism. Unlike many reefs in the Western Indian Ocean, they are not threatened by terrigenous sediments, pollution, overfishing, dynamite fishing or anchoring. Furthermore, only minor bleaching and crown-of-thorns starfish outbreaks have been recorded on several occasions. The reefs lie adjacent to a major shipping route and thus the risk of an oil spill or vessel running aground is always present.

2.8.2 Introduction

South Africa's coral reefs are situated along the extreme north-eastern section of the country's coastline, in the Delagoa Bioregion (Spalding et al. 2007; Porter et al. 2012, 2017). These reefs are the southern-most coral reefs in the Western Indian Ocean, and are limited in extent covering an area of only 40 km^2 (Schleyer 2000). Due to their high-latitude position and marginal nature, they are non-accretive and exist as fossilized sandstone dunes encrusted by coral communities. The reef system can be divided into three complexes, all of which lie within the iSimangaliso Wetland Park World Heritage Site (fig. 2.8.1).

Contributors & acknowledgements: *Michael Schleyer initiated the long-term monitoring and data collection, and David Pearton, Camilla Floros, Justin Hart and Stuart Laing are acknowledged for their contributions in the field. Larry Oellermann, from the South African Association for Marine Biological Research, is thanked for institutional support, and together with the Department of Environmental Affairs, National Research Foundation, Mazda Wildlife Fund and Western Indian Ocean Marine Science Association, provided financial support.*
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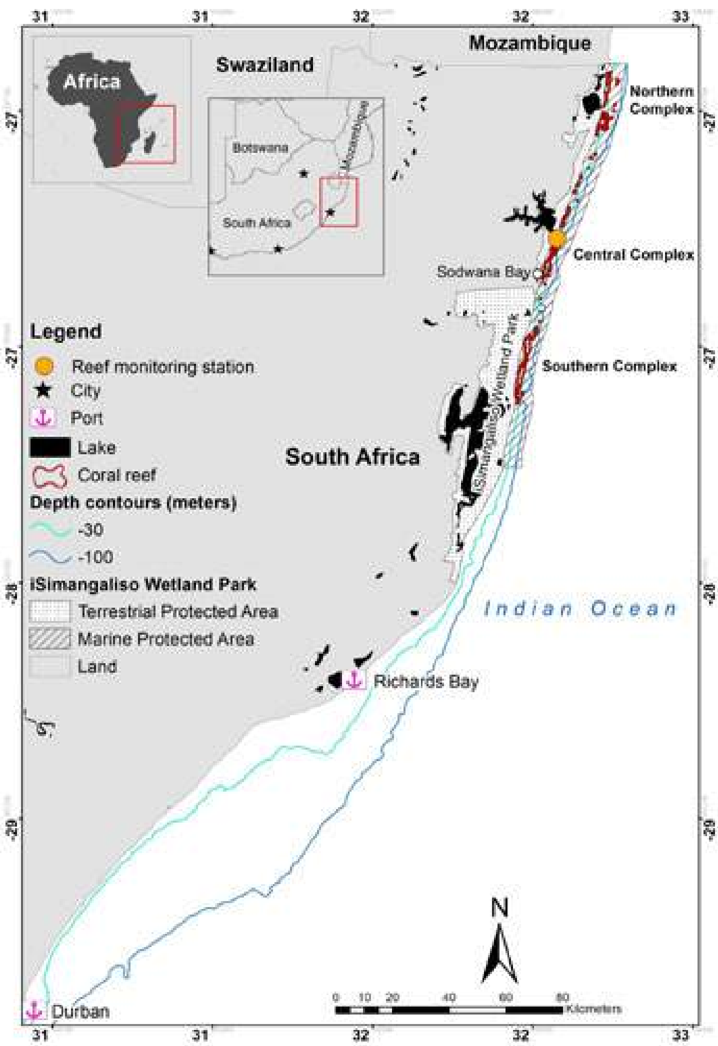

Figure 2.8.1. South Africa's coral reefs located in the extreme north-eastern part of the country. The monitoring site is situated on Nine-mile Reef in the Central Complex, in the iSimangaliso Wetland Park World Heritage Site.

Despite their marginal nature, they exhibit high biodiversity with a mixture of tropical and temperate Indo-Pacific fauna and flora. Soft corals dominate the benthos, followed by the more diverse hard corals (Riegl et al. 1995). The communities comprise at least 93 species of Scleractinia, 39 Alcyonacea, 30 Ascidiacea, 20 Porifera and 104 algae (Schleyer and Celliers 2003; Anderson et al. 2005). Fish communities are similarly diverse with 284 reef-associated species having been recorded (Floros et al. 2012). The high biodiversity of the reefs and the resultant revenue accrued via ecotourism makes these reefs important resources (Dicken 2014). This, coupled with their potential vulnerability to climate change, provided the stimulus for monitoring of the coral communities, which was initiated in 1993 (Schleyer et al. 2008; Porter and Schleyer 2017) (fig. 2.8.2).

2.8.3 Status and trends

Total hard and soft coral cover at the Nine-mile Reef monitoring site (Central Complex) has decreased gradually since monitoring commenced, from 67.5% in 1993 to 55.9% in 2014 (fig. 2.8.2b). The declining cover of soft corals over the 21-year period from 54.3% to 37.7% is primarily responsible for this (Porter and Schleyer 2017). The rate of soft coral cover decline is almost 1% per annum. Contrastingly, hard coral cover increased from 13% in 1993 to 18% in 2005, where it has since stabilised and remained constant (fig. 2.8.2a).

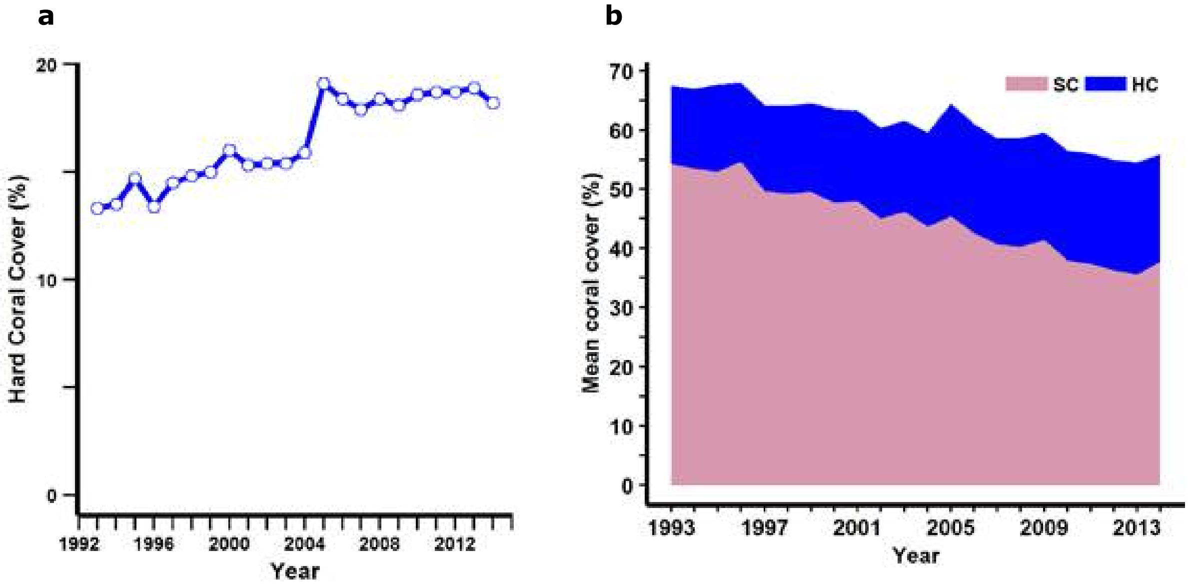

Figure 2.8.2: a) Trend in hard coral cover on South Africa's long-term monitoring site from 1992-2014 (dark blue line); b) Comparison of cover of hard corals (HC, blue, top) and soft corals (SC, pink, bottom) at the site from 1993-2014.

