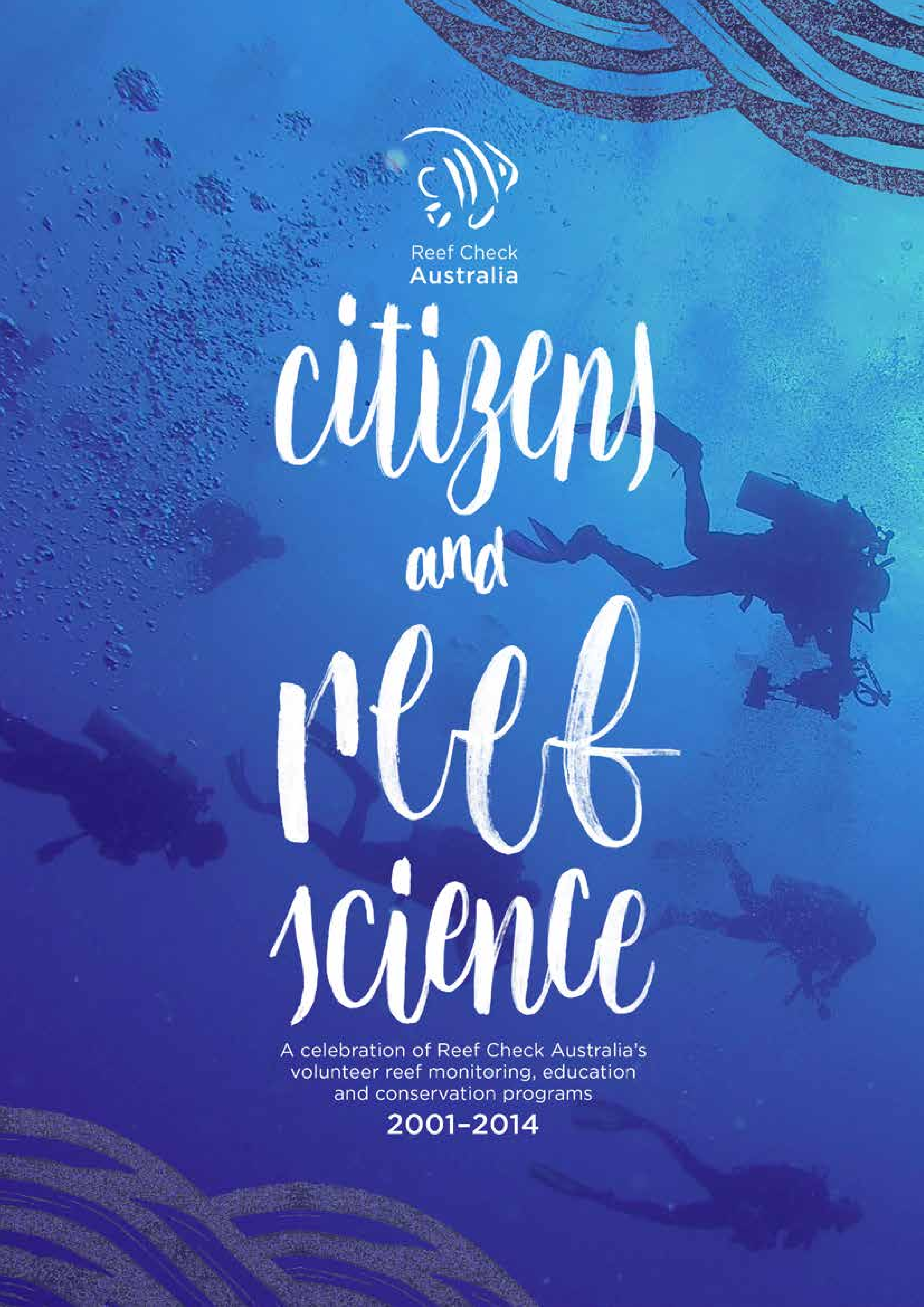

Reef Check Australia

# citizens and reef science

A celebration of Reef Check Australia's volunteer reef monitoring, education and conservation programs

2001–2014

Photo by Matt Curnock (Russell Island, GBR)

## ACKNOWLEDGEMENTS

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Cover photo credit: Undersea Explorer, GBR

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Thanks from us and our oceans.

## WELCOME AND THANKS

As a global community, we face tremendous challenges in the mission to conserve marine life and habitats. Australian reefs are not immune to pressure, despite being acknowledged as some of the best managed in the world. Now is the time for us all to intensify focus on activities that empower people to protect our reefs and oceans.

This report celebrates the achievements of Reef Check Australia (RCA) and our partners within this urgent context. More than a decade's worth of volunteer reef health data and project outcomes are summarised in this report.

Since 2001, trained RCA volunteers have donated more than 65,000 hours to our oceans, collecting data through more than 600 surveys on more than 60 sites along the Queensland coast. Their efforts assist with documenting reef health at local, regional and global scales. This unique dataset has been made possible by a succession of RCA leaders and volunteers, industry champions, dedicated partners, invaluable in-kind support and funding from both government and private grants. We are constantly humbled by the incredible support provided across our network and acknowledge that this report celebrates the range of contributions required to make this work possible.

This report highlights some of the significant achievements and valuable contributions that RCA has made in the fields of marine research, education and conservation. Our goal is to showcase how community action, collaborative partnerships and citizen science initiatives can produce measurable, positive results for people and the planet.

The four case studies focus on data from across Queensland sites, but also offer global comparisons. This summary of work demonstrates that information collected by citizen scientists can produce useful products with powerful outcomes.

The case study findings also generate some interesting questions for further research. We believe these case studies are just the beginning of possible applications for this ever-developing dataset.

Beyond data we need action. RCA volunteers have worked collaboratively to clean up tens of thousands of pieces of debris from above and below the water. Our award winning Reef IQ school program has been accessed by more than 450 schools and organisations from Townsville to Tanzania. The REEFSearch reef identification and observation community program has offered new ways for people to understand and observe reefs as snorkelers, divers or reef walkers. By building connections between citizens, conservation and education, RCA seeks to share findings, inspire action and celebrate all that our oceans have to offer.

This report documents the first few chapters of the RCA story. Long-term monitoring and community work is about longevity. We trust you will not only help us celebrate past achievements, but join us to shape the Reef Check story as we continue to evolve.

**Jennifer Loder,**
*General Manager on behalf of Reef Check Australia Board & Staff*

# Key Messages

## FROM REEF CHECK AUSTRALIA 2001-2014

- Reef monitoring is critical to understand both human and natural impacts, as well as reef recovery. Volunteers armed with the necessary skills, resources and scientific support can collect valuable information that boosts our collective understanding about the marine environment. Beyond collecting data, marine citizen science initiatives can help to build awareness and opportunities for conservation action within their communities.
- We actively seek to generate new opportunities for further analysis, applications and collaborations. This report is both an opportunity to celebrate the achievements of our volunteers, staff, partners and supporters, and to start discussions about next steps.
- RCA has more than 60 priority monitoring sites along the coast of Queensland, capturing a unique spatial and temporal perspective on coral communities. RCA's focus on tourism locations offers a different, but useful representation of reef health, especially within the context of other marine monitoring programs.
- The case studies in this report demonstrate differences in reef communities, marine life and reef health impacts at local, regional and global scales. Please review key points at the end of each case study for additional details. Ongoing monitoring and assessment may help to document community changes due to climate and other environmental changes.
- This report builds an initial framework for case studies. The findings in this report summarise trends evident from preliminary data investigations focusing on the RCA Queensland dataset. Results appear consistent with other studies, but also prompt further questions. Additional analysis for specific indicators, sites or data interactions, as well as changes over time, may offer constructive information around dynamics and trends.
- Limited data appears to be available for many invertebrates monitored by Reef Check (excluding Crown of Thorns Starfish and *Drupella* snails). This highlights the value of the RCA invertebrate dataset and ongoing data exploration.
- Across most RCA sites there was evidence of reef health impacts. Reef impact data showed varying pressures related to environmental and human use factors, which can be beneficial for gauging relevant community education and reef management considerations along the coast.
- Reef Check volunteers collect information using a consistent protocol, offering the opportunity to review how Australian reefs compare to those around the world. RCA's monitoring sites display relatively high coral cover and relatively low levels of nutrient indicator algae. Yet reefs here and abroad do indicate signs of stress.
- RCA data showed notable levels of direct human impacts which could be reduced by behavioural change (such as anchor damage and rubbish). Informed communities are one critical element to implementing best-practice catchment and reef management that can build reef resilience in the short-term while the global community seeks long-term solutions to issues such as climate change that will impact us all.
- RCA data is freely available for research or education applications. Visit our website to review site specific summary data or request to access raw data as a data user.
- With a growing system of citizen science research, dynamic community engagement programs and exciting partnerships, RCA is actively seeking to translate data into meaningful natural resource management outcomes. We invite you to approach us regarding data applications and collaborations.
- Sustainable funding is a key ingredient for programs to offer continuity for stakeholders and science. RCA is researching and developing new and innovative business models to improve the stability and longevity of funding for citizen science.

# Our principles

Reef Check Australia is a citizen science organisation that engages the community to collect locally and globally relevant reef health information that inspires appreciation, understanding and conservation. Our work supports these principles.

## WE BELIEVE IN VOLUNTEERS

RCA is an inclusive, citizen science organisation supporting volunteers in hands-on reef research, education and practical conservation. All community members are welcome to join in understanding and saving our reefs.

## WE STRIVE FOR EXCELLENCE

We are an established not for profit organisation with a clear governance structure, a proven track record and large membership base.

## OUR DATA IS FOR EVERYONE

We are an environmental charity collecting scientific data appropriate for marine experts, reef managers and general public.

## WE ARE OPTIMISTIC

Our approach focuses on what can be done rather than what cannot. Our messaging is positive and we aspire to inspire locally-based action driven by the vision of individuals and communities.

## IN SCIENCE WE TRUST

Reef Check Australia is non-governmental and does not engage in advocacy or political debates, but does empower communities to use rigorous and globally-standardized science to find out for themselves about their reefs.

## WE THINK COLLABORATION MULTIPLIES RESULTS

We partner with other organisations on projects with practical on-ground marine outcomes. This does not mean that RCA endorses the media statements or policies of such organisations.

Photo by Liz Harlin (Flinders Reef, SEQ)

# THE ORIGIN OF REEF CHECK

In 1996, the Reef Check protocol was designed by coral reef ecologist Gregor Hodgson and it was peer reviewed by dozens of reef scientists from several countries. After adjustments, Reef Check was advertised as a volunteer, community-based monitoring program designed to measure the health of coral reefs on a global scale. The goal of the program was to empower community members to collect data that can demonstrate ecologically significant changes in reef health due to human activities. The biological indicators selected for the program shed light on human impacts on reefs, as well as acting as a proxy for ecosystem health.

Globally, Reef Check is the most widely-used community coral reef monitoring program. Our Australian teams are part of a worldwide network of thousands of trained volunteers who monitor and report on reef health in more than 90 countries using the standardised Reef Check scientific survey method (Hodgson *et al.* 2006). Worldwide use of a standard protocol enables a comparison of a set of indicators that quantify human impacts on coral reef health (Drake 1996, Wilkinson, 1996, Hodgson 1999, Hodgson 2000).

The first global Reef Check assessment took place in 1997 and involved surveys of 350 reefs in 31 countries, including 15 in Australia (Hodgson 1999). The results showed for the first time that reefs had been damaged throughout the tropics. Reef Check announced that there was a "global coral reef crisis" and documented overfishing across many areas as a key contributing factor for reef health decline. By 2001, more than 1,500 surveys had been carried out across the Caribbean and IndoPacific. Hard coral cover, which is regularly used as a key indicator for reef health, averaged 31% across surveyed sites. Low levels of indicator fish and invertebrates were recorded at most sites, demonstrating potential concerns about over-harvesting and ecological imbalances. In 2002, "The Global Coral Reef Crisis" report was presented to government Ministers at the World Summit on Sustainable Development in Johannesburg (Hodgson and Liebler 2002).

The global Reef Check surveys represented the first time that reef health data had been documented consistently on a global scale. The dataset created a baseline to document, identify and address potential reef health concerns around the globe. Since then, the Reef Check program has continued to grow, offering cost-effective solutions that empower communities to take an active role in appreciating, understanding and protecting their local

> *Reef Check Australia has continued to build on its excellent reputation of rigorous scientific quality in training teams of citizen-scientists throughout Australia. These dedicated volunteers track the health of coral reefs and support the government's efforts to protect coral reefs during a time when the crisis facing reefs in Australia has only slowly been recognized. Given the importance of Australia as a coral reef country, these efforts have global significance.*

**Dr. Gregor Hodgson**
*Founder and Executive Director, Reef Check International*


Figure 1. Reef Check Australia survey sites (2001-2014).

# Timeline

## A HISTORY OF REEF CHECK & REEF CHECK AUSTRALIA

**1997-2000**

1997 First global coral reef survey carried out by Reef Check as part of the International Year of the Reef, including 14 sites monitored in Australia.

**2001**

2001 Reef Check Australia established and first survey carried out at Osprey Reef, outer Great Barrier Reef.

**2001-2003**

2001-2003 Consultations with AIMS, GBRMPA and reef researchers regarding additional Reef Check data categories for Australia. Reef Check surveys were conducted in Darwin, NT and Ningaloo, WA.

**2003**

2003 First RCA grant from Envirofund to run GBR survey season.

**2005**

2005 Reef Check Australia training course developed, building on the International EcoDiver course. New training and testing materials were added to the global system.

**2006**

2006 Four-year Commonwealth Marine Tropical Science Research Facility & Great Barrier Reef Marine Park Authority program to support volunteers monitoring on 25 Great Barrier Reef dive sites.

**2007**

2007 Initial expansion to South East Queensland for subtropical rocky reef monitoring program.

**2009**

2009 Launch of Reef IQ schools program.

**2011**

2011 Reef Check Australia joined Tourism Queensland's Best Expedition in the World.

**2011-2012**

2011-2012 Start of central QLD monitoring, including Lady Elliot Island, Heron Island and the Fraser Coast.

**2012**

2012 Long-term Reef Check Australia volunteer, Jodi Salmond, awarded Vodafone World of Difference grant to support additional community outreach.

**2013**

2013 Launch of REEFSearch reef identification and observation program.

**2013**

2013 first official pilot program in Western Australia, with 5 monitoring sites established on the Ningaloo Coast.

**2014**

2014: Lucky RCA survey team had the opportunity to meet Sir David Attenborough on Heron Island.


## REEF CHECK PROTOCOLS & DATA

Trained survey volunteers use a standardised Reef Check protocol to record data including reef composition, abundance of indicator fish and invertebrate categories and reef health impacts (Hodgson *et al.*, 2006, Hill and Wilkinson 2004).

- RCA volunteers undertake a four-day training course to learn relevant survey knowledge and skills. Volunteers must demonstrate in-water identification skills with 95% accuracy.
- Teams use detailed maps, mean tide times and GPS coordinates to return to monitoring locations for surveys. Transect locations do not have permanent markers, therefore the precise placement of the tape may vary slightly on each survey, yet offer a representative sample of the monitoring location from year to year.
- A set of four data collection areas (20m long) are marked using a transect tape to form a complete survey.
- Volunteers record data at every 0.5m along the transect line to calculate percent cover of benthic reef habitat categories.
- A team of volunteers record invertebrate and reef impact abundance by searching a 5m wide belt transect along each 20m transect line replicate (4 x 100m$^2$ areas). Abundance data in this report is reported in units of 100m$^2$.
- Fish abundance is recorded by counting fish in a 5x5m tunnel along the transect (4 x 100m$^2$ areas). Fish data is also reported using the area covered in the survey (100m$^2$), as some surveys are shallower than 5m in depth.
- Underwater photographs are used when feasible to support quantitative survey data and offer additional quality control procedures and data exploration opportunities.
- Larger reefs may have multiple dive site locations on different parts of the reef (for example reef flat and reef slope) and multiple research areas within each dive site (for example shallow and deep).
- Summary survey data is accessible through the online Reef Check Australia Reef Health Database.

NOTE:

- Reef Check sampling protocols often select for some of the “best” reefs in the area and therefore may not be representative of overall reef system health (many are better than average reefs).
- The RCA community program is dependent on grant funding, human resources and logistical support from dive tourism operators. Therefore survey records can vary in duration, timing and frequency.
- The case studies in this report present data as averages across years or regions for brevity. To view site-specific data, visit the Reef Check Australia Reef Health Database or register as a Data user to access raw data (FREE).



## REEF CHECK AUSTRALIA INDICATORS

**Invertebrate**

Invertebrate indicators have been selected for ecological and/or economic importance across global regions. In Australia, abundance data is collected for 14 categories on invertebrates. Human uses will vary depending on location.

- Anemones (all species recorded from 2008)
- Banded coral shrimp (*Stenopus hispidus*)
- Crown of Thorns Starfish (COTS, *Acanthaster planci*)
- *Drupella* spp. snails
- Giant clams (*Tridacninae*)
- Lobster (*Panulirus spp.*, Spiny & slipper lobster)
- Sea urchins: collector urchins (*Tripneustes spp.*), Long-spined Diadema (*Diadema* spp. and *Echinothrix diadema*), Pencil urchin (all species)
- Edible sea cucumbers (*Thelenota ananas, Stichopus chloronotus, Holothuria nobilis, Holothuria fuscopunctata, Stichopus variegatus* after 2008, *Holothuria nobilis, Holothuria fuscopunctata* and *Stichopus variegatus* from 2001-2007)
- Triton (*Charonia tritonis*)
- Trochus (*Trochus niloticus*)

**Reef impacts**

Information is recorded for 11 types of reef health impacts within five overarching categories. Photographs are taken whenever possible, to document impact types and severity.

