



National Environmental  
Research Program

TROPICAL ECOSYSTEMS *hub*

## Spatial Management and Sharks on the Great Barrier Reef

A Synthesis of NERP Tropical Ecosystems Hub  
Projects 6.1 & 6.2 Research Outputs 2011-2014

Compiled by RRRC



Australian Government  
Department of the Environment

 Reef &  
Rainforest  
RESEARCH CENTRE

# **Spatial Management and Sharks on the Great Barrier Reef**

**Synthesis of NERP Tropical Ecosystems Hub  
Projects 6.1 & 6.2 Research Outputs 2011-2014**

Ryan Donnelly, Peter Yates, Audrey Schlaff, Mario Espinoza, Jordan Matley,  
Elodie Ledee, Leanne Currey, Fernanda de Faria and Stephen Moore



**Australian Government**  

---

**Department of the Environment**



Supported by the Australian Government's  
National Environmental Research Program

© Reef and Rainforest Research Centre Limited

National Library of Australia Cataloguing-in-Publication entry:  
978-1-925088-58-8

This report should be cited as:

Donnelly, R., Yates, P., Schlaff, A., Espinoza, M., Matley, J., Ledee, E., Currey, L., de Faria, F., Moore, S. (2015) Spatial Management and Sharks on the Great Barrier Reef. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (10pp.).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's National Environmental Research Program (NERP) Tropical Ecosystems (TE) Hub.

The Tropical Ecosystems Hub is part of the Australian Government's National Environmental Research Program. The NERP TE Hub is administered in North Queensland by the Reef and Rainforest Research Centre Limited (RRRC). The NERP Tropical Ecosystem Hub addresses issues of concern for the management, conservation and sustainable use of the World Heritage listed Great Barrier Reef (GBR) and its catchments, tropical rainforests including the Wet Tropics World Heritage Area (WTWHA), and the terrestrial and marine assets underpinning resilient communities in the Torres Strait, through the generation and transfer of world-class research and shared knowledge.

This publication is copyright. The Copyright Act 1968 permits fair dealing for study, research, information or educational purposes subject to inclusion of a sufficient acknowledgement of the source.

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment.

While reasonable effort has been made to ensure that the contents of this publication are factually correct, the Australian Government does not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on the contents of the publication.

Cover photograph: Wikimedia Commons

This report is available for download from the NERP Tropical Ecosystems Hub website:  
[www.nerptropical.edu.au](http://www.nerptropical.edu.au)

February 2015

# Contents

List of Figures .....	ii
Acronyms Used In This Report .....	iii
Acknowledgements .....	iv
About this Report .....	iv
Executive Summary.....	1
Introduction .....	2
Sharks on the Great Barrier Reef.....	3
Key Results .....	4
Management Implications .....	6
Conclusions.....	8
Further Reading .....	9

## List of Figures

- Figure 1.** Hard coral cover 1986-2012 (De'ath et al. 2012) demonstrating the substantial decline in coral cover in the southern third of the Great Barrier Reef since about 2005 ..... 2
- Figure 2.** The study area in the vicinity of Townsville in the central Great Barrier Reef featuring reef sites for acoustic telemetry ..... 4
- Figure 3.** The extent of protection afforded by zoning varies according to the extent of residency and dispersal ..... 5
- Figure 4.** The study area showing the five bays chosen for immature shark surveys across 400km of coastline..... 5
- Figure 5.** A reef in the southern Great Barrier Reef with differential zoning for use by humans (top) and a satellite image depicting the same location for use by marine biota (bottom).... 7

## **Acronyms Used In This Report**

<b>DAFF</b>	Department of Agriculture, Fisheries and Forestry
<b>GBR</b>	Great Barrier Reef
<b>GBRMPA</b>	Great Barrier Reef Marine Park Authority
<b>NERP</b>	National Environmental Research Program
<b>RRRC</b>	Reef and Rainforest Research Centre Limited
<b>TE</b>	Tropical Ecosystems
<b>WTWHA</b>	Wet Tropics World Heritage Area

## **Acknowledgements**

The author gratefully acknowledges the researchers who contributed to the National Environmental Research Program's Tropical Ecosystems Hub. Outstanding science by Dr Michelle Heupel and Professor Colin Simpfendorfer and their research teams has been instrumental in advancing our knowledge of natural systems and communities in the Great Barrier Reef World Heritage Area.