Recruitment success of both soft and hard corals has been erratic between years and has not shown any trends for most of the monitoring period, except from 2010, when a large increase particularly in hard coral recruitment success occurred (Porter and Schleyer 2017) (fig. 2.8.3). Subsequent to 2010, recruitment success of hard corals has declined sharply to previous years' levels. However, soft coral recruitment success has continued to increase from 2010 until 2013.

Mortality of all corals combined, as well as soft and hard corals individually, displayed similar patterns to recruitment success, i.e. values have been erratic for most of the monitoring period but have begun to increase consistently from 2011 to 2014. Continued monitoring will determine if these trends continue. Mobile invertebrates and fish populations have not been monitored during this time period; a revision of the monitoring protocols in recent years will initiate these.

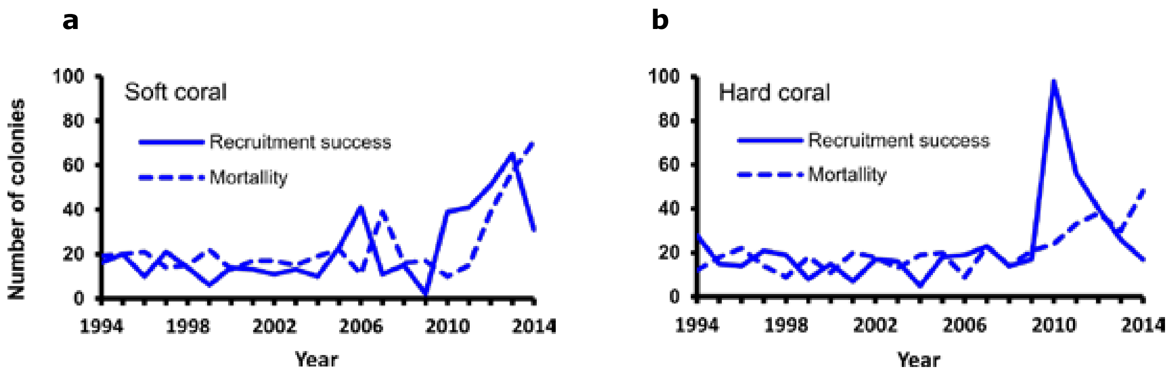

Figure 2.8.3.: Recruitment success and mortality for soft coral a) and hard coral b) at Nine-mile Reef from 1994-2014.

2.8.4 Coral Bleaching 2016

Coral bleaching surveys were conducted in May 2016 at five sites on Two-mile Reef in the Central Complex. At each site, six to seven 10-m long transects were haphazardly placed on areas of reef, and the point-intercept method employed to measure intensities of bleaching using an underwater video recorder. Bleaching severity was assessed within the immediate vicinity of each point and scored on a 5-point scale as: no bleaching, partially bleached or pale but not white, white, bleached and partly dead and recently dead. A total of 700 points were assessed along transects placed at depths of 12-18 m. Mean ± standard deviation was then calculated for the proportion of coral cover bleached using sites as replicates.

Bleaching of the corals ranged from 4.1 to 17.5%, with an average ± SD of 9.4 ± 5.9%. *Montipora* was by far the most commonly bleached genus, comprising 63% of the bleached coral cover followed by *Favia* (10%) and *Pocillopora* (7%). When corals were bleached, 49% were pale but not white, whilst the remaining 51% were white. At the time of the surveys, and four months later in follow up surveys, no bleaching-related mortality was detected.

Bleaching has been previously recorded on several occasions in the region (see Timeline) with highest levels recorded in 2000 (Celliers and Schleyer 2002). In 2000, *Montipora* was similarly found to be the most susceptible genus to bleaching, and a comparable proportion of the coral colonies showed partial bleaching or paling (44%), or full-white bleaching (47%).

2.8.5 Drivers and pressures

South Africa has a population of approximately 55 million and in 2015 had a GDP output of 317.3 billion US dollars (IMF 2015; Statistics South Africa, 2016). Economic growth was marginally above 2% for the period 2008 to 2012 (Statistics South Africa, 2016). Unemployment levels are relatively high at 25.5% (Statistics South Africa, 2016). The majority (63%) of people have completed primary education, whilst only 27.7% and 2.7% have completed secondary and bachelors-degree level education respectively (Statistics South Africa, 2011). South Africa's Ecological Footprint stands at 2.59 per person per hectare. Two local government municipalities encompass the land which lies adjacent to South Africa's coral reefs - uMhlabuylingana and The Big Five False Bay - with a combined population of 192,000 people. The uMhlabuylingana municipality is predominantly rural, with informal settlements at Mbazwana and Manguzi. Of the 33,857 households, 14.2% have electricity and 5.3% have piped water (Local government handbook 2016). The Big Five False Bay is also largely rural, and of the 7998 households 42.6% have electricity while 23.5% have piped water (Local government handbook 2016). The area is prone to periodic droughts and vulnerable to climate change (DEA 2013). Offshore, there is a major shipping route which connects the ports of Durban and Richards Bay with the rest of the east African coast and the Middle East.

In 2013, Operation Phakisa (OP) was initiated which aims to unlock the economic potential of South Africa's ocean. Although a key component of OP is marine protection and ocean governance, other components of OP are likely to increase pressures on the marine environment. At present, pressures on the coral reefs associated with industrialisation, urbanisation and local human populations are negligible however, as the reefs, as well as the adjacent terrestrial environment, fall within protected areas and a UNESCO World Heritage Site – the iSimangaliso Wetland Park. Extraction of marine resources is allowed in certain zones by subsistence and recreational fishers but no bottom fishing or gillnetting is permitted anywhere. Recreational fishing for pelagic fish is considered to be a significant pressure in the region (Sink et al. 2012). Apart from reef associated fish caught by these sectors, other principle pressures largely emanate from various forms of non-extractive resource utilisation such as from the dive-tourism industry and boat traffic associated with the tourism industry (Table 2.8.1 and Timeline). Floros et al. (2013) have shown that fish communities do differ significantly among the different use zones (e.g. high diving zones versus exclusion zones) and Schleyer and Tomalin (2000) found that divers have physical impacts on the reefs which exceed damage levels on undived reefs. Diving and boat pressures are, however, limited to the Central Complex.

Particulate and chemical pollutants, as well as land-based sediments, are likely to be extremely low due to the absence of river conduits (Porter et al. 2017) and a ban on the use of two-stroke outboard engines by charter boats in the Park. However, due to the proximity of an international shipping lane, the reefs are threatened by oil spills and ships running aground (Sink et al. 2012). Typical reef-specific pressures and threats, such as coral bleaching and COTS outbreaks, although present have been low in frequency and in severity (See Timeline) (Schleyer and Celliers 2003).