- Coral bleaching (% impact at colony and population level)
- Coral scars (from Crown of Thorns Starfish, *Drupella* snails and unknown causes)
- Coral damage (from anchors, dynamite and unknown causes)
- Coral disease
- Marine debris (fishing line, fishing nets and general rubbish)

**Substrate**

Percent composition of 25 categories of substrate, which fit within the 10 Reef Check International umbrella categories (Hard Coral, Soft Coral, Sponges, Recently Killed Coral, “Other”, Nutrient Indicator Algae, Rock, Sand, Silt and Rubble). In Australia, abundance of seasonal macroalgae (*Sargassum, Padina* and *Tubinaria* for GBR surveys, with addition of *Asparagopsis* for SEQ surveys) is counted separately and excluded from Nutrient Indicator Algae counts.

**Fish**

Fish indicators have been selected to allow global comparisons, track abundance of key food fish and document abundance of fish with specific habitat requirements or ecosystem roles. Abundance data is recorded for 11 categories of fish. Human uses will vary depending on location. Categories include:

- Barramundi cod (*Cromileptes altivelis*)
- Butterflyfish (*Chaetodontidae*)
- Common Coral Trout >30cm (*Plectropomus leopardus* recorded from 2008)
- Queensland Grouper >30cm (*Epinephelus lanceolatus* recorded from 2008)
- Grouper >30cm (*Serranidae*)
- Humphead wrasse (*Cheilinus undulates*)
- Moray eel (*Muraenidae*)
- Bumphead parrotfish (*Bolbometopon muricatum*)
- Parrotfish >20m (*Scaridae*)
- Snapper (*Lutjanidae*)
- Sweetlips (*Haemulidae*)

# THE REEF CHECK CITIZEN SCIENCE PROGRAM IN AUSTRALIA

RCA survey volunteers participate in a standardised training course and must pass in-water identification tests with 95% accuracy

RCA collaborates with tourism operators to help our teams visit the reef and share findings with guests

Volunteer teams visit monitoring sites annually to collect data, under the supervision of a team leader


Volunteers record information about reef composition, key indicator organisms & reef impacts using quantitative datasheets and photos

All RCA data is stored in our online Reef Health Database and shared through regular summary reports and other communication material

RCA data is freely available for research, management and education applications


Photo by Chris Hamilton (Agincourt Reef, GBR)

Photo by John Rumney (GBR)

## PRECISION STUDY SUMMARY

A key question for users of citizen science data is how well the data reflects real patterns. In 2007, a precision study was conducted to understand and quantify how Reef Check data collection methods and surveyor precision affects the data collected by RCA volunteers (Done *et al.* submitted).

Reef Check uses statistically haphazard transects for surveys (sites are not permanently marked). This approach offers a comparable set of samples within a study area. Teams locate survey sites using GPS coordinates and depth, as well as site maps detailing key features and location details.

Volunteer surveyors are likely to change year to year, therefore inter-observer variability is also a factor to consider in regards to data interpretation (this is true for many monitoring programs). Accordingly, RCA volunteers must complete a training course and accurately identify relevant indicators with 95% accuracy to participate in surveys.

To better understand these factors the precision study aimed to:

1. Quantify variability inherent in the standard RC point intercept sampling method, including transect deployment variation and site characteristics.
2. Quantify variability in substrate data among different observers.

Two study sites were selected to represent different habitat characteristics (one with relatively homogenous benthic cover, one with highly varied benthic composition, with no dominant type). Observers had a range of previous Reef Check surveying experience and science backgrounds.

During the study, seven transects were deployed by a Reef Check Australia staff member. Once all observers had completed a survey, the transect line was recovered, redeployed and resurveyed by all observers.

Taking into account year to year variations in the precise placement of transect lines and the identity of the RCA volunteer, the 95% confidence intervals for all RCA categories ranged from ± 2% to ±24% of the estimated percentage cover. This means that a nominal coral cover or change in cover of 10% is within the range of 7.5% to 12.5% at worst, and a nominal change of 40% is within the range of 31 to 49% at worst.

This level of precision, (which is comparable to that in institutional programs such as Sweatman *et al*. (2008) means that RCA abundance estimates do detect major changes and trends (especially in hard coral) in well-defined study sites. It also reflects both the quality of volunteer training and the effectiveness of the RCA protocols.

Done T., Harvey A., Fantozzi L., Hill J., Schläppy M-L., Lea A., Bauer A., Loder J. (submitted) Precision and representativeness of benthic monitoring on reefs by volunteers: Queensland 2002 – 2014. Submitted to Coral Reefs.

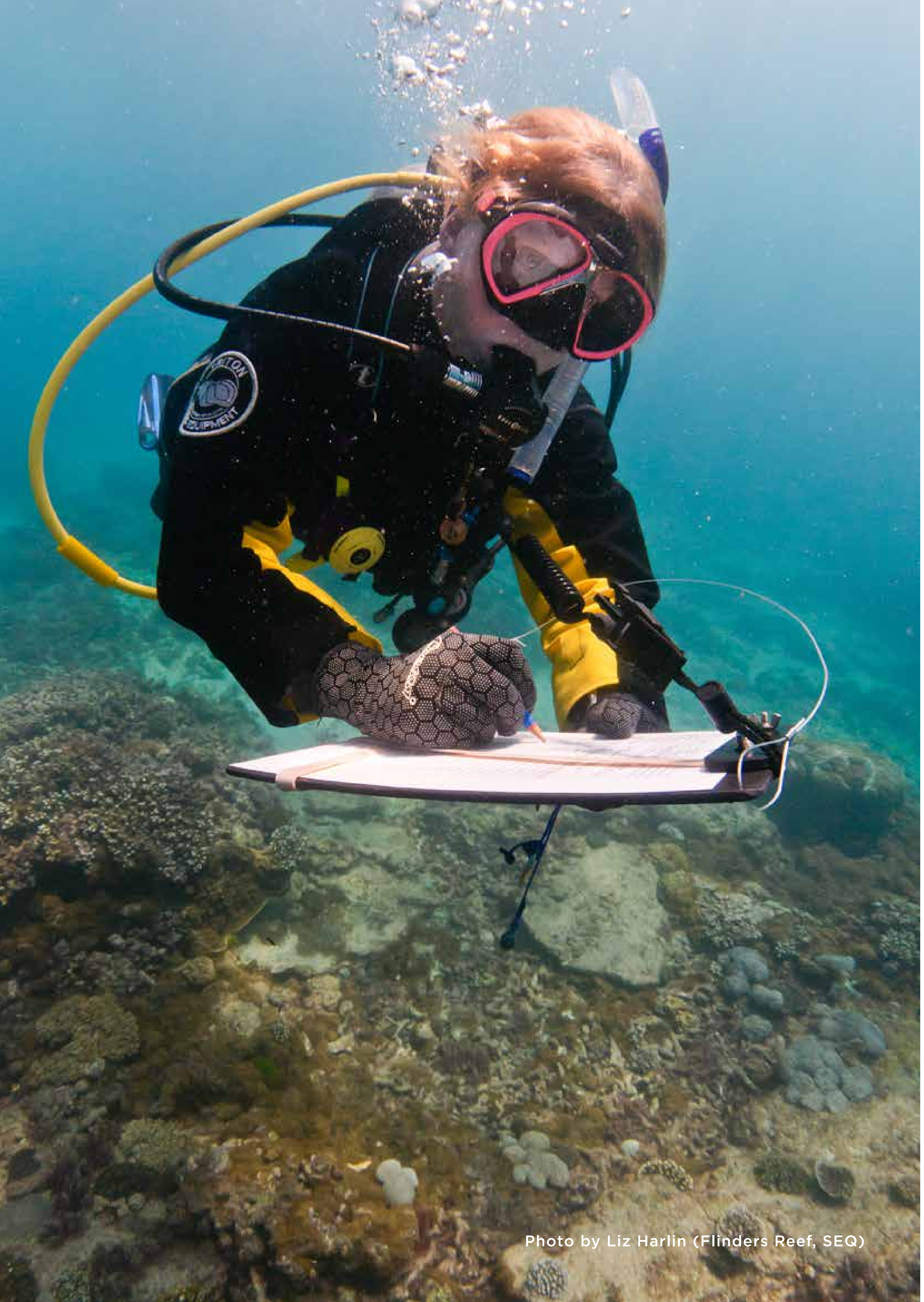


Photo by Liz Harlin (Flinders Reef, SEQ)

# Setting the scene

## THE ROLE OF VOLUNTEERS IN MARINE SCIENCE

Coral reefs have been the subject of scientific investigation for over two centuries. In the 20th century, this research has awakened increased concern about the state and future of coral reefs. This period has also begun to acknowledge the capacity and enthusiasm of community members to contribute to scientific knowledge through ‘citizen science’.

As a baby boomer, I saw the Reef’s wonder and learnt about 1960s threats from oil drilling and Crown of Thorns Starfish (COTS) on the family’s black and white TV. Later, threats from pollution and climate change emerged. Governments, responding to clear signals from the population at large, put in place the high levels of regulation and conservation management in place today.

Citizen concern for reefs was thus already deeply ingrained in Australia in 2001, when RCA was established. RCA offered a new means for motivated people from all walks of life to make hands-on contributions to the Reef’s well-being.

RCA’s links to mainstream science and their attention to standardised protocols and quality control have ensured that the collected data are useful and their limitations – as exist in all ecological data sets – are understood. The excellent precision that trained RCA volunteers achieve for measuring hard coral cover is a credit to RCA training and protocols.

The data set collected by RCA is invaluable. High precision in volunteer data collection means that the year to year trends in coral cover at individual sites reported here are a true reflection of the state of and changes in their study sites. This is particularly true in the context of substantial data sets compiled through other reef monitoring programs, such as the Long Term Monitoring Program of the Australian Institute of Marine Science (AIMS). These programs assess a broad, representative sample of the GBR. RCA’s program focuses on dive tourism areas, highlighting a sample of some of the best reefs in Queensland. These reefs are a better representation of what a recreational diver could expect in terms of living coral.

At the time of this report, it is pleasing to note that there were some sites that have retained or increased their coral cover in this first decade of the 21st Century.  This is a rare good news story that we in RCA are relieved to be able to deliver.  While it our hope that some news will continue to be good, we will report whatever transpires.

I congratulate RCA’s staff and volunteers for their first decade of achievement, and wish them well for the next decade.

**Dr. Terry Done**
*Board Director and Science Advisor for Reef Check Australia*
*Formerly Senior Principal Research Scientist, Coral Reef Ecology, Australian Institute of Marine Science*


# Case study 1

## A DECADE OF UPS AND DOWNS: A GLASS HALF FULL VIEW ON GREAT BARRIER REEF DIVE SITES

The Great Barrier Reef (GBR) is the world's largest coral reef system, composed of some 3,000 reefs stretching 2,300 kilometres along the Queensland coast. Coral reef habitats make up approximately 7% of this diverse and complex system, which supports thousands of marine species (Burke *et al.* 2011).

The GBR is managed by the Great Barrier Reef Marine Park Authority (GBRMPA). GBRMPA is tasked with the job of balancing the benefits, pressures and potential risks associated with human use and activities within and around the Park, such as fishing, tourism, shipping and coastal runoff. To contribute to collective understanding about the reef science and reef management outcomes, a range of organisations collect monitoring data and conduct research across the reef on every topic from coral taxonomy to crustacean populations.

Despite the GBR being acknowledged as one of the best managed reefs in the world (Pandolfi *et al.* 2005), numerous studies have documented a decline in hard coral across the GBR system (Osborne *et al.* 2011, De'ath *et al.* 2012). Long-term monitoring is critical to developing understanding of how reefs are changing over time. RCA's long-term GBR monitoring program was launched in 2001, focusing on engaging volunteers in monitoring reef health at recreational dive sites. The RCA program has depended on support from RCA Industry Champions, who help RCA survey teams access reef tourism sites and also provide a platform to share findings and information with guests.

From 2001 to 2014, RCA teams conducted 461 surveys spanning 27 reefs in the Great Barrier Reef Marine Park and one in the Coral Sea. This case study reports on data from more than 300 surveys on 66 long-term monitoring sites (surveyed on three or more occasions) and 12 additional sites surveyed twice.

Summary data for coral cover, reef composition, abundance of key indicator invertebrates and reef impacts is presented at a subregional level across the northern, central and southern sections of the GBR. This dataset offers a unique opportunity to explore summary trends at some key GBR tourism locations. For individual sites, RCA results provide a measure of the direct impacts on these important tourism sites. Collectively, the results provide information about how these sites are trending in the context of the trends reported across the GBR by other more broadly representative long-term monitoring programs.

> *When I first moved to Australia, the only thing I knew about coral reefs was that I wanted to know more! I discovered Reef Check in 2003 and couldn't believe my luck – here was an organisation that offered education, diving, and opportunities to make a difference conserving our reefs. As my experience increased, I wanted to become a RCA trainer and share my knowledge with as many others as possible. Ten years later, I still volunteer for RCA because now more than ever we need to educate people about the reef.*

**Dr. Erin Graham**
*Researcher, James Cook University (2014)*

# FIRST IMPRESSIONS OF GBR SITES & CHANGES IN HARD CORAL COVER

Hard corals construct the primary structure of coral reefs, therefore hard coral cover is often used as a key indicator and proxy for broader reef health. Hard coral cover at 77 sites on 22 reefs, encompassing some of the Great Barrier Reef's most popular dive sites, was monitored at least three times by trained RCA volunteers at irregular intervals from 2001 to 2014 (255 surveys).

Initial RCA surveys conducted from 2001 to 2005 (n=61) had an average of 33% hard coral cover. Coral cover across the extensive GBR system is patchy; studies estimate average GBR hard coral cover between 20–30% (Brodie and Waterhouse 2012, Sweatman *et al.* 2011). The relatively high average hard coral cover on RCA monitoring sites reflects a tendency for dive tourism operators to select attractive sites with a lot of coral. Therefore, Reef Check sites (Figure 3) tend to represent some of the "best" parts of individual reefs.

When net change in hard coral cover was compared at the site level, 43 sites showed no net change, 23 sites increased by more than 10% (10-41% net change), and 17 sites decreased by more than 10% (10-63% net change). When grouped into subregions (Figure 2), RCA's most northerly sites (in the Cairns to Port Douglas region) showed overall stable or slight increasing trends in average hard coral cover. Hard coral cover on the central GBR sites (Palm Islands, Townsville and Whitsundays) declined slightly on average (note intensive Palm Islands monitoring only from 2005 to 2006). RCA records for the southern GBR are relatively newly established (2011 to 2014), therefore the increases in coral cover should be interpreted cautiously.

Studies from the Australian Institute of Marine Science (AIMS) over the same period documented a GBR-wide decline in hard coral cover, but highly variable trends across subregions (De'ath *et al.* 2012, Osborne *et al.* 2011, Sweatman *et al.* 2011). RCA data did not document a collective decline, yet subregional trends were consistent, demonstrating variability across sites and subregions (Figure 3). Northern sites (Outer Reef, Cairns and Port Douglas) consistently showed higher coral cover and no significant loss, wheras more declines in coral cover were documented in central regions (Townsville and Palm Islands). Both AIMS and RCA studies reported highly variable trends, with some sites showing increasing hard coral cover, some decreasing and some with minimal net changes in cover. Much of the overall decline documented by AIMS studies was a reflection of substantial losses from cyclones and Crown of Thorns Starfish on southern GBR sites, areas not monitored by RCA until 2011.

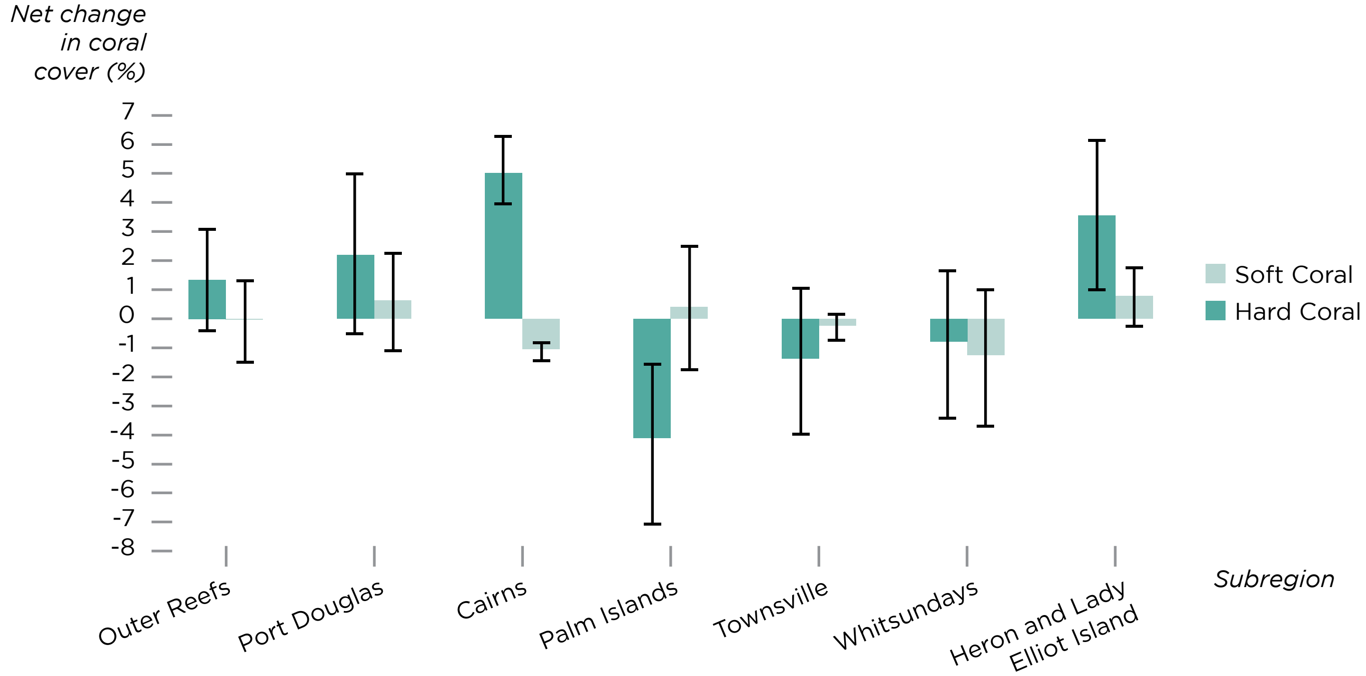



Figure 2. Average net change in cover of hard coral and soft coral between first and last surveys for sites surveyed three times or more from 2001 to 2014. Error bars represent one standard error of the mean.