The author would also like to thank the Australian Government Department of Environment for funding the National Environmental Research Program, and the Reef and Rainforest Research Centre for supporting this program over the past four years. The involvement of primary end users in this research, including the Great Barrier Reef Marine Park Authority and the Queensland Department of Agriculture, Fisheries and Forestry has ensured that the findings are useful and will inform future decision-making.

## **About this Report**

The purpose of this report is to summarise the research context and findings from two projects from the Tropical Ecosystems Hub of the National Environmental Research Program, part of which addresses issues of concern for the management, conservation and sustainable use of the Great Barrier Reef.

The projects focus attention on the importance of movement, habitat and environment for mobile predators, particularly sharks. The projects examine the importance of bays and connectivity to inshore reefs and assess the benefits of the current zoning arrangements to this suite of higher order predator species.

## Executive Summary

Concern about the status of reef predators is increasing around the globe. Understanding the efficacy of spatial management zones for reef predators within the Great Barrier Reef is crucial to successful management and conservation of these populations.

A decade after the Great Barrier Reef was divided into zones for differential human use, it is timely to assess its effectiveness and to identify means by which the spatial management arrangements might be improved.

Research within the National Environmental Research Program examined the movement ecology of several reef predator species to examine how much time was spent at individual reefs and within management zones. It also examined the drivers of juvenile shark biodiversity and abundance in inshore ecosystems of the Great Barrier Reef.

The research indicated that different species have different movement patterns resulting in some species receiving greater protection under current management arrangements than others. Some reef shark species, such as the grey reef shark, spent the majority of their time at a single reef, but did move between reefs indicating moderate protection for these slightly more mobile individuals. Several other sharks (e.g. bull, tiger, silvertip), however, moved widely between reefs and zones and appear to receive little benefit from current spatial management.

Another study examined spatio-temporal variation in the functioning of nearshore areas to better understand their role in maintaining shark biodiversity and abundance. Seasonal surveys of sharks in five bays on the central Great Barrier Reef coast demonstrated the importance of these bays for both juvenile sharks and the adults of some small shark species. The importance to individual species of sharks varied between bays, demonstrating that each bay played different roles, potentially leading to greater stability within shark populations. Environmental drivers such as salinity, turbidity and temperature appear to be the main reasons for differences in function between bays.

The results demonstrate that inshore protected areas are important for maintaining the biodiversity of sharks within the inshore areas of the Great Barrier Reef. The sustainability of the shark take by the East Coast Inshore Finfish Fishery may be enhanced by the improved understanding of the role of nearshore areas for sharks generated by this project.

The results of the research in the 'Movements and Habitat Use by Marine Apex Predators' program indicate current marine protected areas will benefit some species more than others and that management of mobile species requires additional measures such as catch limits to ensure their populations remain viable.

## Introduction

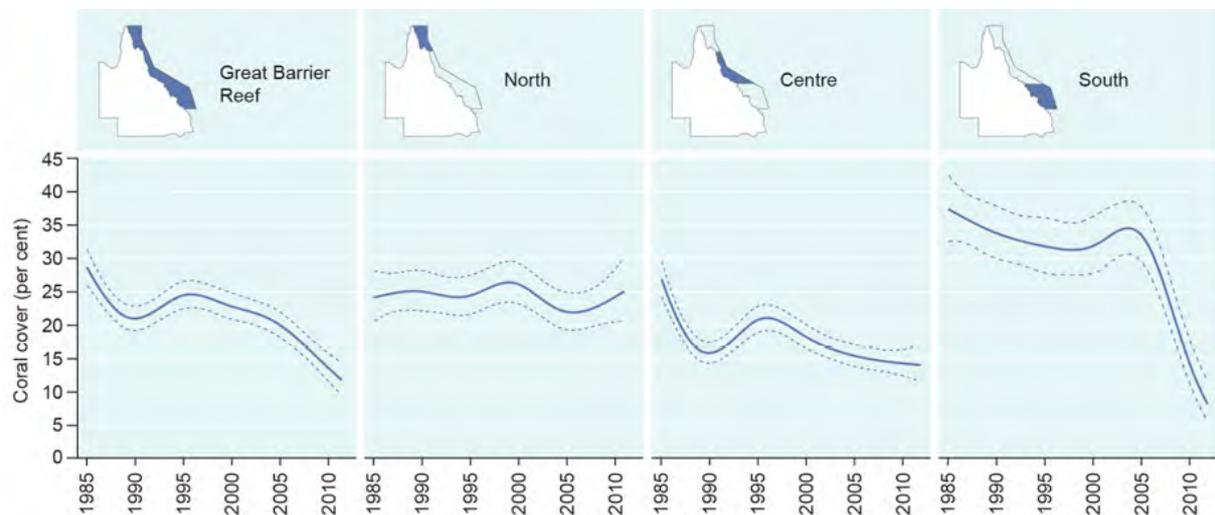
The Great Barrier Reef is one of the great natural wonders of the world, stretching 2,300km across 14 degrees of latitude from the northern tip of Queensland to just south of the Tropic of Capricorn near Bundaberg.