The region is generally predicted to become wetter and warmer, and the water more acidic as a result of climate change (DEA 2013). Underwater temperature monitoring over the last 20 years has, however, revealed a gradual decrease in temperature at the site scale (Porter and Schleyer 2017), although the temperature has been increasing regionally over the last century and a half (Schleyer et al. 2008). The rate of sea level rise approximates 2.7 mm per year (Mather et al. 2009).

Table 2.8.1: Important pressures affecting the Central Complex. Launches- number of boat trips (all are launched from the beach); Dives- number of dives; Fish kept- number of fish retained by fishers and landed.

Year	Launches	Dives	Fish kept
2005	10,371	66,178	
2006	10,366	69,283	
2007	10,164	65,051	
2008	10,714	68,797	
2009	9,334	62,971	
2010	8,907	60,442	
2011	8,219	60,515	8,023
2012	9,338	63,528	8,092
2013	10,131	68,981	6,250
2014	9,616	62,699	5,834

2.8.6 Timeline

1970	Discovery of the coral reefs
1979	Proclamation of the St. Lucia Marine Reserve and a ban on bottom fishing (Southern and Central complexes)
1986	Proclamation of the reefs as wetlands of international importance (RAMSAR status)
1987	Proclamation of the Maputaland Marine Reserve and a ban on bottom fishing (Northern Complex)
1993	Long-term coral monitoring initiated
1994-1999	Minor COTS outbreak
1998-2000	Minor coral bleaching
2000	Proclamation of the iSimangaliso Wetland Park World Heritage Site
2000	Diver carrying capacity determined at 6000 -7000 dives per site per year
2005	Limited coral bleaching
2012	Ban on two-stroke outboard engines for charter boats
2016	Minor coral bleaching <12%

2.8.7 Responses

The conservation of South Africa's coral reefs has been a priority since their discovery and several pieces of legislation are in place to ensure their conservation. The coral reefs (and broader area) are governed by two international agreements. These are the Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (World Heritage Convention) and the Convention on Wetlands of International Importance Especially as Water Fowl Habitat, 1971 (RAMSAR Convention). All South Africa's coral reefs fall within a UNESCO World Heritage Site, the iSimangaliso Wetland Park, proclaimed in 1999 under the National World Heritage Convention Act (Act No. 49 of 1999) (see Porter et al. 1998). Through this, the government has an obligation to ensure "the identification, protection, conservation and transmission to future generations of the cultural and natural heritage" of the iSimangaliso Wetland Park. The legal structure of the World Heritage Convention is introduced nationally via the National World Heritage Convention Act (Act No. 49 of 1999) and is covered in more detail below.

Other international legislation of relevance to the legal framework concerning the reefs includes:

- CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) as many of the organisms found on the reefs are endangered;
- Bonn Convention - Convention on the Conservation of Migratory Species of Wild Animals (1979) as there are several species of migratory animals associated with the reefs;
- UNCLOS – United Nations Convention on the Law of the Sea (1982);
- Basel Convention - Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal (1989) as the region shares its northern boundary with Mozambique;
- CBD – Convention of Biological Diversity (1992) as South Africa is party to the Convention;
- Cartagena Protocol – Cartagena Protocol on Biosafety (2000) as South Africa is signatory to the Convention on Biological Diversity and is automatically bounded by this protocol

At a national level, The National Word Heritage Convention Act (Act No. 49 of 1999) is written within the framework of, and is supportive of the National Environmental Management Act (Act 107 of 1998 and amendments). It brings into domestic law both the World Heritage Convention and its Operational Guidelines. The responsible Minister is the Minister of Environmental Affairs.

National legislation of relevance to the reefs includes the following:

- Constitution of the Republic of South Africa, 1996;
- National Environmental Management Act, 1998 (Act 107 of 1998 and amendments);
- National Environmental Management - Biodiversity Act, 2004 (Act 10 of 2004);
- National Environmental Management - Protected Areas Act, 2004 (Act No. 31 of 2004);
- National Environmental Management - Integrated Coastal Management Act, 2008 (Act No. 24 of 2008);
- National Environmental Management - Environment Conservation Amendment Act, 2003 (Act No. 50 of 2003);
- National Environmental Management - Waste Act, 2008 (Act 59 of 2008);
- Marine Living Resources Act, 1998 (Act 18 of 1998);
- Sea Birds and Seals Protection Act, 1973 (Act No. 46 of 1973);
- Seashore Act, 1935 (Act 21 of 1935); and
- Maritime Zone Act, 1994 (Act 15 of 1994)

As all coral reefs are situated within the iSimangaliso Wetland Park, the iSimangaliso Wetland Park Integrated Management Plan 2011-2016 (iSimangaliso Wetland Park Authority, 2011) is another important legal instrument. The management plan has been approved by the Minister in accordance with Section 25(1) of Chapter IV of the World Heritage Convention Act (No 49 of 1999) and operates within the parameters of all legislation listed above. In addition, several policies and Park Internal Rules relevant to the reefs include: a ban on 2-stroke outboard engines for charter boats; prohibition of any form of fishing on Two-mile Reef; no anchoring; recreational fishing for pelagic species only; spearfishing for pelagic species only; ban on chumming or feeding of fish; no gillnetting or vertical jigging and prohibition of any form of activity on certain reefs (i.e. sanctuary reefs). The day-to-day conservation management of the reefs is undertaken by the provincial conservation agency Ezemvelo KZN Wildlife which is also responsible for law enforcement.

In general, the reefs and the rest of the marine protected area (MPA) are well managed, and the combined use of several Acts has enhanced management effectiveness (Chadwick et al. 2014). The current MPA is also in the process of being expanded offshore and southwards, and is being rezoned as part of Operation Phakisa. From 2009, there has been a lack of enforcement of SCUBA diving permits, and poor offshore enforcement and a lack of offshore enforcement at night (Chadwick et al. 2014). The two existing patrol boats are in need of replacement and lack suitably qualified staff to operate them, and related infrastructure needs maintenance (Chadwick et al. 2014). Much of this is due to an insufficient budget.

2.8.8 Discussion

The most important findings relate to the consistent decline in soft coral cover from the onset of monitoring in 1993, which is difficult to explain. By contrast, hard coral cover rose slightly from 1993 to about 2008, and since then has been relatively stable at just under 20% cover. Water temperatures at the site have been gradually decreasing since monitoring commenced and minor bleaching has been recorded on several occasions in the region, including in the 2016 global bleaching event, but with no recorded mortality of corals. Pollution levels are considered to be extremely low.

The importance of South Africa’s coral reefs was realised soon after their discovery. The Central and Southern complexes were encompassed in a MPA in 1979 and the Northern Complex in 1987, shortly after receiving RAMSAR status. These two MPAs were later consolidated to form part of the marine component of the iSimangaliso Wetland Park Word Heritage Site in 2000. As a consequence the reefs have had a good history of sound conservation management underpinned by several pieces of key international and national legislation.