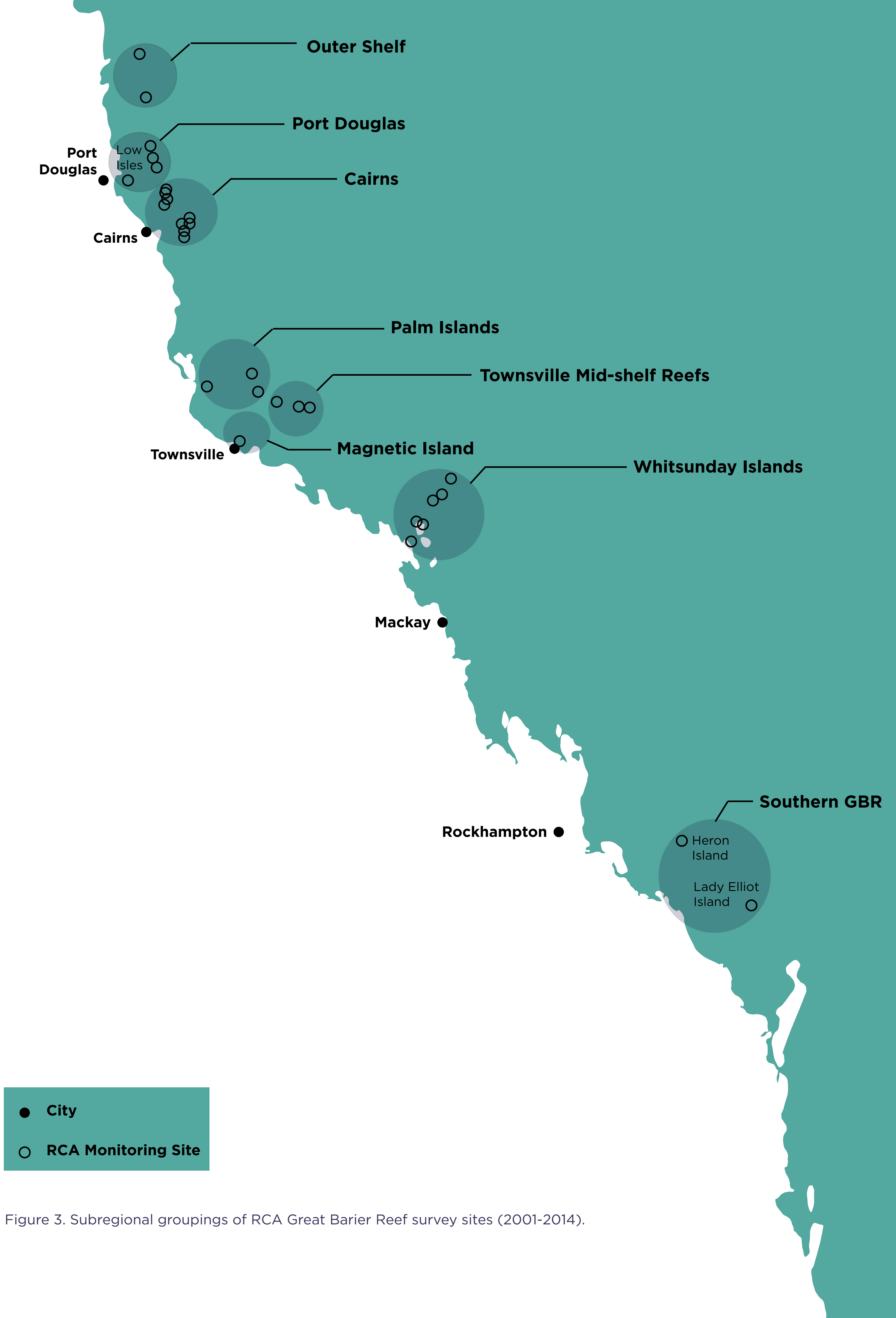



Figure 3. Subregional groupings of RCA Great Barier Reef survey sites (2001-2014).

# CORAL TRENDS FOR RCA SITES ACROSS THE GBR

## Northern GBR sites

**Outer shelf and Coral Sea (Figure 4A):**
From 2001 to 2008, 41 surveys were conducted on six sites across three reefs: Osprey Reef (in the Coral Sea) and Ribbon Reefs 3 and 10 (Outer GBR). Hard coral was the dominant cover at all sites (average cover was 50%) and showed little change over the monitoring period. Five sites maintained consistent cover, while one site showed a slight increase in cover (>10%). Soft coral accounted for an average of 6% coral cover.

**Port Douglas (Figure 4B):**
From 2003 to 2014, 80 surveys were conducted at 13 sites on three reefs (Agincourt, Opal and Low Isles reefs). Most sites had moderate to high hard coral cover (average cover was 40%), although variability among survey sites was high. Average coral cover steadily increased by 20% during the survey period. Soft coral averaged 12% cover across the region and was most abundant at Low Isles (average 41%).

**Cairns (Figure 4C):**
From 2003 to 2014, 30 surveys were conducted at six sites across three reefs (Hastings, Moore and Saxon reefs). Regular sampling ended in 2010 for this region, thus the majority of surveys are from 2003 – 2010. Hard coral cover averaged 31% and increased at most sites during the survey period (20% net increase from 2003-2010). Soft coral averaged 12%, being most abundant at Moore Reef (average 21%).

## Central GBR sites

**Palm Islands (not shown in graphs due to limited monitoring period):**
From 2005 to 2006, 46 surveys were conducted at 18 sites across five reefs (Curacoa, Fantome, Great Palm, Orpheus, Pelorus islands). Five sites in the Palm Island group were intensely monitored from 2005 to 2006, and one site (Pelorus Island) was monitored from 2005 to 2010. Hard coral cover averaged 29% and was relatively stable at most sites. Five sites, however, had major losses (>10%) of hard coral cover over this short monitoring period. All sites except for Juno Bay had notable soft coral communities (average 15% cover).

**Townsville Mid-shelf (Figure 4D):**
From 2003 to 2012, 22 surveys were conducted at six sites on four mid-shelf reefs (Davies, John Brewer, Keeper, and Wheeler Reef), but only Wheeler Reef was monitored beyond 2008. Hard coral cover varied widely among sites (lowest cover at Keeper and John Brewer Reefs), and averaged 32%. Four of the six sites showed no change throughout the monitoring period. Wheeler Reef, however, was heavily impacted by Cyclone Yasi in 2011. Prior to 2011, the site had an average 61% hard coral cover (mostly branching coral). When monitored in 2012, average hard coral cover decreased to 8% (not shown on graph). Soft coral cover averaged 4% across all sites.

**Townsville Magnetic Island (Figure 4E):**
From 2003 to 2014, 61 surveys were conducted at 11 sites in six areas (Alma Bay, Florence Bay, Geoffrey Bay, Middle Reef, Nelly Bay and Picnic Bay) around Magnetic Island. Average hard coral cover was 34%, although the survey period encompassed a marked increase and subsequent decrease in cover at most sites. From 2003 to 2008 coral cover increased (> 10%) at most sites, but from 2009 to 2014, coral cover sharply decreased, with five of eight sites experiencing greater than 25% coral loss. The decline in coral cover was likely a result of Cyclone Hamish, which swept through the region in 2009. Soft coral cover was generally low (average 2%).

**Whitsunday Islands and mid-shelf reefs (Figure 4F):**
From 2001 to 2014, 34 surveys were conducted at six sites across three reefs (Hardy, Hayman and Knuckle reefs) in the Whitsundays. All reef sites maintained moderate to high cover of hard coral (average 48%) and low to moderate cover of soft coral (average 17%). During the survey period, coral cover remained stable at four sites, increased at one site (>10%), and decreased at one site (<10%). Note that RCA has only six long-term sites in this subregion and three of these sites were not monitored post 2010/11.

## Southern GBR sites
**(Figure. 4G)**

From 2011 to 2014, 30 surveys were conducted on 10 sites across two reefs on the Southern GBR: Heron Island (28 surveys) and Lady Elliot Island (LEI) (2 surveys). Average hard coral cover was 39% and there was little change during the survey period. Soft coral cover was relatively low at most sites, averaging 2%.

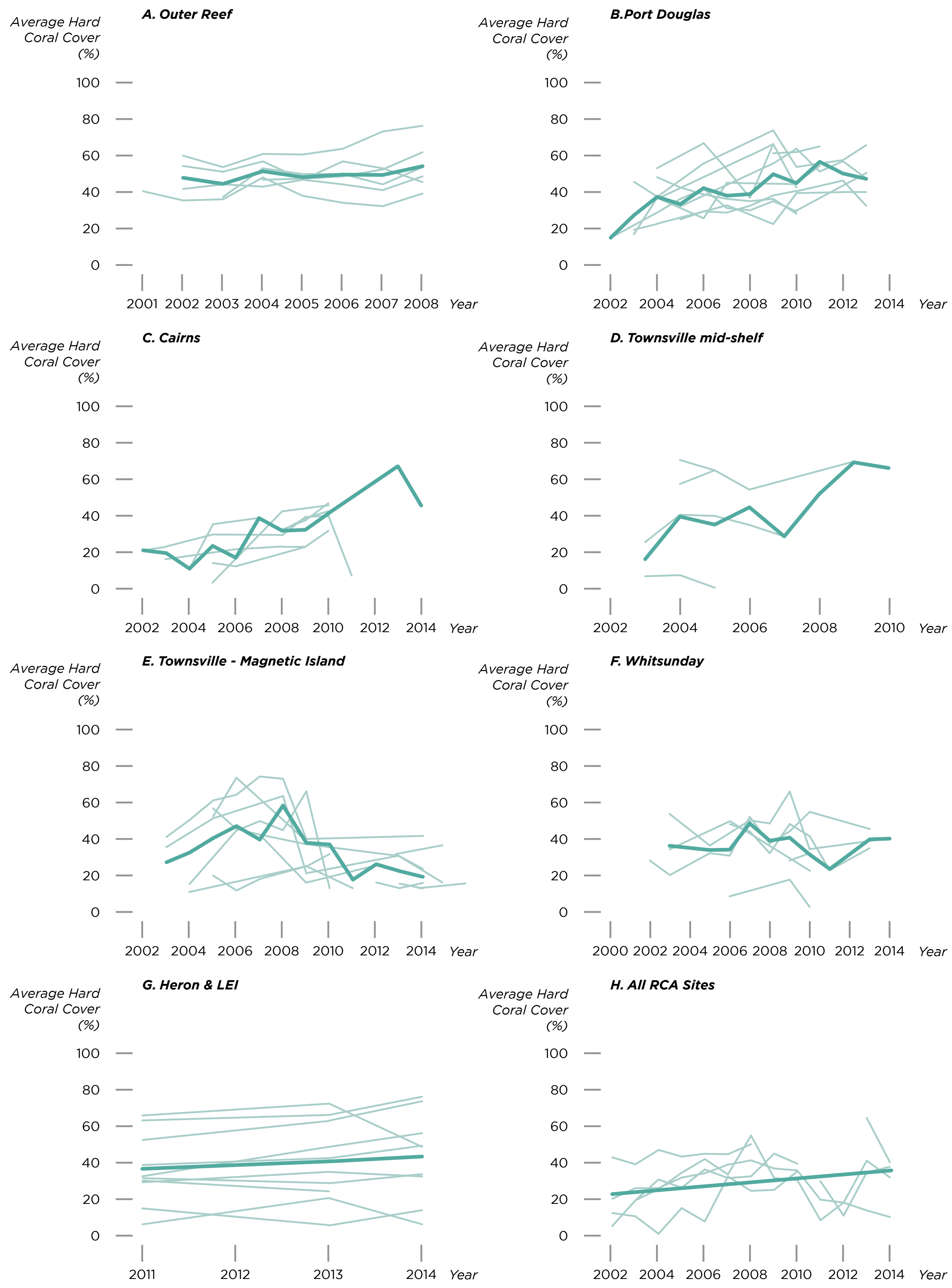



Figure 4. Light green lines represent the percent cover of hard coral at each monitoring site surveyed three times or more times from 2001 to 2014. Subregional average of hard coral cover is shown as a bold green line.

# KEY REEF DWELLERS: INDICATOR INVERTEBRATES

Invertebrates play an important role in the GBR ecosystem. The abundance of some invertebrates can provide clues about ecosystem processes, human use, and changes in the delicate ecosystem balance required for reef health. Some coral predators, such as Crown of Thorns starfish (COTS) and *Drupella* snails, can become pests if populations increase too quickly. Likewise, the ecosystem can suffer when populations of algae grazers, such as sea urchins, become too low. A number of invertebrates are also collected for human benefit including food, souvenirs, and aquarium trade. It appears that limited baseline or monitoring data exists for many invertebrates monitored by Reef Check, aside from COTS and *Drupella* snails (Pearson & Munro 1991, Bruno & Selig 2007, Erikkson & Byrne 2013).

From 2001 to 2014, 327 invertebrate surveys were carried out on GBR sites monitored at least twice (Figure 5). Giant clams, *Drupella* snails, and sea cucumbers were the most common invertebrates.

Giant clams were the most abundant invertebrate recorded, with sites around the Palm Islands having over five times more giant clams than other sites in the GBR. This high abundance at Palm Islands is likely the result of previous clam farming projects.

Average densities of *Drupella* snails were low, ranging from 3.0/100m² at the Outer Reefs to zero at Heron Island. Other studies have documented *Drupella* snail outbreaks in average abundance from 5.0 to 18.5/100m², with a localized maximum at Ningaloo Reef in Western Australia of 175 individuals in a 1.0m² quadrant (Turner 1994). By maintaining baseline data on *Drupella* abundances, RCA can help identify and quantify future outbreaks.

Studies on the GBR suggest over-harvesting of some bêche-de-mer fisheries (the food product from sea cucumbers), yet limited baseline data is available (Uthicke *et al.* 2004, Eriksson & Byrne 2013). Average abundance of RCA edible sea cucumber species (three species before 2008, and five species after 2008) was low or not present in several subregions. Densities at six of the nine subregions were less than 0.2/100m². The highest average abundance of sea cucumbers was at Lady Elliot Island.

Long-spined (*Diadema*) urchins were found in six of the nine subregions. They were most common at Palm Islands. Anemones (all species), COTS and Trochus were also recorded in at least six of the nine subregions during the course of monitoring, but typically in low abundances (0.5/100m² or less). There were slightly higher average abundances of COTS on Townsville mid-shelf reefs (mainly from John Brewer Reef).

While not shown on Figure 4, the low numbers (<0.2/100m²) of banded coral shrimp, lobster, triton, collector urchins and pencil urchins are worthy of additional investigation to understand site-specific abundances and changes.

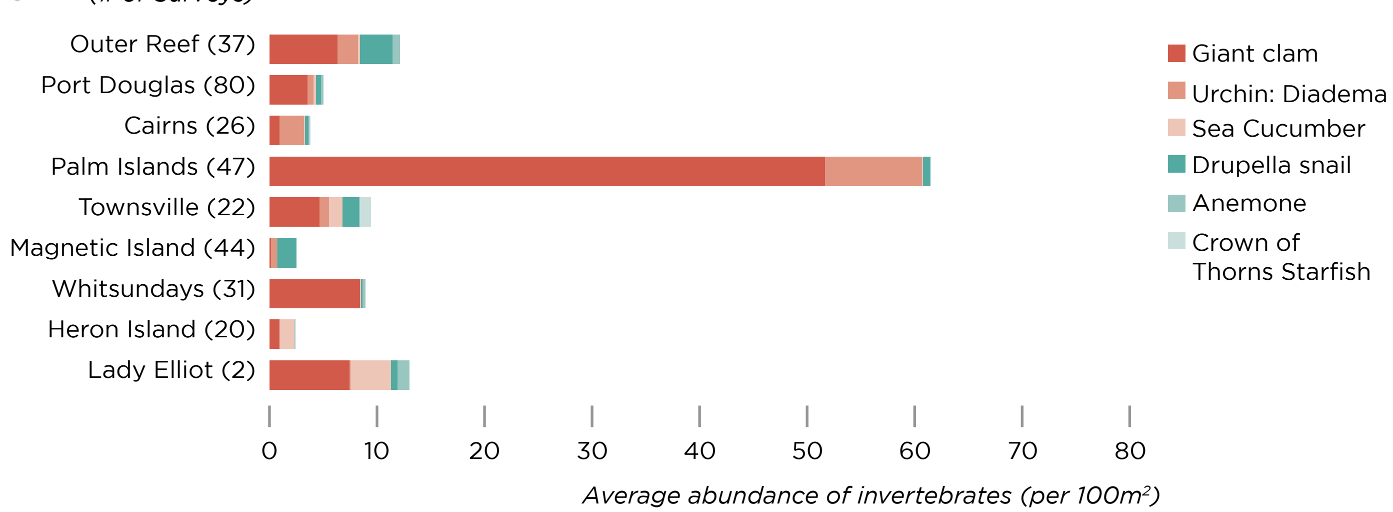



Figure 5. Average abundance of invertebrates (per 100m²) recorded over 327 surveys from 2001 to 2014, displayed in stacked graphs. Invertebrate indicators with average abundances of less than one across all subregions have been excluded from the graph (banded coral shrimp, lobster, triton, collector urchin, pencil urchins). For most data, one standard error of the mean ranged from 0.01 to 1.8, with the exclusion of Palm Island giant clam abundances with an error of 5.2 due to large concentrated numbers at a few sites.



# KEY REEF DWELLERS: INDICATOR FISH

From 2001 to 2013, 169 fish surveys were carried out on GBR sites (Figure 6). Butterflyfish, parrotfish and snapper were the most commonly encountered species and were recorded in every subregion. The Outer Reef sites had the highest average fish abundance while Magnetic Island sites had the lowest abundance.

Barramundi cod, coral trout, sweetlips, bumphead parrotfish (not shown in graph), moray eels (not shown in graph), humphead wrasse (not shown in graph), and Queensland grouper (not shown in graph) were the least common species encountered, with levels less than 0.3/100m² at most sites. Queensland grouper was only observed on one survey in 2009.