Its sheer size and vast array of habitats makes the Great Barrier Reef one of the most complex natural ecosystems in the world. It includes some 3,000 coral reefs, 600 continental islands, 300 coral cays and about 150 inshore mangrove islands.

Coral reefs are the cornerstone of the Great Barrier Reef ecosystem, though they only comprise about seven per cent of the marine park. The remainder is made up of a variety of habitats, ranging from shallow inshore areas, such as seagrass beds, mangroves, sand, algal and sponge gardens, and inter-reefal communities to deep oceanic areas more than 250km offshore.

Inhabitants include 1,625 types of fish, 600 types of soft and hard corals, more than 30 species of whales and dolphins, more than 100 species of jellyfish, 3,000 varieties of molluscs, and 500 species of worms. It also includes more than 130 varieties of sharks and rays, those higher trophic level predator species that play such critical roles in the ecosystem, including regulating populations of prey species and maintaining ecosystem balance.

In 2012 the Australian Institute of Marine Science reported that average coral cover on reefs of the Great Barrier Reef declined by 50% from 1986 levels (Figure 1) (De'ath et al. 2012).



**Figure 1.** Hard coral cover 1986-2012 (De'ath et al. 2012) demonstrating the substantial decline in coral cover in the southern third of the Great Barrier Reef since about 2005.

The Great Barrier Marine Park Authority's 2009 Outlook Report concluded the outlook for the Great Barrier Reef was poor and that climate change, catchment water quality and coastal development were the main risks

North of Port Douglas, coral cover fluctuated but did not decline over time, but cover declined substantially in the southern two thirds of the Great Barrier Reef adjacent developed catchments. This has been largely attributed to the cumulative effects of cyclones, crown-of-thorns starfish and coral bleaching, with insufficient time for recovery between disturbances since around 2006.

In 2004, the Great Barrier Reef Marine Park was divided into zones, providing for a range of uses. The Representative Areas Program was designed to protect biodiversity. It assigned a minimum of 20% of each of 70 identified bioregions (important breeding and nursery areas, such as seagrass beds, mangrove communities, deepwater shoals and coral reefs) into Green Zones, in which all extractive activities, including fishing, are prohibited.

It is now a decade since the zoning arrangements were implemented. In the context of the known threats to the Great Barrier Reef, the current projects assessed the effectiveness of the zoning for the conservation and management of sharks and examined the manner in which it might be improved.

## ***Sharks on the Great Barrier Reef***

The tropical waters of northern Australia have one of the highest levels of shark and ray diversity and endemism in the world. Half of the species present are found nowhere else. It is estimated that there are more than 130 species on the Great Barrier Reef (Last and Stevens, 2009).

Sharks produce a small number of well-developed young that have high survival rates. They tend to grow slowly, mature late and are relatively long-lived. These characteristics can leave them vulnerable to decline in population recruitment if adults are removed from the system through fishing or if juveniles fail to survive to maturity due to other factors, such as degradation of critical nursery habitat.