Due to the area’s protected area status, the chief pressures on the reefs are largely from the recreational fishing of pelagic fish species and disturbance factors caused by the high number of boat launches and divers from the tourism industry. These activities have stabilised in number over the years, and are highly concentrated and restricted to certain areas, as specific usage zones have been delineated within the MPAs.

2.8.9 Recommendations

1. Coral reef monitoring should be continued, supported and expanded to include other sites and include the monitoring of other parameters, in particular fish, coral health (bleaching and disease) and possibly solar radiation.
2. Monitoring of both extractive and non-extractive resources should be continued to ensure that thresholds are not exceeded.
3. The MPA should be expanded further offshore to provide increased buffering from illegal foreign fishing vessels.
4. The Word Heritage Site northern border should be extended further north to incorporate the Ponta da Ouro Partial MPA in Mozambique with their collaboration, so that a transboundary site is created.
5. Existing oil slick and ship-wreck prevention/mitigation and clean-up contingency plans should be reviewed and updated.
6. Operational equipment to conduct adequate enforcement offshore must be acquired.
7. Vacant posts in MPA sections must be filled.

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2.9 Tanzania

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2.9.1 Summary

The coral reefs of Tanzania are under great pressure from both anthropogenic and natural stressors. There is regular monitoring of these reefs, with some intermissions when funding has been difficult. Coral reef health (as shown by live coral cover) has fallen over the last 30 years, but not by a large amount, and has been stable around 35 to 45% until 2015. By contrast, fleshy macroalgae levels on reefs ranged between 10 to 20%. Fish abundance and diversity has varied significantly between years, with numbers highest in 2008, falling thereafter and rising again in 2014. The most abundant fish on the reefs are the wrasses (Labridae) and damselfish (Pomacentridae). Prime commercial species and larger individuals were relatively scarce on the reefs.

Preliminary reports suggest that the 2016 bleaching event in Tanzania was less severe than expected. Repeated cycles of coral bleaching, and partial mortality and recovery of many sites, and resistance of some sites to bleaching in 2016 may be an indicator of resilience to climate change and suggests the need for enhanced conservation measures. Management of coral reef resources is seeing improvement though at a slow rate. The approach of management through cooperation with communities is encouraging, with Beach Management Units and Village Fishery Councils having the potential to play a greater role in marine resource conservation and management. Government has also taken the lead in coral reef monitoring in MPAs. We recommend that coral reef monitoring be expanded to include more sites and other parameters (particularly coral bleaching and disease), the monitoring networks should be strengthened, monitoring methods should be harmonised and a unified national coral reef database should be created and used.

2.9.2 Introduction

Tanzania lies south of the Equator, between latitudes 1°S and 12°S and longitudes 29-40°E, and has the greatest reef area among the countries of the region (3580 km^2; Spalding et al. 2001). Coral reefs are located along about two thirds of Tanzania's continental shelf. Fringing reefs and patch reefs predominate. The fringing reefs form margins along the edge of the mainland or islands and the patch reefs are often extensions of fringing reefs. However, because the continental shelf is narrow, coral reefs are mainly restricted to a narrow strip along the coast. The islands of Unguja, Pemba and Mafia, as well as numerous small islands all along the coast, are for the most part surrounded by fringing reefs. Coral development is hindered in shallow reefs near freshwater inlets particularly after heavy seasonal rains (Hamilton and Brakel, 1984), and around the two main estuaries (Rufiji to the north and Ruvuma in the south) due to excessive sedimentation in these areas. In the Ruvuma these sediments occasionally affect even the (westernmost) reefs of Mafia Island Marine Park (Machano 2012).

While coral reef studies in the 1960s and 1970s reported high diversity and luxurious growth of corals and reef resources (Talbot, 1965; Ray, 1968; Hamilton, 1975), surveys since then have described a general degradation of the coral reef environment and its resources.

Coral reef communities in Tanzania comprise at least 273 species from 63 genera and 15 families (Obura 2004). This figure is expected to grow as further studies are carried out and the local taxonomic expertise continues to expand. Fish communities are similarly diverse but there is a lack of data on nation-wide diversity levels i.e. most studies have reported reef-specific rather than regional fish species diversity. Over 90% of the marine fisheries in the country are artisanal, focusing on coral reef fish (Jiddawi and Öhman 2002). Besides finfish, coral reefs are fishing grounds for cephalopods, gastropods, echinoderms and bivalves, thus providing animal protein to a large proportion of the human coastal population. In addition, coral reefs are one of Tanzania's major tourist attractions, bringing foreign currency into the country and providing a livelihood for coastal people.

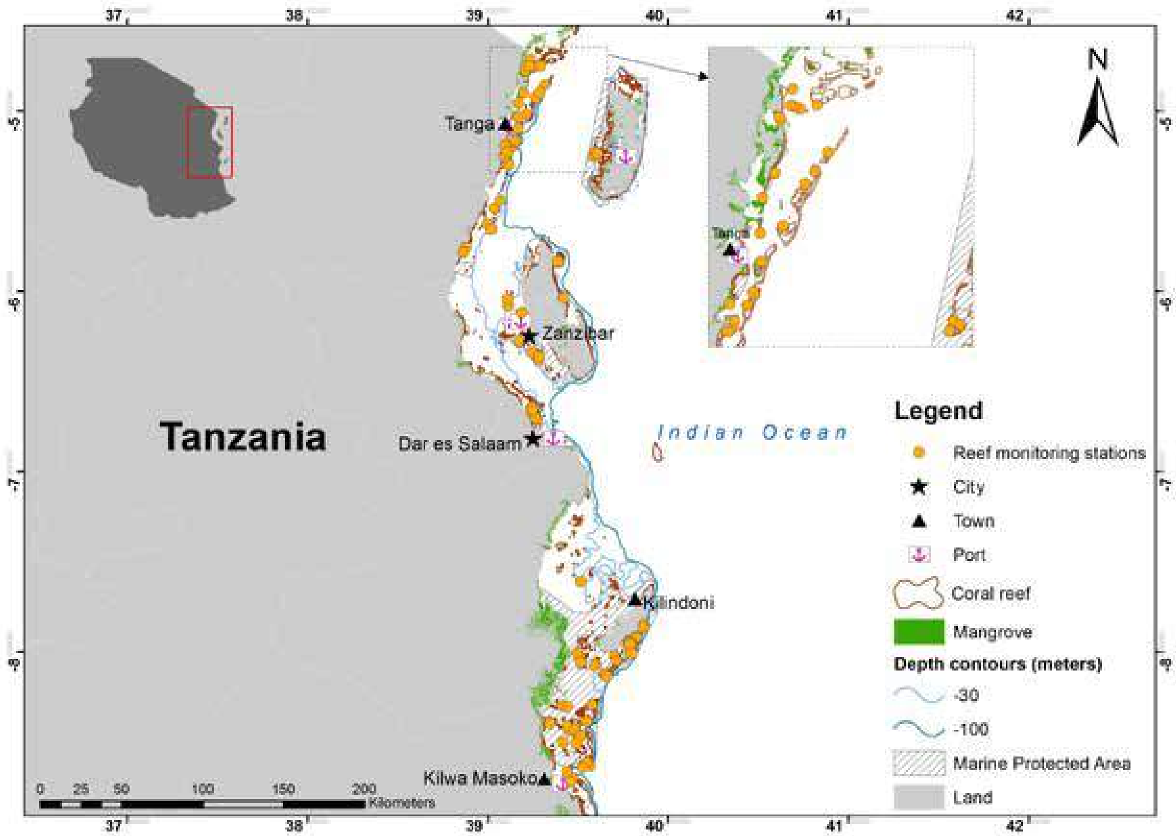

Figure 2.9.1: Tanzania's coral reefs and monitoring stations, focusing on the central and northern regions for which data were included in this study.