Broadly, fish abundance appears to be comparable to other GBR studies. For example, GBR Marine Park Authority fish surveys recorded coral trout abundance at approximately one per 100m² at Cairns, Townsville, Whitsundays, and Palm Island reefs (McCook *et al.* 2010). Abundances of coral trout, humphead wrasse, parrotfish and sweetlips were also comparable to a study on predatory fish across the GBR (Ayling & Choat 2008). Parrotfish are considered an important and widespread herbivore (Cheal *et al.* 2012) and were heavily represented in RCA surveys. Distribution and abundance of herbivorous fish species (Wismer *et al.* 2009) and corallivorous butterflyfishes (Emslie *et al.* 2010) are heavily influenced by differences in habitat structure across the GBR shelf. Thus, varying abundances of butterflyfishes and parrotfishes at different survey sites (such as high abundance on the Outer Reef and low abundance on the inshore reefs of Magnetic Island) is not unexpected.

Complex relationships exist around fish community structure, which can be impacted by environmental factors such as water quality, reef zone, habitat availability (Fabricius *et al.* 2004, Wismer *et al.* 2009, Cheal *et al.* 2012), and direct human pressures (Di Iulio Ilarri *et al.* 2008, Russ *et al.* 2008). Many RCA surveys are conducted at tourism locations, which may influence fish community, abundance and modify behavior (Albuquerque *et al.* 2015, Shackely 1998, Welsh & Bellwood 2011). For example, mobile and roving species are more abundant after tourists have departed (Di Iulio Ilarri *et al.* 2008). Due to the complex nature of these relationships and lower numbers of fish surveys, further investigation into spatial and temporal trends at both the subregional and site level is warranted.

The majority of RCA GBR survey sites are in green (no-take) zones (77%). Comparison between protected and non-protected areas was not undertaken in this report; however numerous studies have shown that popular targeted food fish, such as coral trout, are found in higher abundances in green zones (Williamson *et al.* 2004, Sweatman *et al.* 2008, McCook *et al.* 2010).

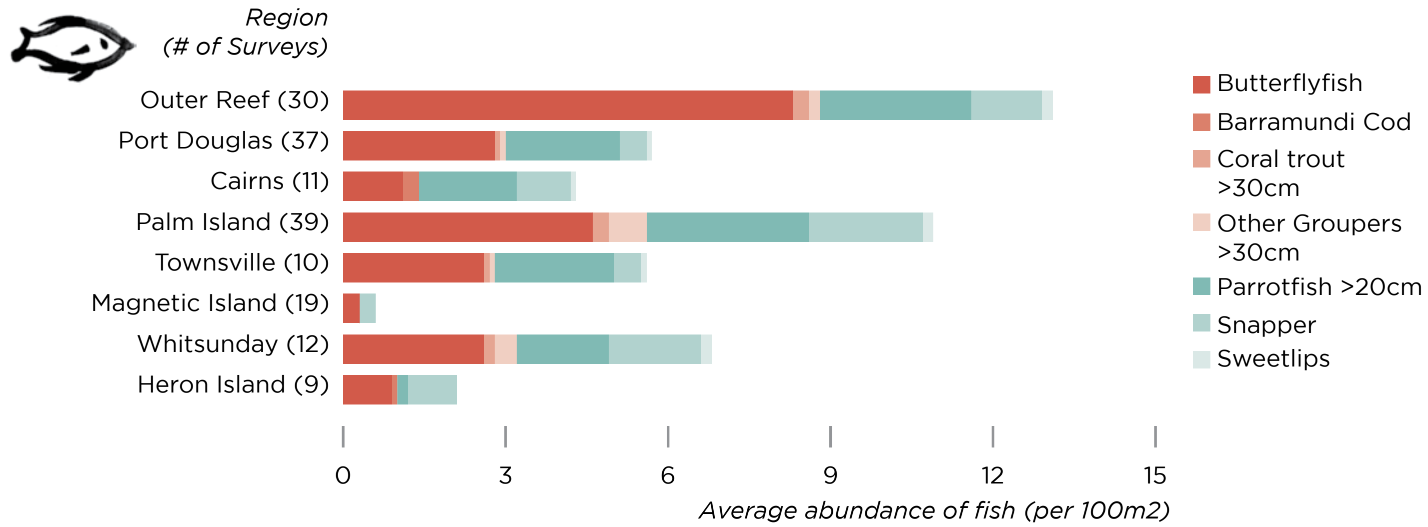



Figure 6. Subregional average abundance of fish (per 100m²) recorded over 169 surveys from 2001 to 2013. Queensland grouper, moray eel, bumphead parrotfish, humphead wrasse have been excluded from the graph (abundances of <1/100m²). For most data, one standard error of the mean ranged from 0.01 to 1.0, with the exclusion of Port Douglas snapper abundances with an error of 6.8 (due to large numbers at a few sites).

## SIGNS OF REEF STRESS

When 331 surveys from 2001 to 2014 were pooled by subregion, coral bleaching, coral damage (from unknown causes), coral disease, *Drupella* snail scars, and unknown coral scars were recorded in all subregions (Figure 7).

Coral bleaching was observed on one or more occasions in the majority of surveys (70%), but the affected population was typically low (average 2.1%; not shown in graph). The RCA GBR survey season typically takes place in cooler months (March-July), reducing the likelihood of surveys coinciding with major coral bleaching events, which are often caused by exceptionally high water temperature.

Coral damage from unknown causes was recorded in all subregions in abundances of 1.4/100m² or greater (78% of surveys).

Coral disease was also recorded in all subregions (28% of surveys), but in varying degrees of abundance. The highest coral disease counts were recorded on sites with some of the highest average coral cover in the Southern GBR. Only eight of the 331 surveys reported coral disease counts greater than 4.0/100m².

Coral scars from *Drupella* snails and unknown causes were recorded in all subregions (33% of surveys). The highest abundance of *Drupella* scars occurred on Outer Reef sites, while the highest abundance of scars from unknown causes occurred on reefs at Cairns, Palm Island and Heron Island. Scars from COTS were recorded in low numbers in all subregions except for Lady Elliot Island and Heron Island (zero counts). Townsville mid-shelf reefs had the highest average abundance of COTS scars. These findings demonstrate minimal COTS activity at RCA monitoring locations during surveys, possibly attributable in some sites to COTS eradication programs implemented by tourism operators.

Marine debris levels were low across all subregions, with a maximum subregional average of 0.04/100m² around Palm Island reefs.

At the subregional scale, differences in coral cover reflect the variability in the history of disturbance in the area (Bruno & Selig 2007, De'ath & Fabricius 2010, Osborne *et al.* 2011, Sweatman *et al*. 2011). A study by the Australian Institute of Marine Science (De'ath *et al*. 2012) attributes 48% of reef mortality in the GBR to cyclone damage, 42% to earlier COTS predation, and 10% to coral bleaching.

Most RCA results are consistent with these studies, documenting coral damage as a primary reef impact (RCA does not differentiate specific causes of damage other than anchors) and lower levels of impacts from coral bleaching. However, most RCA surveys reported low numbers of COTS scars, which is likely related to survey locations and survey timing. The relatively high abundance of coral scars from unknown causes is evidence of recent coral mortality events, which could be from any number of sources such as bleaching mortality or older COTS scars of which causation cannot be confirmed.

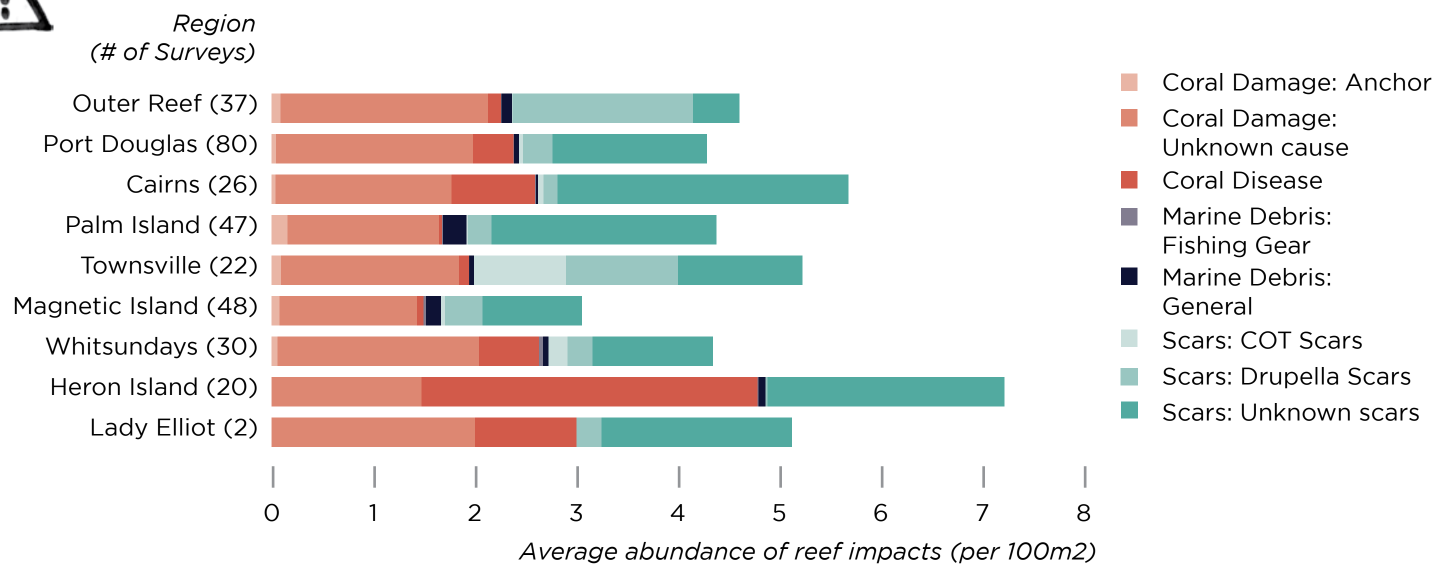



Figure 7. Subregional average abundance of reef impacts (per 100m²) recorded over 331 surveys by Reef Check Australia volunteers from 2001 to 2014. Error bars have been excluded to simplify data presentation. For most data, one standard error of the mean ranged from 0.01 to 0.9.



## Case study 1 SUMMARY & KEY POINTS

Many GBR sites monitored by RCA have maintained or increased in coral cover in this millennium's first decade, yet all coral reefs globally are confronted by the consequences of climate change and ocean acidification (Baker *et al.* 2008, Bellwood *et al.* 2004, Pandolfi *et al.* 2003). Australia also faces pressures closer to home due to water quality issues, fishing, dredging and coastal development (Bruno & Selig 2007, Hoegh-Guldberg *et al.* 2007, De'ath & Fabricius 2010, Burke *et al.* 2011, Brodie & Waterhouse 2012).

This case study can serve as a reminder that the GBR continues to host notable and healthy coral reefs. We hope this will be a prompt for positive, science-based community action to protect and steward this valuable resource. The study also demonstrates the important data that citizen science initiatives can contribute within the spectrum of science on the GBR.

**Key points:**

- RCA data illustrate the kind of reef that can be expected at many dive tourism locations. Initial RCA surveys conducted in the GBR from 2001 to 2005 had an average of 33% hard coral cover. This demonstrates the Reef Check methodological preference for monitoring sites with high coral cover.
- From 2001-2014, coral cover at 43 RCA GBR sites showed no net change, 23 monitoring sites increased by more than 10%, and 17 sites decreased by more than 10%.
- Major losses at RCA sites often appeared to coincide with cyclone impacts, but there are additional complex factors that may be relevant.
- Subregional trends in hard coral cover were evident. Northern sites showed higher coral cover and no notable loss. Some declines were evident in central regions, particularly on nearshore reef sites.
- The 'better than average' trends in hard coral cover at some RCA sites, compared to other GBR studies are likely explained by three intertwined considerations: initial site selection, site disturbance history and site survey history.
- The RCA program formula can select for long-term monitoring at sites with continued good conditions. There are a handful of GBR monitoring sites that have been impacted by COTS or cyclones, where monitoring has not continued due to either limited tourism access or project resources. Sustainable funding resources would help to reduce this influencing factor.
- Across most sites there is evidence of reef health impacts in varying degrees and types. Coral bleaching, coral damage, coral disease, *Drupella* snail scars and unknown coral scars were recorded in all subregions in varying abundances. Additional site-level investigations into how observed reef impacts change over time would be benefical.
- Giant clams, sea cucumbers and *Drupella* snails were the most commonly recorded invertebrates across GBR subregions. Limited monitoring data is available for many invertebrates monitored by RCA, demonstrating the value of the dataset.
- Butterflyfish, parrotfish and snapper were the most commonly encountered species and were recorded in every subregion. Fish abundance data appear to be relatively consistent with other GBR studies, although additional analysis would be required to investigate complex relationships around community structure. Expanded monitoring would be useful to provide further insights.
- RCA offers a different, but useful representation of GBR reef health, especially when considered in the context of other more broadly representative reef monitoring programs.


Photo by Liz Harlin (Flinders Reef, SEQ)

# Case study 2

## CATCHMENT TO CORALS: SUPPORTING SUBTROPICAL REEFS THROUGH COLLABORATION

In 2007, Reef Check Australia expanded operations to survey subtropical reefs in South East Queensland (SEQ). Since then, teams have expanded to more than 20 priority reef monitoring sites from the Sunshine Coast to Gold Coast. RCA volunteer monitoring activities provide valuable reef health data, as a number of Reef Check survey sites do not have other regular long-term monitoring programs.

SEQ reefs live on the edge. These subtropical reefs are located in a transitional zone where tropical and temperate marine species co-exist (Harriot *et al*. 1999, Beger *et al*. 2014). Not only are these unique systems subject to natural extreme environmental conditions, but they also live in close proximity to extensive urban areas.

Already there are documented impacts on SEQ reefs from more localised chronic issues such as water quality and fishing pressure, as well as acute events such as floods (Smith *et al.* 2008, EHMP 2010, Gibbes *et al.* 2013). These compounding pressures result in complex interactions with unclear implications for reef communities, perhaps particularly so for subtropical communities (Munday *et al.* 2009, Figueira & Booth 2010, Graham *et al.* 2010, Lybolt *et al.* 2011). These issues will intensify with population growth in SEQ, as the population is projected to reach 4 million people in 2026 (QOESR 2011). As such, long-term monitoring of these habitats is critical (Wallace *et al.* 2009).

SEQ Catchments is the Natural Resource Management (NRM) body for the region that hosts these unique coral communities. Since 2007, SEQ Catchments has been instrumental in supporting development of the RCA SEQ project.

To shape project growth, we have worked collaboratively with SEQ Catchments and other pivotal organisations to increase marine data available for making catchment-level management decisions and increasing knowledge about these unique reef habitats on the doorstep of SEQ. The regional RCA program demonstrates the role that citizen science organisations can play in NRM activities.

> *Reef Check has shone a light on the amazing diversity of our coral reef communities within Moreton Bay and broader South East Queensland. Community volunteers have been able to link up with leading researchers to paint a picture of the health and threats posed to our reefs, inspiring many to undertake actions to conserve these special environments. Reef Check has been integral to building strong community momentum for marine conservation and is an important piece in the puzzle of holistic catchment and natural resource management across South East Queensland.*

**Simon Warner**
*CEO, SEQ Catchments (2014)*

## DEVELOPING A DATASET

The SEQ program began in 2007, with a handful of key sites along the coastline. In 2009, RCA established a regional base and since then, teams have expanded to more than 20 priority reef monitoring sites in the SEQ Catchments NRM area.

RCA's volunteer reef monitoring program has grown by developing working relationships with researchers, traditional owners, tourism operators, management agencies, educators and community groups. Selection of RCA monitoring sites involved feedback from a wide range of stakeholders, with a goal to build on existing data, help fill knowledge gaps and survey areas of community interest.

The regional NRM body, SEQ Catchments, has supported the development of the SEQ initiative from the early days by providing advice, expertise and in-kind support. RCA monitoring data has contributed to the process of review for the SEQ Natural Resource Management Plan 2009 to 2031. The NRM coral target is that '*By 2031, the condition and spatial distribution of soft and hard corals is maintained at 2005 levels.*' RCA data has been integrated into regional datasets to help evaluate this milestone now and in the future.

Across eight annual survey seasons (2007 to 2014), RCA volunteer teams have conducted 142 reef health surveys in South East Queensland. Data for 26 monitoring sites, spanning 17 reefs, with two to seven years of data records (n=130) are presented in this report.

## FROM SURVEYS TO SUMMARIES

On average, hard coral covered 24% of the benthic substrate in SEQ, demonstrating notable coral communities in the region. There were some differences evident when the Sunshine Coast, Moreton Bay and Gold Coast subregions were compared. The Sunshine Coast (n=42 surveys) and Moreton Bay (n=75 surveys) had similar levels of average hard coral cover (24%) and soft coral (7% and 10% respectively).

Compared to more northern SEQ sites, the Gold Coast (Palm Beach Reef, n=5 surveys) had lower hard coral cover (14%), but similar soft coral (8%). RCA Gold Coast monitoring sites included 2 other non-coral locations at Narrowneck Artificial Reef and the Gold Coast Seaway. These sites had no records of hard coral growth and were excluded from coral analysis, but were included in other indicator comparisons as they form important marine habitat. All subregions had similar levels of sponge (4-5%). Site expansion on the Gold Coast would improve representation.

From 2007-2014, RCA survey data documented minimal net changes in hard coral cover at the subregional level. The largest subregional net change was a 6% increase in hard coral cover across Sunshine Coast sites. Moreton Bay sites demonstrated a small 1% decline and there was no cumulative change (although small, steady declines since 2008) for Palm Beach Reef on the Gold Coast. These results align with other broader studies, documenting relatively stable subtropical coral communities (Harriott & Banks 2002, Wallace & Rosen 2006, Dalton & Roff 2013).