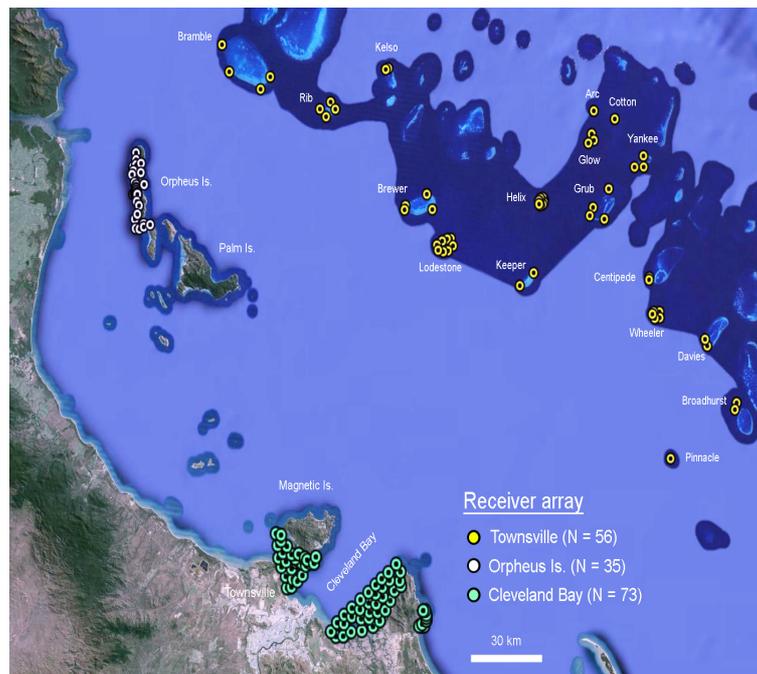
Some sharks on the Great Barrier Reef interact with commercial and recreational fisheries. In 2013-14, 201.3t of shark was reported from the commercial sector operating inside the Great Barrier Reef Marine Park (DAFF, 2014).

The featured projects presented new knowledge about the scale of daily and seasonal movements of sharks and sought to establish the basis for no-take areas that offer more effective protection to these mobile animals. The projects focus on the movement and habitat use of inshore shark populations, including those that move into and out of bays and those that move within and between coral reefs.

Project results will influence any future design improvements to the spatial management arrangements for the conservation of biodiversity and the management of sustainable use on the Great Barrier Reef.

## Key Results

The reef project team established extensive arrays of acoustic listening stations in the central Great Barrier Reef near Townsville (Figure 2). Acoustic receivers were positioned at 17 reefs over a distance of 150km and team recorded environmental data in order to determine whether the drivers of shark movement were related to environmental variables.

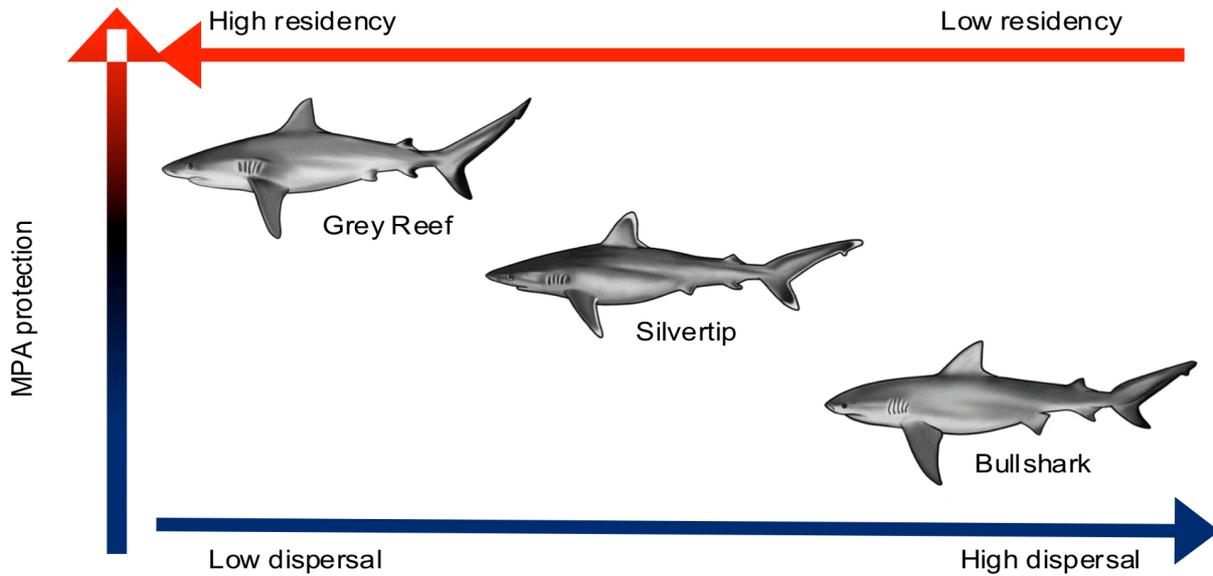


**Figure 2.** The study area in the vicinity of Townsville in the central Great Barrier Reef featuring reef sites for acoustic telemetry.