2.9.3 Status and trends

Coral cover has remained high on Tanzanian reefs, with fluctuations between about 30% and 50% since 1992 (Fig. 2.9.2a). Prior to significant mortality in the 1998 coral bleaching event, coral cover ranged between 40 and 50%, dropping to just under 30% in 1999. After this, recovery has occurred, though with a decline in 2005 and again in 2015. Coral cover levels in Tanzania are considered high for East Africa, with 30-40% live coral cover being reported for healthy reefs elsewhere (McClanahan and Arthur 2001, Obura, 2004). Nevertheless, there are some reefs e.g. Kitutia in Mafia and Chumbe in Zanzibar that suffered significant mortality in the 1998 bleaching event but have slowly recovered.

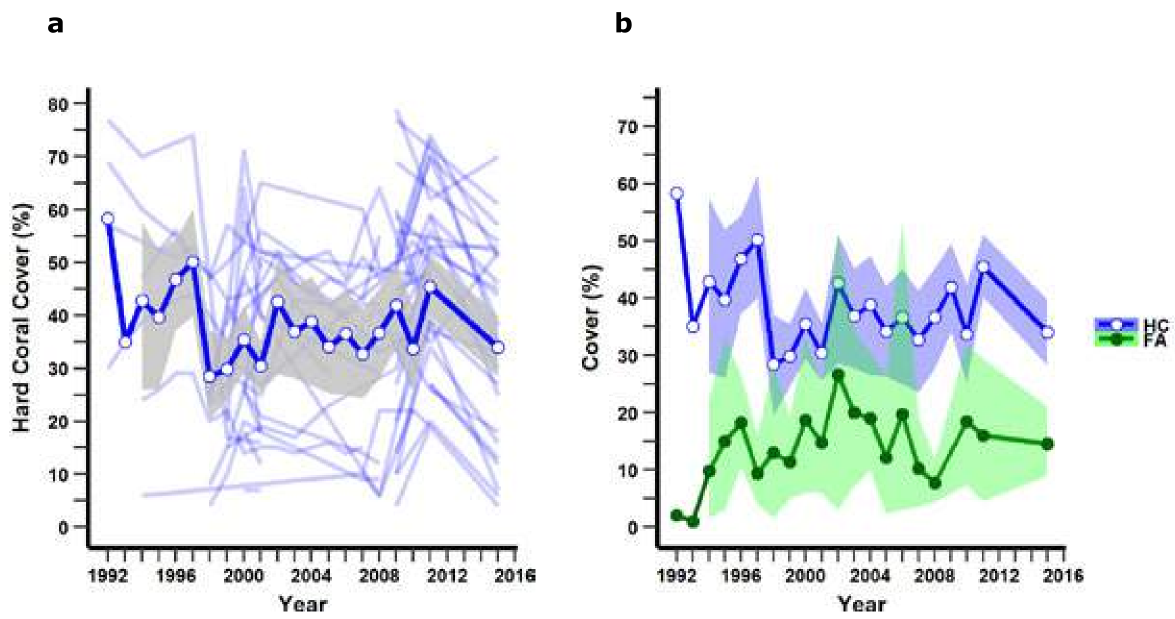

Figure 2.9.2: a) Trend in hard coral cover on Tanzanian reefs (national mean (dark blue line), 95% confidence limit (grey shaded area), individual monitoring stations (light blue lines)); b) Trend in mean hard coral cover (blue line, open circles) and fleshy algae (green line, closed circles) in Tanzania (coloured shaded areas represents 95% confidence limits of the mean)

Acropora species dominate in most sites, but because of their sensitivity to disturbance, their percent cover shows significant spatial and temporal fluctuation. *Montipora, Galaxea, Fungia, Favia* and *Porites* are genera that are also common, and have better survived natural disturbances where *Acropora* mortality has been high. Coral recruitment success has been erratic between years and has not shown significant trends over the monitoring period. Coralline algal cover has remained below 10% with higher levels recorded in 2015 than in previous years.

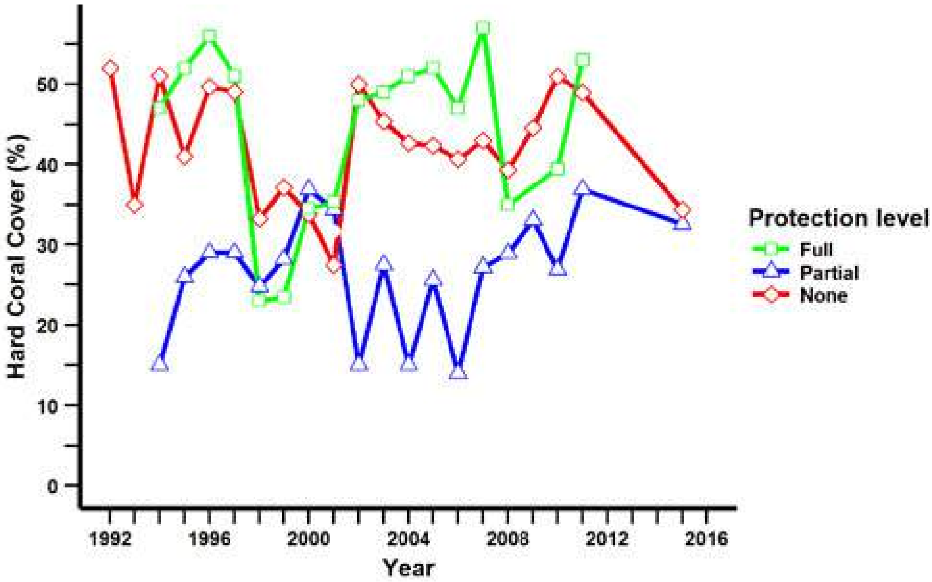

Figure 2.9.3. Comparison of hard coral cover among three management regimes with different levels of protection in Tanzania from 1992-2016.

Fleshy algae (macroalgae and turf algae combined) have been a common feature on all reefs, more so where reef degradation has occurred, and algal cover has fluctuated greatly between reefs and over years, ranging between 5 to 35% on average (Fig. 2.9.2b). The fishing of herbivores has partly contributed to this prevalence, leading to algal smothering of corals in some instances. Studies have shown a positive correlation between hard coral cover and both fish biomass and diversity (Garpe et al. 2006, Yahya 2011).

Fish populations have been monitored using different methods and objectives. For example some datasets have concentrated on commercial fish species while others have considered ecological roles of the fish species. The abundance of reef fish increased from 1999 and appears to peak in 2008, with lower levels after this (Fig 2.9.4). Populations of prime fisheries species (i.e. carnivores and piscivores such as the emperors (Lethrinidae), snappers (Lutjanidae), groupers (Serranidae), jacks (Carangidae) and barracuda (Sphyraenidae)) were low and there was a scarcity of larger (> 40cm) fish. Conversely, the relative abundance of the smaller Scaridae has increased.