However, there have been changes in hard coral cover recorded at the research site level (Figure 8). Net change in relative hard coral cover (net change/average hard coral cover) was used for reporting, as some sites have low levels of hard coral cover, therefore small net losses are relatively important. For example, Kings Beach on the Sunshine Coast had 14% hard coral cover recorded in 2009, which dropped to 0% cover when surveyed after the 2011 Brisbane flood event. The good news for Kings Beach is that recent surveys suggest slow recovery of hard coral at this site.

Data for seven research sites showed relative increases in hard coral cover by more than 25% (4 Sunshine Coast, 3 outer Moreton Bay) and six sites decreased by 25% or more (1 Sunshine Coast, 3 outer Moreton Bay, 2 inshore Moreton Bay). Seven sites did not demonstrate changes greater than 25% (5 increased and 4 decreased) and two sites had no net change in hard coral cover. Two sites had no hard coral recorded in the course of monitoring.

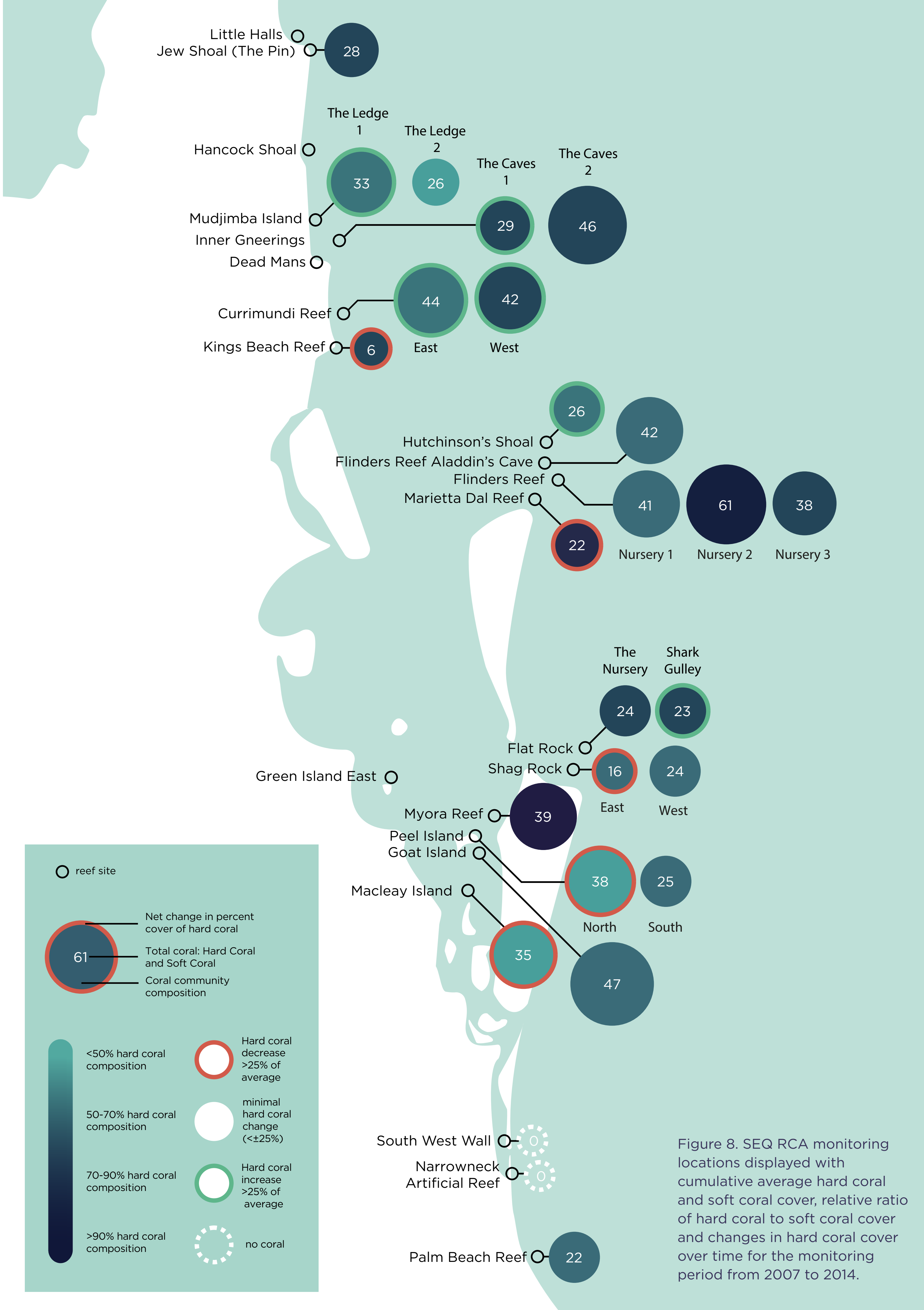



Figure 8. SEQ RCA monitoring locations displayed with cumulative average hard coral and soft coral cover, relative ratio of hard coral to soft coral cover and changes in hard coral cover over time for the monitoring period from 2007 to 2014.

## INVESTIGATING INDICATOR INVERTEBRATES

Indicator invertebrate categories for subtropical SEQ are the same as for tropical RCA. This approach maintains program consistency, with the goal of observing possible geographical range shifts due to climate change or other changing environmental factors.

Data from 2007 to 2014 survey seasons (116 surveys) showed the highest recorded abundance of indicator invertebrates on the Gold Coast (average of 18.5/100m$^2$) (Figure 9). Given the smaller number of monitoring sites on the Gold Coast, additional sites would be useful to expand representation. Despite lower numbers of RCA indicator invertebrates, the Sunshine Coast region is rich in nudibranchs—see Project highlights section.

The Gold Coast had the highest recorded abundance of anemones (7.3/100m$^2$), concentrated at Palm Beach Reef. Currimundi Reef on the Sunshine Coast also hosted concentrated numbers of anemones, along with Flat Rock and Shag Rock in Moreton Bay.

All three indicator sea urchins were recorded in great abundance in the Gold Coast subregion. Pencil urchins (all species) were the most abundant (5.2/100m$^2$), concentrated around Palm Beach Reef. Pencil urchins were not recorded in any notable numbers in other regions. Long-spined urchins were abundant on the Gold Coast (4.9/100m$^2$), but also recorded on some Moreton Bay sites (3.0/100m$^2$), concentrated at Flat Rock, Flinders Reef, Myora Reef and Shag Rock. Collector urchins were recorded in similar abundances on Moreton Bay and Gold Coast sites (0.4 and 0.5/100m$^2$).

Coral-eating *Drupella* snails were found in all regions, but were more abundant on Sunshine Coast (0.9/100m$^2$) and Moreton Bay sites (0.8/100m$^2$). *Drupella* snails appeared to concentrate around certain sites, including Shag Rock, Flinders Reef and Kings Beach. Abundances of banded coral shrimp, giant clams and lobster were relatively low across all subregions (<0.3/100m$^2$).

There have not been photographically confirmed sightings of Reef Check edible sea cucumber species or trochus on SEQ surveys, although there are certainly other species of sea cucumbers in the region. No Crown of Thorn starfish or Triton have been recorded on SEQ surveys, but there are photographic reports of these indicators from local volunteers and partners.

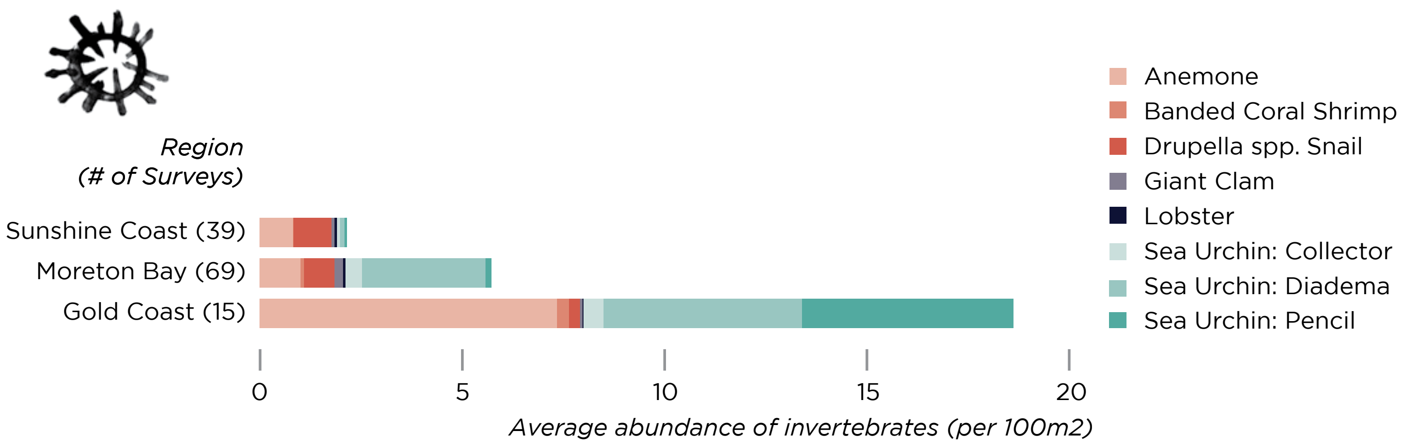



Figure 9. Subregional average abundance of invertebrates (per 100m$^2$) recorded from 116 surveys by Reef Check Australia volunteers from 2007-2014. Anemone data was only collected from 2008. For most data, one standard error was less than 0.3, except for Gold Coast anemones (2.6), *Diadema* urchins (1.0) and pencil urchins (1.2).



## INVESTIGATING INDICATOR FISH

Compared to other core survey components, fewer fish surveys have been conducted in the South East Queensland region on priority sites (n=77) due to low underwater visibility and/or limitations in survey team capacity. The fish data presented for SEQ offers an interesting snapshot (Figure 10), but should be interpreted with caution as the RCA dataset for fish abundance is limited and seasonal variations in this transitional region can be significant (DERM 2012, Beger *et al.* 2014).

RCA indicator fish species monitored in SEQ are based on the same set of indicators for the tropical program. These categories have been maintained for program consistency and with the purpose of observing possible geographical distribution shifts due to climate change or other shifting environmental factors.

Moreton Bay surveys have recorded the highest counts for butterflyfish (2.9/100m$^2$, with highest abundances at Flat Rock and Flinders Reef). Butterflyfish also account for one of the most abundant fish recorded on Gold Coast (2.1/100m$^2$) and Sunshine Coast (1.0/100m$^2$) surveys. Snapper have been found in highest abundances on the Gold Coast (1.9/100m$^2$ recorded on the Gold Coast Seaway and Palm Beach Reef) and were also one of the more abundant fish in Moreton Bay (1.2/100m$^2$) and on the Sunshine Coast (0.8/100m$^2$).

Parrotfish were recorded in Moreton Bay in higher abundances than other subregions (0.7/100m$^2$, with highest abundances at Flat Rock and Flinders Reef). Sweetlips were found in similar abundances across the subregions (0.3/100m$^2$). Moray eels were recorded only on the Sunshine Coast and Gold Coast (0.1/100m$^2$). Grouper have only been recorded in Moreton Bay, but in low abundances (0.05/100m$^2$, n=8 individuals over the course of monitoring) and one on the Sunshine Coast.

The data is comparable to other studies in the SEQ region, documenting relatively low abundances of large, edible reef-associated fishery target species such as snapper and grouper (DeVantier *et al.* 2010). Tropical species of barramundi, bumphead parrotfish, coral trout and Queensland grouper have not been recorded in SEQ. Species range shifts associated with climate change may bring more tropical species to transition areas such as SEQ (Figueira & Booth 2010).

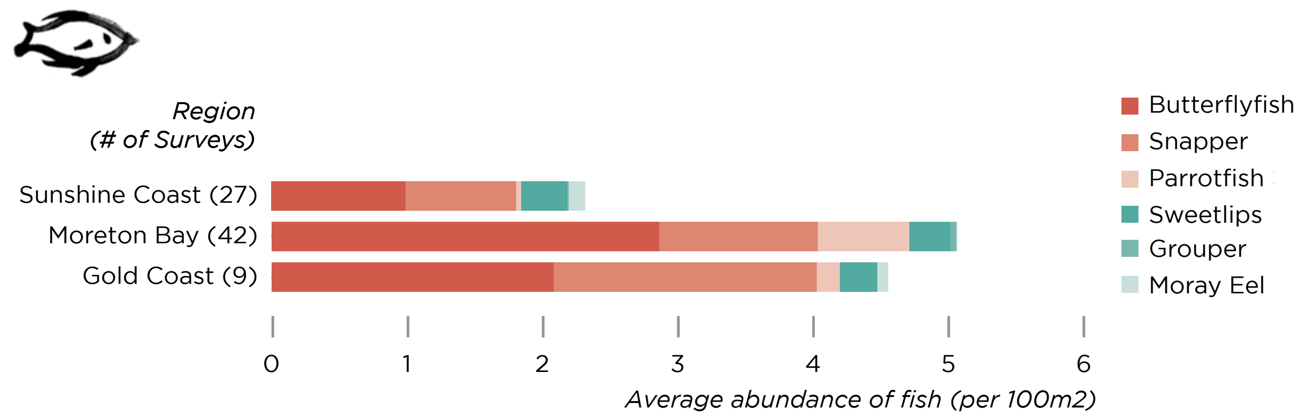



Figure 10. Subregional average abundance of fish (per 100m$^2$) recorded from 77 surveys by Reef Check Australia volunteers from 2007-2014. RCA fish indicators of barramundi, bumphead parrotfish, coral trout, humphead wrasse and Queensland grouper have been excluded from the graph (zero counts, except for three humphead wrasse recorded in 2007 with no photo confirmation). For most data, one standard error was less than 0.3, except for Sunshine Coast snapper (0.5), Gold Coast snapper (0.7) and Gold Coast butterflyfish (0.6).

## INVESTIGATING REEF IMPACTS

Across 121 surveys from 2007 to 2014, subregional reef impact levels were lowest on Sunshine Coast sites (5.6 impacts/100m²). Moreton Bay surveys (7.0/100m²) and Gold Coast surveys (6.4 impacts/100m²) had higher recorded levels of impacts overall, but with varied composition (Figure 11).

Moreton Bay and Sunshine Coast sites had similar levels of coral bleaching (2.0/100m²), although Moreton Bay sites showed slightly higher estimated population-level (3.5% vs 2.3% of the coral population) and colony-level impacts (15.8% vs 10.8%).

Moreton Bay also had higher levels of recorded damage for both anchor damage (0.2/100m²) and physical damage from unknown causes (1.5/100m²). Many inshore coral communities in Moreton Bay are growing on soft or unconsolidated substrate, therefore have a tendency to overturn, particularly in shallow areas (Fellegara & Harrison 2008).

Moreton Bay and the Sunshine Coast had similar levels of coral disease (0.6/100m²). Most of the recorded disease appears to be characteristic of white syndrome and may be Australian Subtropical White Syndrome (Dalton *et al.* 2010, Godwin *et al.* 2012), although further research is required. All three regions showed similar average abundances of *Drupella* snail scars (0.2/100m² respectively). Similar abundances of coral scars from unknown causes (mortality from indistinguishable causes such as former bleaching or disease) were found on the Gold Coast (1.7/100m²), Moreton Bay (1.7/100m²) and the Sunshine Coast (1.5/100m²).

Gold Coast sites had the highest abundances of rubbish (0.8/100m²) and discarded fishing gear (2.7/100m², concentrated at the Gold Coast Seaway). Given that coral-based reef impacts were only relevant to Palm Beach on the Gold Coast, site expansion would be useful for greater understanding of reef health in this subregion.

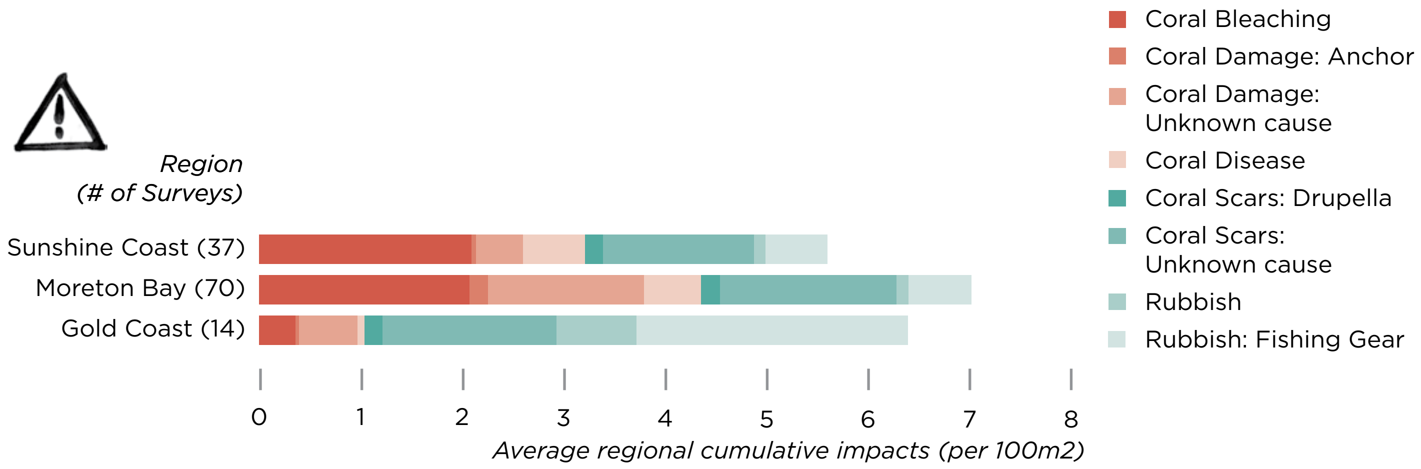



Figure 11. Subregional average abundance of reef health impacts (per 100m²) recorded from 121 surveys by Reef Check Australia volunteers from 2007-2014. For coral related impacts, 7 surveys have been excluded from the Gold Coast dataset, due to no coral at these locations. Other impact categories are pooled for all 14 surveys in the subregion. For most data, one standard error was less than 0.3, except for unknown scars on the Sunshine Coast (0.5) and Gold Coast (0.6).

## Case study 2 SUMMARY & KEY POINTS

Long-term datasets that detect both natural and human-induced changes are critical for reef management. As of 2014, the RCA monitoring program has started to build a substantial and useful data record of subtropical reefs in SEQ, helping to fill a gap in regular monitoring for some of these sites.