Forty grey reef, 27 silvertip and 39 bull sharks were tagged with transmitters and their movement patterns were monitored. These species are very common along the Great Barrier Reef. They are known to use coral reef habitats, but were expected to differ in their behaviour and spatial ecology.

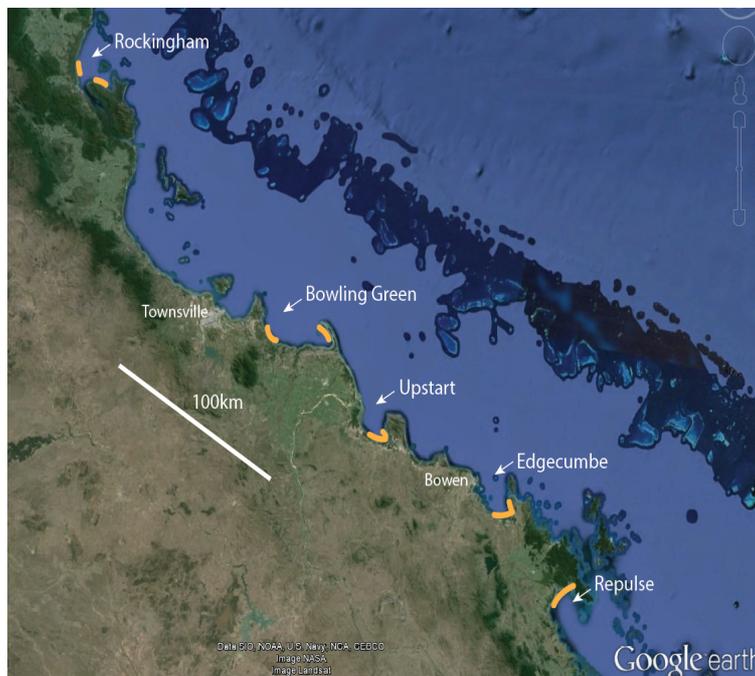
Grey reef sharks were found to spend most of their time within the study site, particularly females. Silvertips spent about half of the time within the site and bull sharks just some of the time within the site. In addition, grey reef sharks did not move between reefs as much as silvertips; and bull sharks were found to be highly mobile and use a very large amount of space.

The project team found seasonal differences in movement patterns, indicating that there could be scope for temporal application to spatial zoning. The timing of the movements related to breeding and feeding. Figure 3 demonstrates the variability in residency and dispersal among the reef associated sharks studied and how this manifests in varying degrees of protection afforded by current spatial zoning arrangements.



**Figure 3.** The extent of protection afforded by zoning varies according to the extent of residency and dispersal.

The bay project focused on a region that is sheltered from ocean swells by the Great Barrier Reef and is characterized by shallow, sheltered embayments with silty substrates, along with mudflat and mangrove-lined foreshores (Figure 4). The project examined the importance of different types of inshore habitat (protected bay vs open coastline) and marine park zoning (open vs closed to gillnet fishing) and how environmental factors, such as freshwater discharge from rivers affect how these nursery areas function.



**Figure 4.** The study area showing the five bays chosen for immature shark surveys across 400km of coastline.

The team caught and released 1,987 sharks from 22 species. The study demonstrated broad-scale diversity in immature shark communities along the tropical coast of Queensland. There was substantial variability between bays and the bays sampled served multiple functions, including nursery areas, refuge or foraging areas and mating grounds.

Shark abundance was most strongly associated with lower water clarity. Abundance also decreased with increasing distance from mangroves. The high productivity of mangrove habitats can support large populations of fish and invertebrates on which young sharks feed. The structural complexity of mangrove habitats may also provide anti-predator benefits for young sharks within close proximity.