The fish diversity reported varies between regions, e.g. 350 species in Mafia Island (Garpe and Öhman 2003) and 369 species in Mtwara (Obura 2004). A common feature to almost all monitored Tanzanian sites is that wrasses (Labridae) and damselfish (Pomacentridae) showed the highest species richness, perhaps partly due to the fact that the Pomacentridae and many of the smaller Labridae are generally not fished.

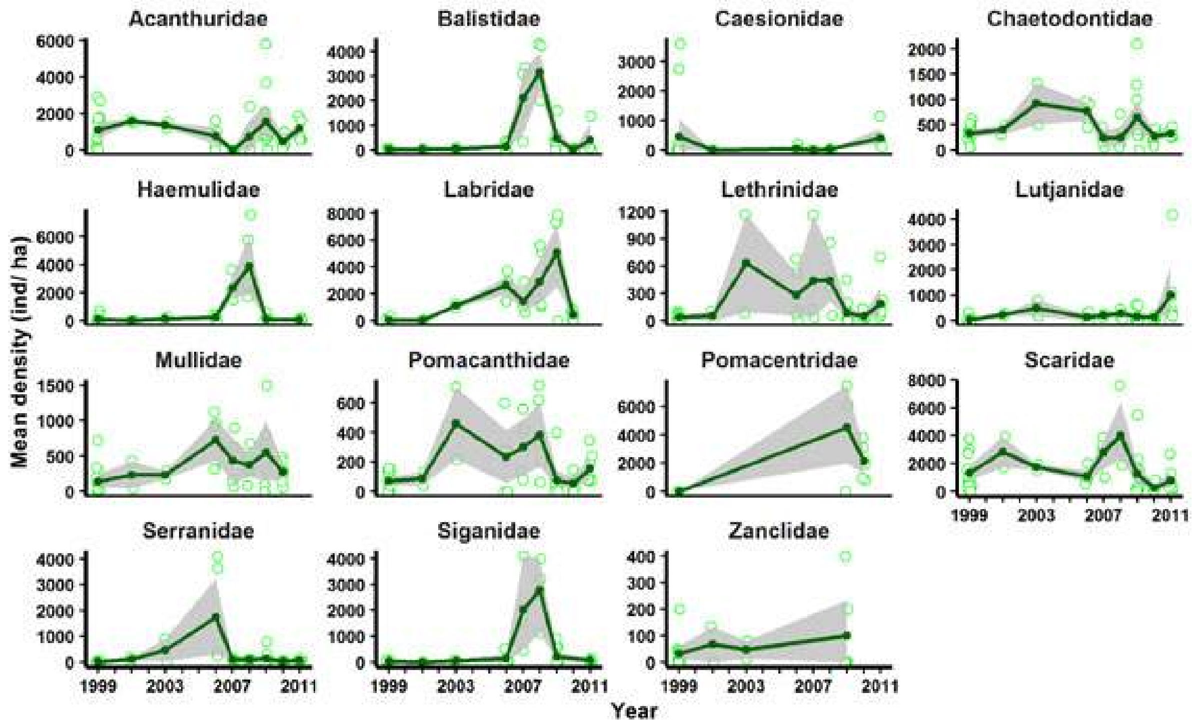

Figure 2.9.4. National averages of fish abundance for 15 fish families on coral reefs in Tanzania between 1999 and 2011. Open circles represent surveyed sites and shaded areas represent the 95% confidence limits.

Macro-invertebrate monitoring has focused on sea urchins, clams, sea cucumbers and starfish. In general they are widespread but at low densities across reefs and years. The densities of invertebrates with high economic value (lobsters and large gastropods) were very low. It is not clear whether this is due to over-exploitation as many have been historically targeted for flesh and shells (Richmond 2002), or habitat destruction. Some macro-invertebrates such as octopus are quite cryptic and not easily observed. Nevertheless, the octopus fishery is a significant one in Tanzania, and occurs almost exclusively on coral reefs and intertidal rocky flats.

2.9.4 Coral Bleaching 2016

Coral bleaching started around mid-March 2016 and ceased in June, which is similar to the timing of the 1998 bleaching. Peak bleaching occurred during late March and into April. Bleaching of 80–90% was observed on some reefs, such as Sinda reef off Dar es Salaam (M. Richmond and C. Muhando pers.comm) and northern Chumbe reef, Zanzibar (U. Kloiber pers. comm.). Bleaching information was mostly collected by divers and snorkelers from MPAs, research institutes and dive centres, and reported on the online reporting form developed for the WIO (http://cordioea.net/bleaching_resilience/wio-coral-bleaching-alert/). About 70 bleaching reports were made, between, March and June, and from the whole coastline from Tanga in the North to Mnazi Bay in the South. Reported bleaching levels ranged from low (5 -10%) to extreme (>90%).

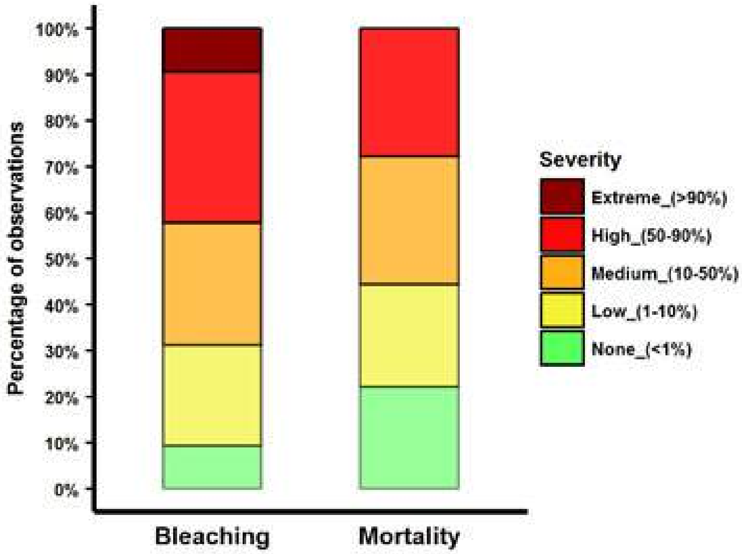

Figure 2.9.5. Observations of coral bleaching (n=64) and associated mortality (n=18) observations collected in Tanzania in 2016. Categories represent the severity of bleaching/mortality reported as percentage of coral cover bleached/dead estimated at the site level.

The most affected corals were *Acropora*, common to all sites. Fungia, Pocillopora, Porites and the faviids were also greatly affected by bleaching. Preliminary reports indicate varied outcomes, ranging from significant recovery from bleaching in Mtwara and Tanga (E. Mbije pers. comm.), and little recovery in some reefs off Zanzibar town. The effects of bleaching varied spatially and between species and growth forms. For example on Chumbe reef in Zanzibar, short-branched and digitate species and massive Porites recovered quite well, while branching and table *Acropora* suffered significant mortality. Depth was also probably a factor. On reefs with high mortality, cover of algal turf on dead corals increased significantly. One common observation throughout the country was that the anemone *Heteractis magnifica* remained bleached, months after the first bleaching occurrences.