The RCA dataset can contribute to a better understanding of the ecology and biology of these subtropical reefs, as well as documenting how these habitats may be changing over time. This is particularly important given the uncertainty around how transitional marine habitats like those of SEQ will be impacted by both regional pressures and changing climate regimes (Munday *et al.* 2009, Figueira & Booth 2010, Graham *et al.* 2010, Lybolt *et al.* 2011).

Beyond the inherent ecological and cultural values, the reefs of SEQ provide important ecosystem services for the region, ranging from supporting habitat for fish to providing tourism value. Implementing best-practice science and management at the regional level will be critical to help these systems build resilience to cope with more global issues such as climate change (Beger *et al.* 2011, Olds *et al.* 2014).

**Key points:**

- The high average coral cover (24%) at RCA SEQ monitoring sites indicates selection for coral-dense locations, but also demonstrates that SEQ subtropical reefs can host substantial coral communities.
- The Sunshine Coast and Moreton Bay subregions hosted similar levels of hard coral cover, while the Gold Coast (Palm Beach Reef) had lower cover. All subregions had similar levels of soft coral and sponges.
- At the subregional level, many reef communities monitored by RCA appear to be relatively stable, with minimal net changes in hard coral cover. The Sunshine Coast subrgion showed an increase in hard coral cover.
- At the site level, some sites appear to be faring better than others over time. Large changes in hard coral cover were obeserved between 2007 -2014, with seven sites increasing by more than 25%, and six sites decreasing by more than 25%. The remaining nine sites reported change of less than 25%.
- The highest abundance of indicator invertebrates was recorded on the Gold Coast. The most abundant invertebrates were anemones and sea urchins. Coral-eating *Drupella* snails were found in all regions, but were more abundant on Sunshine Coast and Moreton Bay sites (perhaps due to greater hard coral cover).
- Butterflyfish and parrotfish were more common on Moreton Bay surveys, while snapper were more common on the Gold Coast. Fish abundance results are comparable to other studies in the SEQ region, documenting what appear to be low abundances of large, edible reef-associated fishery target species.
- Coral impacts were recorded in all three subregions, although the impacts differed in composition. Moreton Bay had higher levels of physical damage to corals, while Gold Coast sites had the higher counts of rubbish and fishing gear. Moreton Bay and Sunshine Coast sites had similar abundances of coral bleaching and coral disease. All subregions had comparable levels of coral scarring from *Drupella* snails and unknown causes.
- The RCA citizen science program is situated to contribute valuable data for making catchment-level management decisions about the unique reef habitats on the doorstep of SEQ, including contributing to monitoring targets for the SEQ Catchment's NRM plan.

Photo by Matt Curnock (Ribbon Reef 3, GBR)

# Case study 3

## A TALE OF TWO REEF SYSTEMS: COMPARING QUEENSLAND'S TROPICAL AND SUBTROPICAL REEFS

When considering Queensland's corals, most of us think of the tropical iconic Great Barrier Reef (GBR). Yet corals extend along the entire state's coast in varying assemblages, abundances and environments. Discussions around species range shifts, reef adaptation and reef health threats have prompted growing research to understand the relationships between tropical and subtropical reefs.

Subtropical reefs, like those found across South East Queensland (SEQ), may have additional natural capacity to handle changing environmental conditions due to their existence in highly-dynamic environments (Fellegara 2008, Dalton & Roff 2013). Subtropical regions also offer habitats for a growing number of tropical marine species (Wallace & Rosen 2006, Hoey *et al.* 2011, Beger *et al.* 2014). Yet, research appears to indicate that subtropical reefs likely offer limited options as a stable refuge for tropical reef communities under pressure from changing environmental conditions (Lybolt *et al.* 2011, Dalton & Roff 2013, Beger *et al.* 2014).

Additional information is needed to understand the relationships between these systems (Beger *et al.* 2011). Trained RCA volunteers have been monitoring the health of coral reefs on the GBR since 2001 and subtropical reefs in SEQ since 2007.

This case study presents a comparison of findings from surveys on the GBR's tropical coral reefs and SEQ's subtropical reefs. The dataset is particularly relevant for investigating transitions from tropical to temperate oceans. Both of these areas are important ecologically, culturally, socially and economically. Beyond that, both regions face growing pressures from human activities, including climate change, making it important for us to understand how these places are changing and the relationship between regions. The opportunity to directly compare findings for these distinct, yet related regions can offer new insights to understanding marine ecology on the Queensland coast.

> *"Reef Check Australia is playing a crucial role locally, regionally and internationally in providing highly useful, quantitative monitoring data on present status and trends of coastal marine ecosystems, with a focus on coral and rocky reefs. RCA is a fine example of 'citizen science' in action and deserves our continued support."*
>
> **Dr. Lyndon DeVantier**
> *Coral Ecologist (2011)*

# A COMPARISON OF QUEENSLAND REEFS

For the purposes of this regional comparison of RCA data, the division for tropical GBR coral reefs and SEQ subtropical rocky reefs was drawn at the southern end of the Great Barrier Reef Marine Park. All sites north of this boundary (including those outside the Marine Park in the Coral Sea) were identified as GBR and sites southwards were identified as SEQ, including the Fraser Coast.

The GBR is a tropical coral reef icon. For millions of years, corals have been secreting limestone to build the largest struture made by living organism on the planet. Reef-building corals grow most easily in relatively warm, shallow, clear waters with low nutrients. The complex limestone matrix they construct creates habitats for a diverse assemblage of marine life.

The subtropical reefs found in SEQ are considered to exist on the marginal edge of coral growth (Perry & Larcombe, 2003). The corals here are generally limited from building reef structures by environmental factors such as light, temperature, water chemistry and/or turbidity (Fellegara & Harrison, 2008, Kleypas, McManus & Menez 1999), yet they host a mix of tropical, subtropical and cool water marine species (Harriott *et al.* 1999, Beger *et al.* 2014).

Beyond natural environmental differences, management of RCA survey sites differ in the two regions. "Green" zones (no-take Marine National Park) accounted for 70% of GBR monitoring sites (with another 6% in scientific zones), and 28% of SEQ monitoring sites. This demonstrates a bias towards green zone areas in RCA monitoring sites, as 33% of the Great Barrier Reef Marine Park is in Green zones.

SEQ also encompasses several marine parks, including Great Sandy Marine Park (where 57% of RCA sites are in green zones) and Moreton Bay Marine Park (with 33% of RCA sites in green zones).

# SEQ & GBR REEF COMPOSITION

***(428 surveys GBR, 128 SEQ)***

Pooled data showed higher average coral cover (37%, ranging from 0 to 83%) on tropical coral reefs of the GBR than the subtropical rocky reefs of SEQ (20%, ranging from 0 to 68%) (Figure 12). While the GBR's tropical coral reefs host greater coral species diversity and have the capacity to build reef structure (Harriot & Banks 2002), there are areas in SEQ with substantial and comparable hard coral cover (Harrison *et al.* 1998, Beger *et al.* 2014, Sommer *et al.* 2014). Both regions showed similar soft coral cover (9% GBR and 10% SEQ). In both regions, sites were preferentially selected for locations with initial high coral cover. SEQ sites had a higher cover of rock (36%) compared to GBR sites (28%), and lower cover of coralline algae (<1% SEQ compared to 2% GBR), which is consistent with other latitudinal reef studies along the East Australian coast (Harriott & Banks 2002, Dalton & Roff 2013).

SEQ reefs had higher cover of sponge (4% vs 1% GBR) and the Reef Check non-target "Other" category (7% vs 2% GBR), which includes sessile living organisms such as anemones and ascidians. This corresponds with other studies reporting higher cover of non-coral benthic cover in subtropical and temperate coral communities (Harriott & Banks 1999, DeVantier *et al.* 2010). SEQ also had higher overall levels of algae, both average benthic cover of "Nutrient Indicator Algae" (7% vs 5% GBR) and average counts of macroalgae (average 2.8 counts/ 100m$^2$ compared to 0.8 counts/100m$^2$ on the GBR). Higher abundance of macrolagae appears be common on subtropical reefs (Harriott & Banks 2002) and may be a natural state of these systems compared to tropical communities. There are also studies indicating that algae and benthic invertebrates influence coral cover dynamics on subtropical reefs (Hoey *et al.* 2011, Dalton & Roff 2013)

Both regions had low levels of bleached hard and soft coral (<1%) and recently killed coral (1% cover on the GBR, <1% in SEQ). This result indicates that there were no major coral mortality events in either region that were captured in RCA survey data.

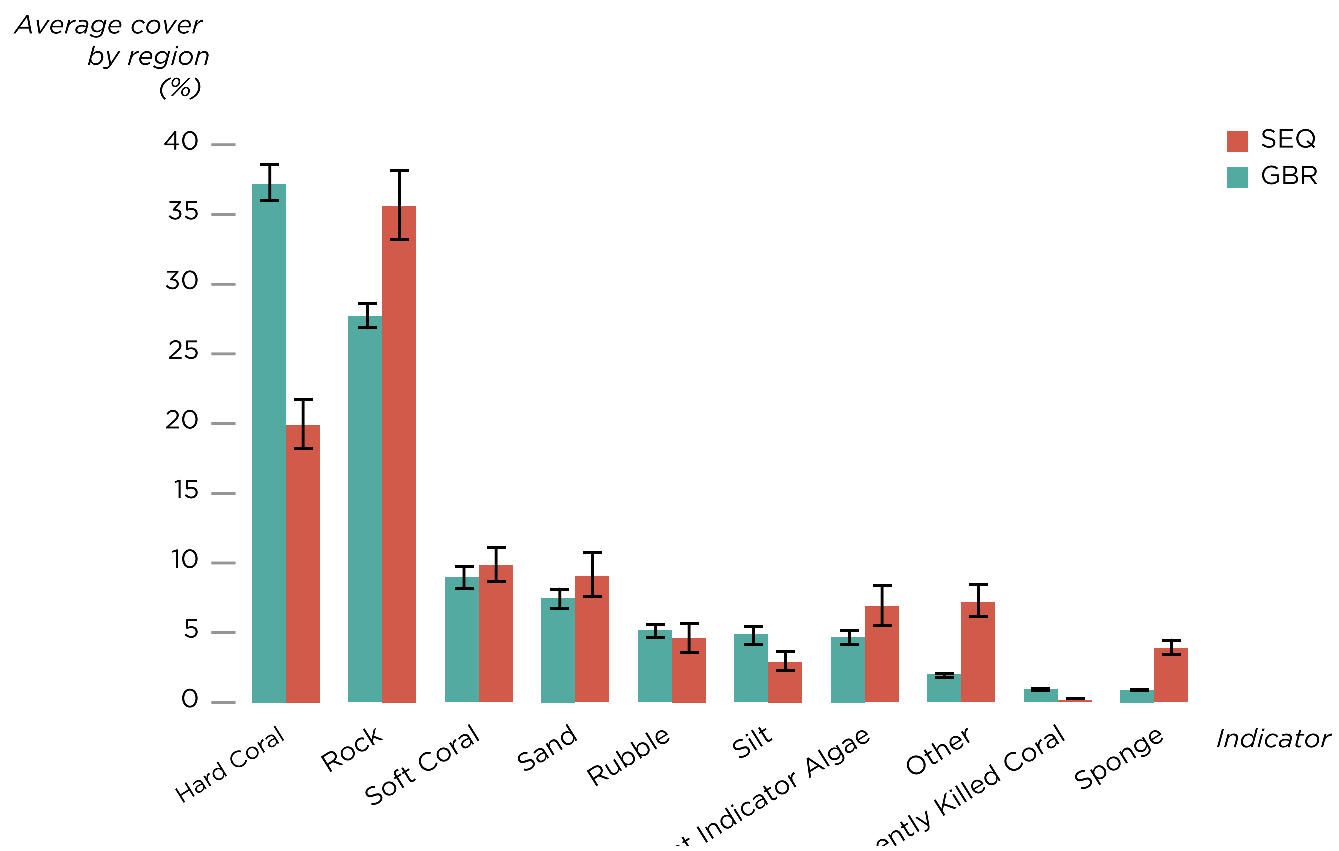



Figure 12. Pooled regional data from 428 GBR surveys (within Great Barrier Reef Marine Park and outer Coral Sea) and 128 SEQ surveys (all sites south of southern border including Woongara Coast) for 2001 to 2013. Error bars represent one standard error of the mean. Nutrient indicator algae is classified as any fleshy algae that is not identified as one of RCA's seasonal macroalgae.

# COMPARISON OF REEF IMPACTS

***(396 surveys GBR, 124 SEQ)***

Visual reef impact surveys indicated differing reef health threats and severities for the two regions (Figure 13). On average, a higher abundance of coral damage was recorded on GBR surveys (average of 1.7/100m$^2$, compared to 1.0/100m$^2$ SEQ) and coral damage was recorded more frequently on GBR surveys (80% GBR, 68% SEQ). *Drupella* snail scars were recorded slightly more frequently on GBR surveys (33% of surveys) compared to SEQ (26%) and found in higher average abundances (0.5/100m$^2$ compared to 0.1/100m$^2$).

SEQ had a notably higher average of fishing gear than the GBR (average of 0.9/100m$^2$ per survey compared to 0.02/100m$^2$). Fishing gear was recorded more frequently on SEQ surveys (59% of surveys, compared to 5% GBR). Some of this discrepancy is likely due to the high number of tourism and green zone locations included in RCA's GBR sites (70% of sites are in green zones on the GBR versus 28% in SEQ). Fishing gear findings are consistent with other studies documenting fishing gear on Sunshine Coast surveys (DeVantier *et al.* 2010). The frequency and abundance of "general" rubbish was slightly higher in SEQ (found on 26% of sites in average abundance of 0.2/100m$^2$ compared to 20% sites in abundance of 0.1/100m$^2$ on the GBR). In SEQ, 22% of sites had more than five pieces of rubbish recorded on a survey (400m$^2$).

**Reef Impacts continued...**

The average abundance of unknown coral scars was similar for the regions (1.5/100m² in GBR, 1.4/100m² in SEQ), as was frequency of sighting (67% and 64% respectively). Coral bleaching levels were comparable for the regions, found slightly more frequently on GBR sites (70% compared to 62% SEQ surveys), but with an average of 2% of the coral population impacted in both regions.

The average abundance of coral disease was slightly higher in SEQ (0.5/100m², impacting an estimated 1.5% of the population, compared to 0.4/100m², impacting an estimated 0.5% of the population on GBR sites) and recorded more frequently (46%, compared to 28% of GBR surveys). Comparing data from 2009 onwards, GBR sites show higher average levels of coral disease (0.9/100m², impacting an estimated 0.8% of the population and recorded on 62% of surveys (compared to SEQ 0.6/100m², impacting an estimated 1.7% of the population found on 50% of surveys).

There are several potential explanations around findings.and coral disease relationships. GBR survey records date back longer than those for SEQ (2001 compared to 2007 for SEQ), therefore, results could support other studies indicating increased levels of coral disease over time (Harvell *et al.* 1999). Coral disease has been associated with reef stressors such as extreme temperatures and sedimentation (Bruno *et al.* 2007, Pollock *et al.* 2014), which could be more severe in some of the SEQ regions surveyed.

Changing RCA methodologies may have also influenced estimates, as coral disease data collection protocols changed in 2009 from estimates of percent population impacted to counts of impacted colonies. For data pre 2009, counts have been estimated based on coral population and for 2009 onwards, percent of the coral population impacted by coral disease was estimated.

These results may also reflect increased knowledge and capacity for identifying coral disease from improved knowledge in this expanding field of study in addion to evolving volunteer training materials. New sites have also been added in both locations, including GBR locations with higher levels of coral disease. SEQ consistently showed higher estimated population level impacts of coral disease, which likely reflects the similar average disease counts, but relatively higher impact due to lower coral cover in this region.

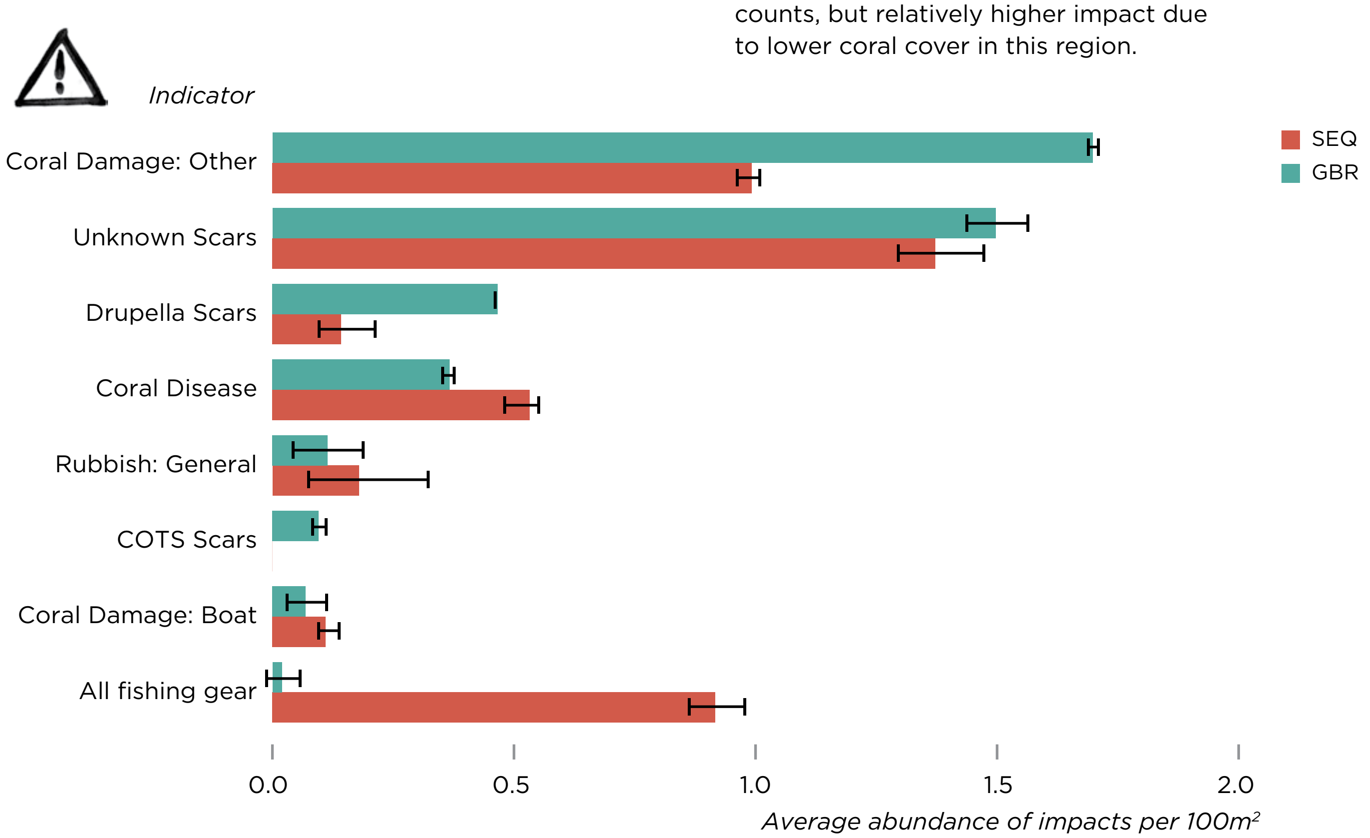



Figure 13. Regional average abundance of reef impacts (per 100m²) recorded from 397 surveys on the GBR and 123 surveys in SEQ by Reef Check Australia volunteers from 2007 to 2013. Error bars represent one standard error of the mean.