Diverse communities were encountered in this study and the results suggest that body size may be more influential in the spatial structuring of coastal shark fauna than life-history stage. Spatial variations in shark fauna indicate that data on shark community structure and nursery function from restricted areas may not accurately portray patterns occurring over larger geographic scales.

## ***Management Implications***

The large size of many shark species means that they are often highly mobile. This mobility complicates management, especially in regions such as the Great Barrier Reef where there is a complex mosaic of zones that are open and closed to fishing, and the sheer size of the reef system.

The challenges of designing spatial management arrangements are many. It is known that a wide range of shark species use coral reefs. Some species exhibit a high degree of individual and seasonal variability. In some species, males and females have different behaviours or larger sharks tend to be more mobile than smaller ones. Consequently, it is important to account for sex and size related differences in spatial management approaches.

It is inevitable that reef shark species will move in and out of zones where fishing is permitted and not permitted. Figure 5 shows the differential zoning arrangements at a reef in the southern Great Barrier Reef and a satellite image of the same reef. Some shark species may benefit more from marine protected areas, while others are likely to get limited protection. This can be determined by the extent of residency and dispersal practiced by different species and the zoning plans at individual reefs.



**Figure 5.** A reef in the southern Great Barrier Reef with differential zoning for use by humans (top) and a satellite image depicting the same location for use by marine biota (bottom).

Recognition of the complex movement patterns of sharks reveals that single reef or habitat type management is unlikely to be sufficient to mitigate threats to most reef sharks. Individuals move readily among reefs and zones thus deriving highly variable levels of protection from fishing pressure.

Spatial management through marine protected zones cannot be the sole management approach applied. Further fishery regulations such as catch and size limits will be required to enhance and ensure protection of mobile predator populations. This concept also applies to individuals resident on reefs open to fishing. Lack of movement between reefs means adult dispersal is limited and localised depletion at an individual reef can occur.

## Conclusions

The projects in the 'Movements and Habitat Use by Marine Apex Predators' program indicate the complexity of variables for consideration when designing spatial management arrangements for the Great Barrier Reef.

The importance of higher order predator species to community stability and function, however, suggests that consideration of movement and habitat use of these species at various stages of their life is important for the conservation of biodiversity. This is particularly important, given the modification of coastal habitats for human habitation and the concomitant effects on water quality; and the predicted changes to the environment accompanying a changing climate.

Given the differences in movement patterns, a single management strategy will not be equally effective for all shark species. Future management, including protected area design should also consider individual and seasonal variability; functional connectivity of a species; and the effect of reef isolation on shark dispersal.

It was concluded that marine park zoning alone will not provide adequate protection to wide-ranging species and that additional management measures are necessary. These include consideration of temporal variability, fishery management and, in some cases, restoration of habitats in coastal catchments.

Future research requirements identified include:

- surveying additional habitat types (e.g. shoals) to see what role these habitats play for mobile predators;
- examination of the role of reef variability in zoning to determine whether underlying characteristics are driving variability in reef shark numbers within the Great Barrier Reef;
- further examination of the connectivity, extent of movement and efficacy of management of threatened predator species;
- spatial heterogeneity and environmental drivers that will help the Great Barrier Reef Marine Park Authority to demonstrate benefits of nearshore no-fishing zones; and
- improved understanding of the role of nearshore areas to enhance Fisheries Queensland's ability to manage shark stocks sustainably.

These research needs were endorsed for juvenile nursery research, which seeks to understand how juvenile population segments connect with adult segments.

## Further Reading

Ceccarelli, D.M., Frisch, A.J., Graham, N.A.J., Ayling, A.M. and Beger, M. 2014. Habitat partitioning and vulnerability of sharks in the Great Barrier Reef Marine Park. *Reviews in Fish Biology and Fisheries* 24: 169-197.

De'ath, G., Fabricius, K.E., Sweatman, H. and Puotinen, M. 2012. The 27 year decline of coral cover on the Great Barrier Reef and its causes. *Proceedings of the National Academy of Sciences* 109(44): 17995-17999.

Great Barrier Reef Marine Park Authority, 2012. *A vulnerability assessment for the Great Barrier Reef: Sharks and rays*. GBRMPA, Townsville.