Seawater temperature has been monitored for almost two decades on some reefs. A strong seasonal pattern is shown, with lowest temperatures in July–August and highs in March–April (Fig. 2.9.6). Temperatures have reached as low as 23.4 and as high as 33.9 °C. However the yearly average is 27.5 °C. In late March to early April 2016, at the peak of coral bleaching, water temperatures repeatedly reached 31°C.

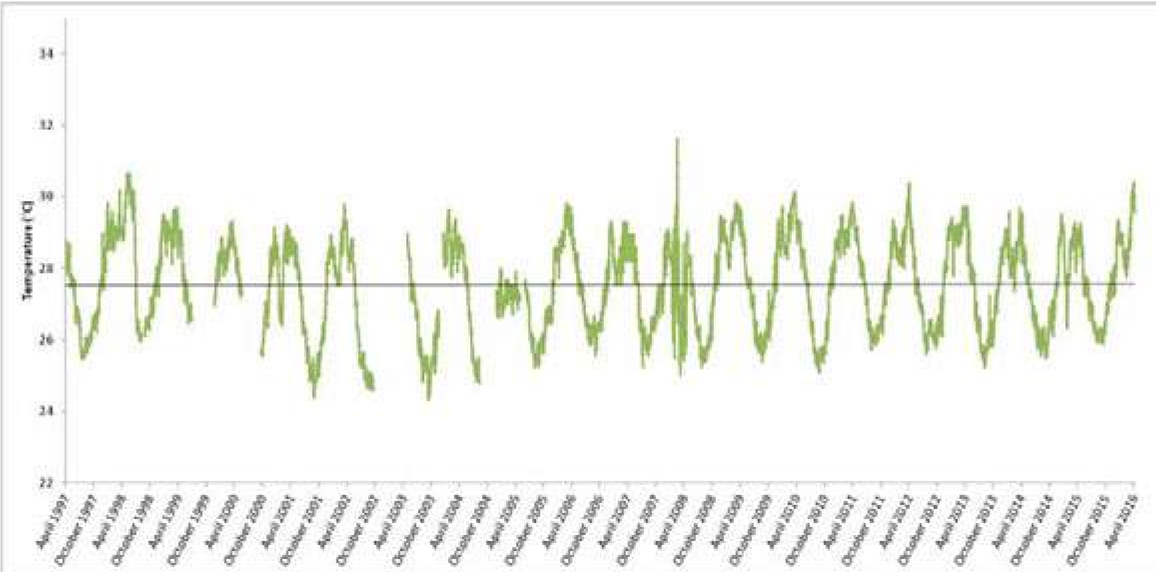

Figure 2.9.6. Trends in seawater temperature on Tanzanian reefs (source: C. Muhando, IMS)

2.9.5 Drivers and pressures

Tanzania's population was projected to be approximately 50 million in 2016, from 44 million counted in the 2012 national census, with a growth rate of about 3%. The gross domestic product (GDP) growth rate for 2015 was 7% (TNBS 2016), and with about 25% of the population living along the coast, coastal resources are under significant stress. Increase in the coastal population and poor economy as well as unplanned coastal tourism and coastal development have also been implicated in coral reef degradation. Additionally, climate change associated coral bleaching has contributed greatly to coral reef degradation, particularly the major bleaching event in 1998.

Fishing is a very important activity amongst those who live in the coastal areas. It is a vital source of food, employment, recreation, trade and economic wellbeing for the coastal population. In Tanzania, coastal fisheries are mostly artisanal, using traditional gears and small vessels such as outrigger-canoes and small boats with sail or outboard engines. This artisanal fishery is concentrated in inshore shallow waters, due to the narrowness of the continental shelf and the limited range of the traditional vessels. The number of fishermen has been increasing in the last two decades. According to fishery statistics of 2012, the total number of fishers were 70,892 using 16,303 vessels, and a total catch of 79,489 tonnes (50,069 tonnes in mainland Tanzania and 29,420 tonnes in Zanzibar).

Destuctive fishing is a major pressure on Tanzanian reefs, specifically dynamite fishing and drag nets (e.g. Ngoile and Horrill 1993, Johnstone et al. 1998, Mohammed et al, 2000), and lately, ring nets. Dynamite fishing grew to be a major problem in the 1990s in Mtwara and Tanga regions (Guard and Masaiganah 1997) but was more or less successfully reduced in both regions through an aggressive response from the authorities and joint Police/Navy and local enforcer patrols. Unfortunately dynamite fishing has resurfaced in recent years and is a common occurrence again in both regions, in Dar es Salaam and in the Songosongo Archipelago.

Pollution and aquaculture currently are at low levels, though sedimentation near the river mouths is of greater concern. Aquaculture is being promoted as an alternative livelihood to ease pressure on fisheries, so has potential for environmental and ecological damage if not managed and regulated carefully. Tourism and its associated increase in boat traffic and tourists on reefs is on the rise. However, there has been a rise in non-coral focussed water tourist activities such as sport fishing and wind sports such as kite surfing; these may help to reduce tourism pressure on coral reefs.

The prevalence of coral diseases is low and sites close to large cities are the most affected (Mohammed 2016), but it is a less significant stressor than coral bleaching and competition and overgrowth of corals. The most common diseases can be divided into 'band' diseases (specifically skeletal eroding band, black band disease and brown band disease) and non-band diseases (e.g. ulcerative white spots and white syndrome). *Acropora* and *Echinopora lamellosa* were the most vulnerable corals, particularly to ulcerative white spot disease. There have been several outbreaks of Crown-of-Thorns starfish in the last decade, though not widespread (Ussi 2014). Overgrowth by corallimorpharians, not considered an important benthic component of reefs in Tanzania before 1996 (Kuguru, 2002, Muhando and Kuguru, 2002, Kuguru et al. 2004), is now a common feature on many reefs off Zanzibar town for example (Yahya, pers. obsv.).

2.9.6 Timeline

1968	Ray proposes a management plan for the Tanzanian coast
1970	The Fisheries Act designates eight marine reserves in the country and makes dynamite fishing illegal
1975	Dar es Salaam Marine Reserves (Fungu Yasin, Mbudya, Pangavini and Bongoyo Island) gazetted
1975	Maziwe Island Marine Reserve in Pangani, Tanga gazetted
1994	Marine Parks and Reserves Act comes into force
1994	Tanga Coastal Zone Conservation and Development Programme (TCZCDP) established
1994	Chumbe Island Coral Park, a privately managed MPA, gazetted
1995	Mafia Island Marine Park (MIMP) gazetted
1997	Menai Bay Conservation Area, gazetted
1998	El Niño-induced coral bleaching causes high coral mortality countrywide
2000	Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP) declared
2003	Fisheries Act (2003), caters for establishment of Beach Management Units
2005	Formation of the Tanzania Coral Reef Task Force
2009	Tanga Coelacanth Marine Park (TACMP) gazetted
2009	Dar es Salaam Marine Reserves (DMRs South) i.e., Kendwa, Inner and Outer Sinda, Inner and Makatube Islands gazetted
2009	Shungi Mbili, Nyororo and Mbarakuni Island Marine Reserves in Mafia gazetted.
2010	Kwale, Mwewe, Kirui and Ulenge Island Marine Reserves in MkingaTanga gazetted
2013	Multi-agency Task Team against Environmental Crime including Blast Fishing formed
2014	Zanzibar Coral Reef Monitoring Network formed
2015	Marine Conservation Unit (MCU) Regulations of 2015
2016	Coral bleaching countrywide with up to 90% bleaching on some reefs
2016	Proclamation of Jozani-Chwaka Bay National Park as a UNESCO Man and Biosphere Reserve

2.9.7 Responses

Management of coral reefs in Tanzania is tied to the management of fisheries, which is controlled via licensing, policies and regulations, and marine managed areas. The ocean in Tanzania is, in theory, open access for nationals, so everyone has a right to fish. All fishers and fishing vessels are required to have a license but there are no quotas, so this is not restrictive. With the exception of industrial fishers, there is effectively no control exercised on the number of licences issued and the fees are quite affordable. Laws and regulations include gear-specific regulations (e.g. mesh size for nets and basket traps, restriction of spearfishing), village level or customary by-laws, and periodic closures of fishing in areas where need arises.