## COMPARISON OF INDICATOR INVERTEBRATES

***(397 GBR surveys, 119 SEQ)***

GBR reefs had notably higher average abundances of giant clams (3.2/100m² compared to 0.1/100m² SEQ), and giant clams were more frequently recorded on surveys (85% GBR, 26% SEQ) (Figure 14). These results are not surprising, given that the SEQ region is near the southern range extent for this group (Smith 2011).

The three RCA indicator sea cucumbers were also recorded in higher abundance (0.4/100m²) and frequency on the GBR (33% of surveys compared to 4% SEQ, only 5 recorded all 2008 or earlier). *Drupella* snails were recorded in similar frequencies on GBR and SEQ (44% and 41% of surveys), but in higher abundance on the GBR (0.9/100m² compared to 0.7/100m² in SEQ). These results may be partially attributable to higher overall coral cover on the GBR.

SEQ reefs had an overall higher average abundance of the three indicator urchins. SEQ sites showed slightly higher abundances of long-spined urchins (2.1 compared to 1.8/100m² GBR, 45% of sites SEQ compared to 31% GBR), but only notably higher abundances of pencil urchins (0.8 compared to 0.03/100m² GBR, recorded on 17% of sites SEQ compared to 5% GBR) and collector urchins (0.3/100m² compared to 0.01/100m² GBR, recorded on 14% of sites compared to 2%). Anemones were also found in higher abundances in SEQ (1.37 compared to 0.17/100m² GBR) and on more surveys (39% compared to 35%).

Both regions showed low abundance of banded coral shrimp (0.01/100m² GBR and 0.09/100m² SEQ) and lobster (0.02/100m² GBR and 0.07/100m² SEQ). Trochus were found in average abundances of 0.08/100m² across GBR sites. Low abundance of Crown of Thorns Starfish (<0.07/100m²) and triton (0.01/100m²) have been recorded on GBR sites and these indicators have not been recorded on SEQ surveys.

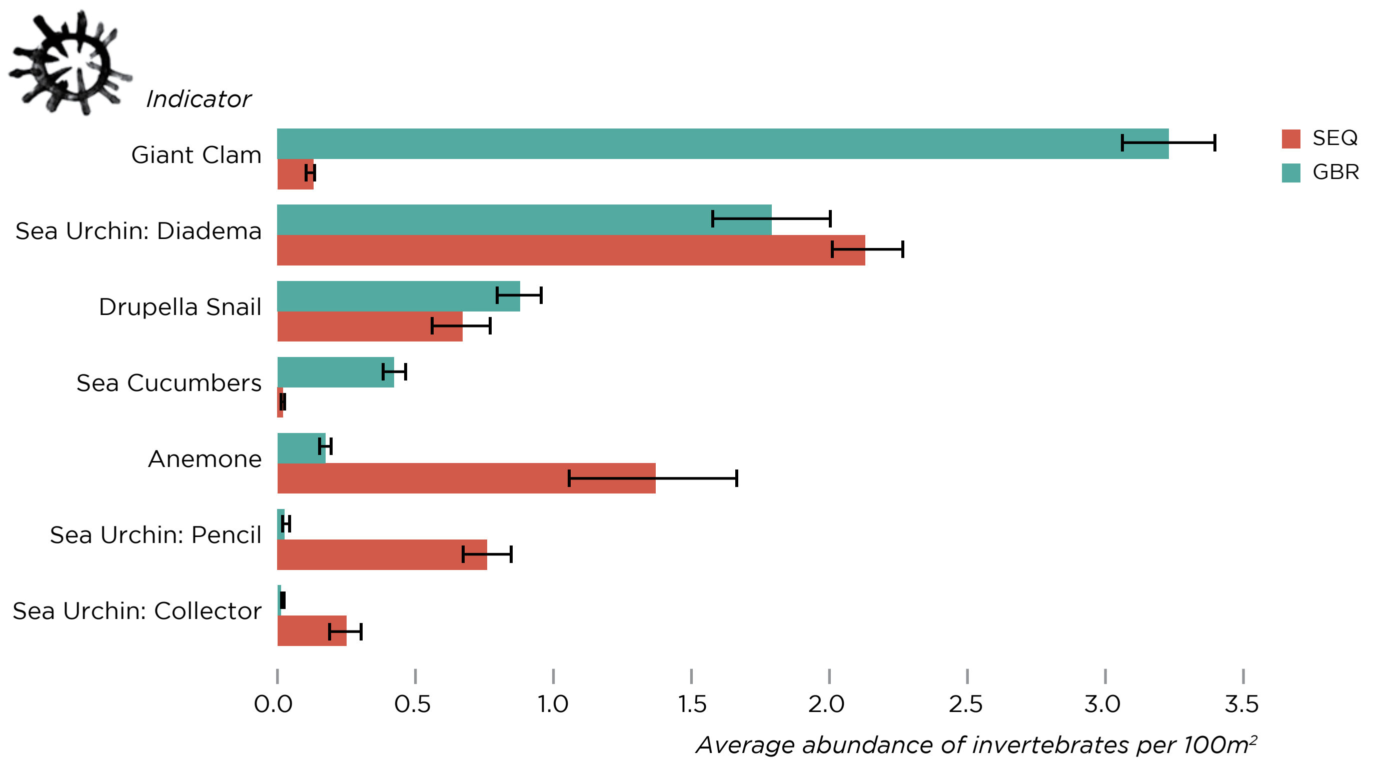



Figure 14. Subregional average abundance of invertebrates (per 100m²) recorded from 398 surveys on the GBR and 188 surveys in SEQ by Reef Check Australia volunteers from 2007 to 2013. Error bars represent one standard error of the mean. Anemone data was only collected from 2008. 45 reef sites surveyed around the Palm Island group (2005-2006 surveys) were removed from giant clam summary results due to extreme giant clam numbers from historical clam farming projects (average 9/100m²). Trochus, Crown of Thorns Starfish, lobster, banded coral shrimp and triton were recorded in abundances of less than 0.1/100m² and are not shown on the graph.

## COMPARISON OF INDICATOR FISH

***(221 surveys GBR, 69 SEQ)***

Butterflyfish, snapper and parrotfish (excluding bumphead parrotfish) were the most commonly recorded fish for both the GBR and SEQ regions (Figure 15). Butterflyfish were recorded in greater average abundance on the GBR (3.6/100m$^2$ compared to 2.0/100m$^2$ SEQ) and in greater frequency (73% of surveys compared to 65%). Parrotfish were also recorded in greater abundances on GBR sites (2.2/100m$^2$ compared to 0.4/100m$^2$) and found more frequently on surveys (43% compared to 6%). Higher abundances of herbivorous fish, such as parrotfish, on tropical reefs have been found in other studies (Hoey *et al.* 2011).

Snapper showed more similarities across the regions, with average abundances of 1.1/100m$^2$ on GBR sites and 1.2/100m$^2$ on SEQ sites (57% and 52% of surveys respectively). Sweetlips were also found in similar abundances (0.2/100m$^2$ GBR and 0.3/100m$^2$ SEQ), but were recorded more frequently on SEQ surveys (41% of surveys compared to 23% GBR).

Barramundi cod, bumphead parrotfish, coral trout and Queensland grouper were only found on GBR surveys, but in low abundances (<0.1/100m$^2$) and infrequently sighted (ranging from 1% of surveys for Queensland grouper to 33% of surveys for coral trout).

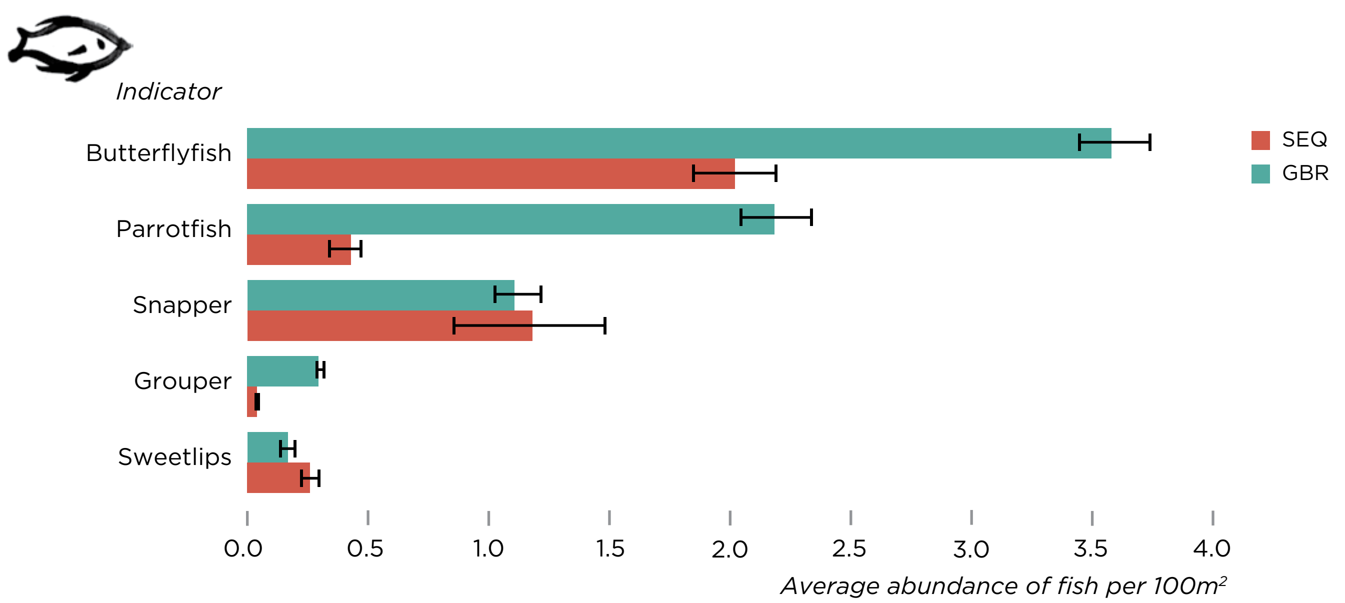



Figure 15. Regional average abundance of fish (per 100m$^2$) recorded from 221 surveys on the GBR and 69 surveys in SEQ by Reef Check Australia volunteers from 2007 to 2013. Error bars represent one standard error of the mean. Snapper excludes the outlier of a single school of 1,300 snapper recorded on Opal Reef, GBR in 2009. Reef Check indicator fish with cumulative averages of less than 0.1/100m$^2$ were not displayed on the graph (this includes barramundi cod, bumphead parrotfish, humphead wrasse, moray eel and Queensland grouper). Coral Trout and Queensland grouper were not added to surveys until 2008 and average abundances are based on surveys from 2008 to 2013.



## Case study 3 SUMMARY & KEY POINTS

Results from pooled regional surveys on the GBR's tropical coral reefs and SEQ's subtropical reefs showed differences in substrate composition, abundance of fish and invertebrate communities and reef impacts. These results demonstrate there are considerable, yet compositionally different coral communities in subtropical locations, which is consistent with other studies (Harrison *et al.* 1998, Harriott & Banks 2002, Sommer *et al.* 2014, Dalton & Roff 2013).

RCA's volunteer reef monitoring program supports understanding the complex relationships between tropical and subtropical reef communities. The broad data collected through the RCA monitoring protocols at sites along the Queensland coast has revealed findings that reiterate the call for additional research (Beger *et al.* 2011). This citizen scence dataset supplements more detailed studies about reef composition and biodiversity, as well as documenting reef threats to inform science and management decisions.

Given SEQ's unique position as habitat for tropical, subtropical and temperate marine species, it can serve as a stepping stone for tropical species' range shifts due to climate and other environmental changes (Beger *et al.* 2014, Sommer *et al.* 2014). This long-term set of data is valuable to support monitoring of future changes.

**Key points:**

- GBR sites hosted higher average hard coral cover than SEQ, but soft coral cover was similar for the regions. Rock and non-coral living benthic categories such as sponge and ascidians were higher in SEQ. Subtropical reefs of SEQ also hosted more substantial algae communities.
- GBR surveys recorded higher average abundances of giant clams, the three RCA indicator sea cucumbers and *Drupella* snails. SEQ surveys recorded higher average abundances of the three RCA indicator urchins, as well as anemones. Both regions showed low abundance of banded coral shrimp and lobster. COTS and triton were only recorded on GBR surveys.
- Butterflyfish, snapper and parrotfish were the most commonly recorded fish for both the GBR and SEQ regions. However, butterflyfish and parrotfish were recorded in greater abundances on GBR surveys. Snapper and sweetlips showed similar abundances across the regions. Groupers were found in greater abundance on GBR surveys. Barramundi cod, bumphead parrotfish, coral trout and Queensland grouper were only found on GBR surveys, but in low abundances.
- The differences in mobile invertebrate and fish regional communities was expected, considering many of the selected RCA indicators are tropical. RCA programs can also offer a tool for monitoring species range shifts from tropical to subtropical habitats.
- On average, a higher abundance of coral damage, as well as scars from *Drupella* snail and COTS were recorded on GBR surveys. SEQ had a notably higher average of fishing gear, although results are influenced by the high number of tourism and green zone locations included in RCA's GBR sites. The average abundance of coral disease was slightly higher in SEQ and this trend is worthy of further investigation. The average abundance of coral scars from unknown causes was a notable impact type for both regions. Similar low average levels of coral bleaching were recorded in both regions.
- There are some useful discussion topics resulting from regional comparisons of RCA surveys along the Queensland coast. Reef impact data indicated varying pressures from environmental and human use factors, which can be beneficial for gauging relevant community education and reef management considerations.

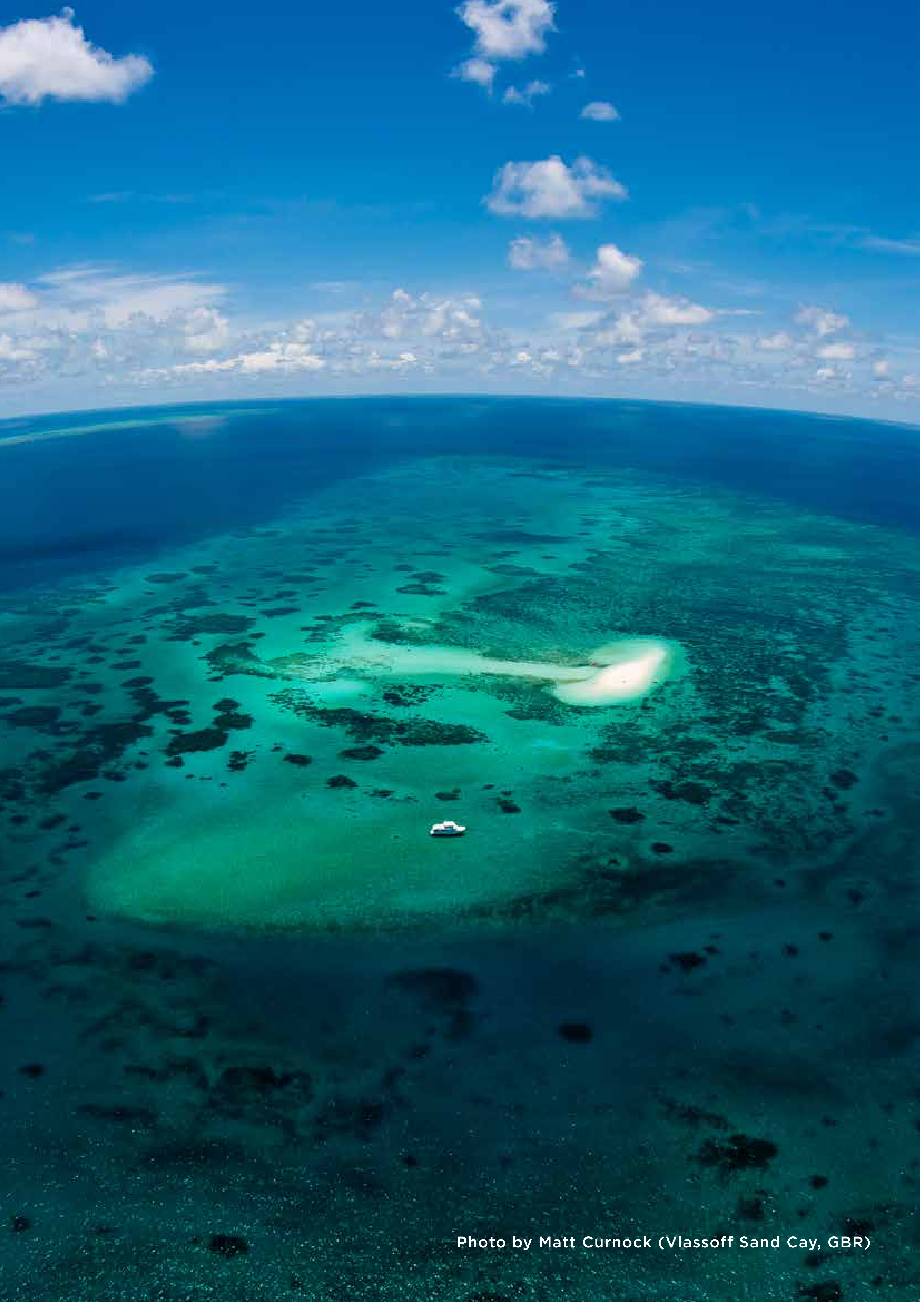


Photo by Matt Curnock (Vlassoff Sand Cay, GBR)

# Case study 4

## A GLOBAL CONTEXT FOR AUSTRALIAN REEFS: COMPARING REEF HEALTH TRENDS USING THE REEF CHECK SURVEY METHOD

While reefs cover less than 1% of the planet, they are widely dispersed and highly variable, making globally standardised monitoring a challenging task. Australia's waters are home to more coral reefs than any other country, accounting for an estimated 17% of global reefs (Burke *et al.* 2011). The majority of Australia's substantial reef habitat is within the Great Barrier Reef (GBR).