Great Barrier Reef Marine Park Authority, 2009. *Great Barrier Reef Outlook Report*. GBRMPA, Townsville.

Great Barrier Reef Marine Park Authority, 2014. *Great Barrier Reef Outlook Report*. GBRMPA, Townsville.

Harry, A.V., Macbeth, W.G., Gutteridge, A.N. and Simpfendorfer, C.A. 2011a. The life histories of endangered hammerhead sharks (Carcharhiniformes, Sphyrnidae) from the east coast of Australia. *Journal of Fish Biology* 78(7): 2026-2051.

Harry, A.V., Tobin, A.J., Simpfendorfer, C.A., Welch, D.J., Mapleston, A., White, J., Williams, A.J. and Stapley, J. 2011b. Evaluating catch and mitigating risk in a multispecies, tropical, inshore shark fishery within the Great Barrier Reef World Heritage Area. *Marine and Freshwater Research* 62(6): 710-721.

Heupel, M.R., Williams, A.J., Welch, D.J., Ballagh, A., Mapstone, B.D., Carlos, G., Davies, C. and Simpfendorfer, C.A. 2009. Effects of fishing on tropical reef associated shark populations on the Great Barrier Reef. *Fisheries Research* 95(2-3): 350-361.

Last, P.R. and Stevens, J.D. 2009. *Sharks and rays of Australia*, 2nd ed, CSIRO Publishing, Collingwood, Vic.

Heupel, M.R., Simpfendorfer, C.A. and Fitzpatrick, R. 2010. Large-scale movement and reef fidelity of grey reef sharks. *PLoS ONE* 5(3): e9650.

Department of Primary Industries and Fisheries, 2006. *The Queensland East Coast Inshore Fin fish fishery - background paper: sharks and rays*. Department of Primary Industries and Fisheries Brisbane.

Rose, C., Gribble, N.A., Stapley, J., Buckworth, R. and Lenanton, R. 2003. *Northern Australian sharks and rays: the sustainability of target and bycatch fisheries, phase 1*. Department of Primary Industries, Brisbane.

Chin, A., Kyne, P.M., Walker, T.I. and McAuley, R.B. 2010. An integrated risk assessment for climate change: analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. *Global Change Biology* 16(7): 1936-1953.

DAFF, 2014. *East Coast Inshore Fin Fish Fishery Update – 2011 to 2014*. Queensland Department of Agriculture, Fisheries and Forestry, Brisbane.

Heupel M.R and Simpfendorfer C.A. 2014. Importance of environmental and biological drivers in the presence and space use of a reef-associated shark. *Marine Ecology Progress Series* 496: 47-57.

This report provides a synthesis of one key theme in the NERP Tropical Ecosystems Hub, and is one of several such reports in a series of information products that summarise NERP research findings relevant to policy and management in tropical North Queensland. Other NERP synthesis products include:

- Carmody, J., Murphy, H., Hill, R., Catterall, C., Goosem, S., Dale, A., Westcott, D., Welbergen, J., Shoo, L., Stoeckl, N., Esparon, M. (2015) The Importance of Protecting and Conserving the Wet Tropics: A synthesis of NERP Tropical Ecosystems Hub Tropical Rainforest Outputs 2011-2014. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (64pp.).
- Devlin, M., Fabricius, K., Negri, A., Brodie, J., Waterhouse, J., Uthicke, S., Collier, C., Pressey, B., Augé, A., Reid, B., Woodberry, O., Zhao, J-x., Clarke, T., Pandolfi, J., Bennett, J. (2015) Water Quality - Synthesis of NERP Tropical Ecosystems Hub Water Quality Research Outputs 2011-2014. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (55pp.).
- Donnelly, R., Sweatman, H., Emslie, M., Russ, G., Williamson, D., Jones, G., Harrison, H. (2015) Effects of Management Zoning on Coral Trout Populations in the Great Barrier Reef Marine Park. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (12pp.).
- Johnson, J.E., Marsh, H., Hamann, M., Duke, N., Burrows, D., Bainbridge, S., Sweatman, H., Brodie, J., Bohensky, E., Butler, J., Laurance, S. (2015) Tropical Research in Australia's Torres Strait region. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (33pp.).