The legal framework in the country is founded on the Constitution of the United Republic of Tanzania. National legislation of relevance to the reefs includes the: Fisheries Act of 2003; National Environmental Policy (NEP, 1997) (the umbrella guiding policy on environmental protection and management); National Biodiversity Strategy and Action Plan (NBSAP, 2015) as one of the requirements for the international Convention on Biological Diversity (CBD); National Integrated Coastal Environment Management Strategy (NICEMS, 2003); The National Tourism Policy (1999); National Environmental Management Act (2004); The Zanzibar Fisheries Act (2010); the Marine Conservation Unit of Zanzibar Regulations (2015); and the National Fisheries Sector Policy (2015).

International conventions relevant to the national legal framework concerning reefs include: CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) as many of the organisms found on the reefs are endangered; Bonn Convention - Convention on the Conservation of Migratory Species of Wild Animals (1979) as there are several species of migratory animals associated with the reefs; UNCLOS – United Nations Convention on the Law of the Sea (1982); the Cartagena Protocol on Biosafety (2000), which Tanzania accepted in 2003; and the Convention on Biological Diversity (signed in 1992, ratified in 1996).

The Fisheries Act of 2003 provides for the formation of village marine resource management units, namely Beach Management Units (BMUs). In Zanzibar the equivalent of the BMU is the Village Fishermen's Committee (VFC). Collaborative Fisheries Management Areas (CFMA), while not formally recognised in the legislation, are an approach that is gaining ground.

Mainland Tanzania currently has three Marine Parks and fifteen Marine Reserves established and gazetted under the Marine Parks and Reserves Act. Zanzibar has increased the area under conservation significantly (by over 10% with 4 established and 2 new MPAs and the expansion of the Menai Bay Conservation Area and the boundaries of PECCA, the Pemba Channel Conservation Area (to almost encircle the entire Pemba island).

The Tanzania Coral Reef Task Force (TzCRTF) was formulated after the regional Western Indian Ocean Coral Reef Task Force (WIO CRTF) of the Nairobi Convention was established in 2002. A secretariat was established at the National Environment Management Council (NEMC) which caters for national roles and needs, while capacity building is handled by the Vice President's Office (VPO), and technical issues by the Institute of Marine Sciences (IMS). A counterpart body, the Zanzibar Coral Reef Monitoring Network (ZCRMN) was launched in 2014 under the Zanzibar Department of Environment (DoE) through its Integrated Coastal Zone Management (ICZM) committee.

Coral reef monitoring in Tanzania has evolved since it started in the 1980s (see Daffa, 2001, Muhando, 2008). Methods have been refined and the workforce decentralised. Several international and local conservation and donor agencies/organs have been involved, as well as the private sector, research institutions and government departments responsible for marine resource management. Zanzibar's reefs have had the longest monitoring record, with reefs off Zanzibar Town, namely Bawe, Changuu and Chapwani having been monitored since 1992. Methods are based on standard protocols (English et al. 1994) although for a short period the Reef Check method was used by community rangers in Tanga.

Over the last decade there have been small scale coral restoration (e.g. near Dar es Salaam harbour as part of climate change mitigation activities) and artificial reef initiatives (Reef Balls™ in Jambiani, Zanzibar and artificial reefs made from scrap items by fishing groups and used as fish aggregating devices in Bagamoyo). These are still in their infancy and their effect, permanence and potential for expansion is not yet clear.

2.9.8 Discussion

Coral reefs in Tanzania, as in the rest of the region, are under great stress, both from anthropogenic activities and from natural factors such as extreme or sudden and prolonged changes in environmental conditions, rough sea conditions, diseases, predator outbreaks and natural competition for space and food. Management of these reefs depends on detecting changes in health status, and this is accomplished by regular monitoring, using standard protocols. Unfortunately, monitoring programmes in Tanzania depend on donor or other funding for implementation. On a positive note, coral reef monitoring has evolved from initiatives by academic institutions, NGOs and projects, to Government-funded monitoring within marine protected areas (MPAs).

Coral reef health (as shown by live coral cover) has fallen over the last 30 years, and recovery from individual impacts has been slow. Nonetheless, levels of coral cover are comparable to other sites in East Africa. Phase shifts towards algal dominated reefs have not occurred in many places, even after the major bleaching event of 1998. The 2016 bleaching event, though very severe in other regions, had lower than anticipated impact on Tanzania's reefs. It may be that resistance gained from previous bleaching, early onset of the southeast monsoon and the start of the cool season may have helped the bleached corals to recover. Macro-invertebrate densities on the reefs are on the low side, probably due to overexploitation. Recovery of these organisms is likely being hampered by continued exploitation. Fish abundance was highest in 2008 perhaps due to the the mass bleaching in 1998, which led to coral mortality and algal dominance, on which herbivorous fish thrived (Lindahl *et al.,* 2001). The long term history of high coral mortality (in 1998), recovery to near-original conditions for most sites and resistance of some sites to renewed bleaching indicates that these reefs may be resilient to climate change (e.g. McClanahan *et al.,* 1999, 2009) and should be a priority for future conservation actions.

Management of coral reef resources is improving, though at a slow rate. Cooperative management with communities is encouraging, with BMUs and VFCs having the potential to play a greater role in marine resource conservation and management. The current SWIOFish approach of managing fisheries by fishery type (thus coral reef fisheries are managed separately) and giving greater significance to research for management is quite promising. Conservation initiatives now include the expansion of existing MPAs (e.g. the boundaries of Menai Bay Conservation Area in Zanzibar have been expanded under the Marine Conservation Unit regulations of 2015), establishment of new MPAs and exploration of the possibility of establishing transboundary MPAs.

2.9.9 Recommendations

Based on the current state of the coral reefs in Tanzania, their anthropogenic and natural stressors, and management initiatives currently applied, the following recommendations are made:

1. Coral reef monitoring should be continued, supported and expanded to include more sites and other parameters, particularly coral bleaching and disease.
2. Strengthening of coral reef monitoring networks is needed, nationally and regionally.
3. There is a need for harmonisation of monitoring methods.
4. Capacity building in coral reef monitoring is required.
5. It is important to have a unified national coral reef database.
6. Strengthening of MPA management is essential.
7. Inter and intra-institutional collaboration and cooperation should be promoted.
8. Marine spatial planning at some reef sites may help reduce stress from different reef users.

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