This case study presents a snapshot of data from almost 9,000 surveys on more than 2,000 monitoring sites around the world. Reef Check surveys are a helpful tool to build knowledge about how Australian reefs compare to those around the world in order to contribute to global health assessment and knowledge base. International comparisons are particularly important given the ever-growing body of science documenting reef decline and increasing reef threats around the world (Hoegh-Guldberg 1999, Hughes *et al.* 2003, Bruno & Selig 2007, Burke *et al.* 2011). Global data sets offer the potential to explore the outcomes of management actions such as marine protected areas or tourism regulation in light of different ecological, social and economic contexts (Selig & Bruno 2010, Burke *et al.* 2011). Additional data beyond the standard metric of hard coral cover can be important for understanding reef health (Bruno & Selig 2007) and Reef Check offers datasets on abundances of invertebrates and fish, as well as reef health impacts.

Part of the power of Reef Check data is in the consistent standard protocols that allows for local and global comparisons (Hodgson 1999, Hill & Wilkinson 2004). The international datasets collected by Reef Check across sites in the Caribbean and the IndoPacific allow for comparison of ten global substrate categories, seven invertebrate categories, nine fish categories and six reef impact types. Reef Check's global method, supporting trained volunteers to collect standardised data for rapid reef health assessment is unique in the world.  Reef tourism locations are heavily represented in the data set, and thus it provides a more focused perspective of reef health than other monitoring programs. The specially-selected simple, robust monitoring categories facilitate the role of citizen scientists to meaningfully contribute to documenting reef health (Hodgson 1999).

Reef Check findings can help to generate discussion around how Australian monitoring sites compare to their Caribbean and IndoPacific counterparts. The study also highlights the role that citizen science can play in contributing to critical monitoring for improved knowledge for reef management.

> *Reef Check teams often get to places that government officials cannot. This increases our coverage and detail in global reports that decision makers are using to set policy for the management of reefs around the world.*
>
> **Dr. Clive Wilkinson**
> *Global Co-ordinator Global Coral Reef Monitoring Network (2009)*

# SETTING THE BASELINE

The first global Reef Check assessment took place in 1997 (Hodgson 1999). From 1997 to 2001 more than 1,500 reefs were surveyed across the Caribbean and IndoPacific. Hard coral cover, a common indicator for reef health, averaged 31% across surveyed sites, with mean hard coral cover of 26% across Caribbean sites and 35% across the IndoPacific (Hodgson & Liebler 2002). In that study, low levels of edible and collectible indicator fish and invertebrates were recorded at most sites, providing some early evidence of over-harvesting and ecological imbalances on a global scale. For this reason, the 2002 publication was entitled "*The Global Coral Reef Crisis — Trends and Solutions*" and was presented at the World Summit on Sustainable Development in Johannesburg that year. Numerous studies have now documented the general decline of reef health around the world (Harvell *et al.* 1999, Hughes *et al.* 2003, Selig & Bruno 2007, Eriksson & Byrne 2013). Threats to reef health (such as ocean acidification, sedimentation, extreme temperatures, over-harvesting etc.) are forecast to continue increasing (Burke *et al.* 2011).

Sixteen years after the launch of Reef Check, a review of data from 8,745 surveys on 3,724 reef sites in more than 94 countries showed interesting trends on varying scales (1,838 surveys in the Caribbean and 6,907 surveys in the IndoPacific, including 678 surveys from Australia).

Reef Check monitoring sites are selected to align with research, community and management criteria within each region. Therefore, while global comparisons offer some interesting insights, they must be interpreted within the limitations of the scientific design, and are affected by both how and why teams select sites, as well as how often sites are surveyed.

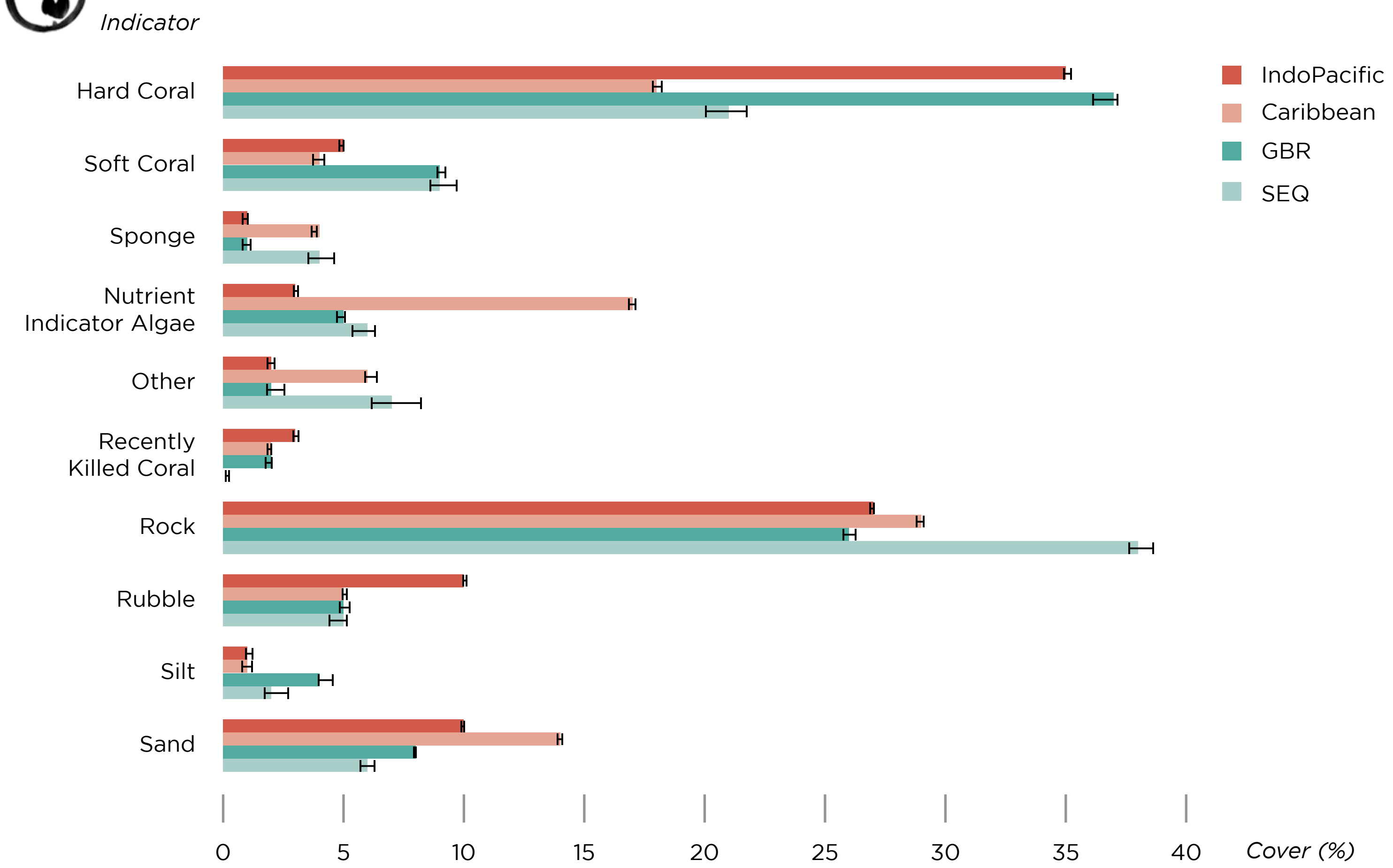



Figure 16. Pooled regional data for 4 major global Reef Check regions from 8,745 surveys, showing average benthic cover of the 10 main Reef Check Global substrate categories for data collected from 1997 to 2013. Error bars represent one standard error of the mean. Note that the y axis scale was only represented to 40% for ease of visualization.



# COMPARISONS ACROSS THE WORLD, COUNTRIES AND REGIONS

Data was pooled for two main global regions (IndoPacific and Caribbean), with a focus on Australian comparisons. Therefore, Australia has been separated into the GBR and SEQ regions, as there were some clear differences between these two regions that warranted a separate assessment.

Average hard coral cover across GBR sites (37%) was comparable to the broader IndoPacific region (34%) (Figure 16). Within Australia, there was a notable difference in coral cover between the GBR (37%) and SEQ (21%). Of note, hard coral cover in the SEQ subtropical reef region was comparable to hard coral cover in the Caribbean (21%). Soft coral cover was higher in Australia (9% both in SEQ and the GBR) than the rest of the IndoPacific (5%) and the Caribbean (4%). Sponge cover across all regions was relatively low (ranging from 1% average cover in the IndoPacific and the GBR to 4% in the Caribbean and SEQ). There were trends with regards to the Reef Check non-target "other" category, which includes benthic organisms such as anemones, corallimorphs and ascidians. South East Queensland (7%) and the Caribbean (6%) had higher average percent cover of "other" than the GBR (3%) and IndoPacific (2%).

The Caribbean had the highest percent cover of nutrient indicator algae (17%). Australia had just slightly higher overall nutrient indicator algae levels (5%) than the IndoPacific (3%), with higher levels in SEQ (6%). Nutrient indicator algae is any fleshy algae (for RCA it excludes seasonal macroalgae), which can be a sign of high nutrient loading and low numbers of herbivores, although some algae on reefs are an essential part of the ecosystem. Higher levels of silt were recorded on Australian sites (3% SEQ, 4% GBR) than the IndoPacific (1%). Recently killed coral across all regions amounted to less than 3% cover.

Lower hard coral cover and high levels of nutrient indicator algae in the Caribbean have been attributed to the die off of long-spined *Diadema* sea urchins in the 1980s, as well as overfishing of herbivorous fish (Hughes *et al.* 1987, Mumby *et al.* 2006). The lower hard coral cover in the SEQ is likely a result of the subtropical location, being less favorable for reef-building corals (Kleypas *et al.* 1999). The IndoPacific is acknowledged as the centre of biodiversity for corals (Roberts *et al.* 2002) and encompasses an estimated 75% of global reefs (Bruno & Selig 2007). The higher coral cover in the broader IndoPacific and on the GBR (compared to SEQ and the Caribbean) can likely be attributed to these factors.

The overall average global hard coral cover across all Reef Check monitoring sites from 1996-2013 was 28%, slightly down from the 2002 Reef Check report of 31% cover. While the global coral cover average may seem low, only 91 of approximately 3,800 reefs (2%) surveyed by Reef Check had more than 70% cover, and the maximum coverage was 85%. These findings are comparable to a comprehensive assessment of IndoPacific reef data from 1968 to 2004 (n=6,001 surveys from eight monitoring programs, including 1,501 Reef Check surveys) which showed average hard coral cover of 22%, with 6% of surveyed reefs hosting hard coral cover of greater than 60% (Bruno & Selig 2007).

Average hard coral cover across sites reflects Reef Check's protocol of selecting monitoring sites with high coral cover. Reef Check's protocols and reliance on the recreational dive sector means that surveys have historically been established on the best quality dive sites in each area, often with a lot of coral. Therefore, the coral estimates presented here may be higher than other published estimates based on representative samples, regardless of initial reef state.

This report does not investigate the role that marine protected area (MPA) status may play in the results. Site information reported to Reef Check International showed that 69% of Caribbean monitoring sites had some level of protection, compared to 43% of IndoPacific sites, 72% GBR and 40% SEQ. MPAs have varying levels of excluded activities, degrees of effectiveness and enforcement. The 2011 Reefs at Risk analysis of global reef threats documented that 27% of global reefs were within MPAs (Burke *et al.* 2011). However, only 6% of MPAs were regarded as "effectively managed" and another 13% of reefs were rated as "partially effective" (Burke et al. 2011).

# DOCUMENTING GLOBAL CORAL CHANGE

Compiling a global dataset originating from hundreds of citizen science teams in dozens of countries is an enormous task. To reduce the effect of irregular site visits and the addition of new sites, long-term hard coral data was analysed by calculating the net change in percent cover of hard coral on sites with consecutive years of data (Figure 17). On sites with skipped years of surveys, a linear interpolation for the deviation in the skipped years was used.

Overall, most year to year changes in hard coral cover were less than 10% across the IndoPacific, Australia (GBR and SEQ) and the Caribbean, but some subtle trends were evident. Both the IndoPacific and Caribbean sites seemed to indicate a decline in hard coral cover 1997/98, which would correspond with global cover losses from the major coral bleaching event (Wilkinson 2000, Hodgson & Liebeler 2002, Bruno & Selig 2007).

The main differences between regions were that many inter-annual changes were positive in Australia and negative in the Caribbean. The tendency for consecutive years of increase may suggest that GBR and IndoPacific sites tended to recover following disturbance (Done *et al.* 2010, Osborne *et al.* 2011, Graham *et al.* 2010), whereas consecutive years of decline in Caribbean sites suggest a lack of resilience (Hughes *et al.* 1987, Gardner *et al.* 2003, Mumby *et al.* 2006). However, since 2010, pooled data for GBR sites have shown a decreasing trend, which corresponds with other studies (Osborne *et al.* 2011, De'ath *et al.* 2012). The Australian Reef Check organisation was not officially established until 2004, therefore in prior years the small sample sizes may not be sufficient to reflect regional changes in coral cover. The low sample sizes in 2010 to 2012 are the result of limited program resources and again draw attention to the importance of sustainable funding for citizen science initiatives.

Data for the SEQ region of Australia are presented separately, as they are a characteristically unique subtropical coral community. The SEQ program was started in Australia in 2007, and therefore has a shorter dataset compared to the GBR.

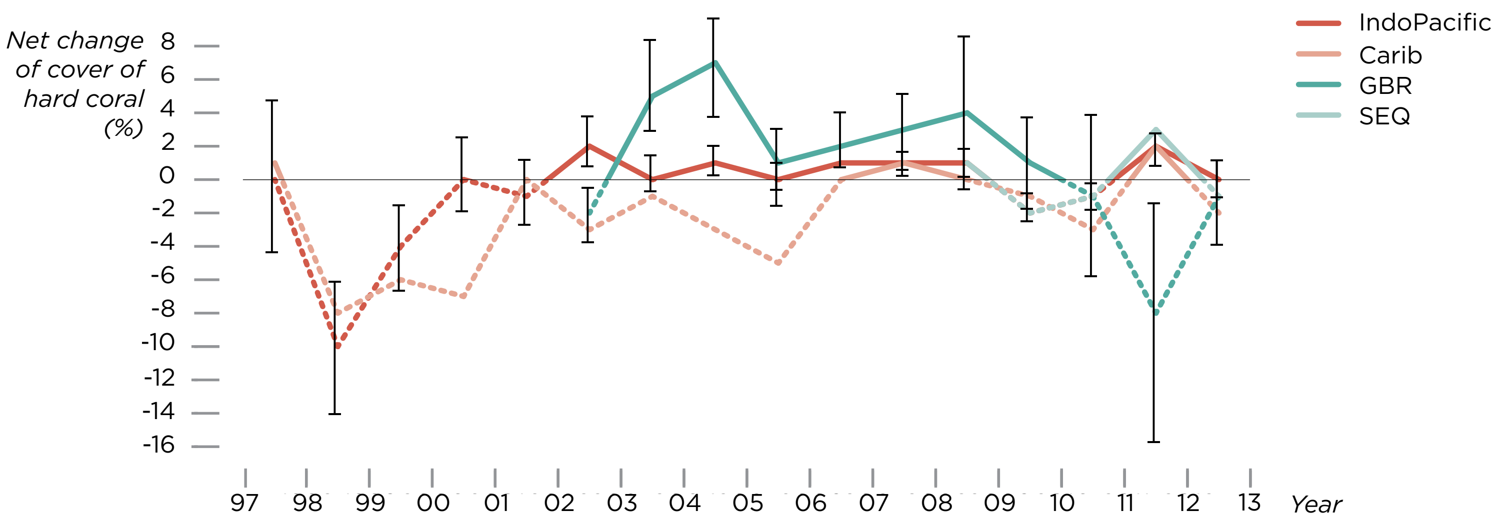



Figure 17. Pooled regional data showing net change in average hard coral cover for four major Reef Check regions for surveys conducted from 1997 to 2013. Annual positive net growth is shown as solid lines and net declines are shown as dashed lines. GBR trends prior to 2003 are should be interpreted with caution due to low numbers of surveys. SEQ trends prior to 2008 are not displayed on the graph due to low numbers of surveys. The numbers underneath the graph represent the number of regional sites with consecutive surveys used for calculations. Many more surveys were undertaken that are not shown here because they were not in the same locations in consecutive years.



# COUNTING ON INDICATOR INVERTEBRATES

There are seven common invertebrate indicators and nine fish indicators used across the global program. These have been selected for broad distributions and ease of identification by volunteers, as well as for their ecological and economic importance. This report presents data from 8,544 invertebrate surveys conducted from 2001 to 2013, encompassing 1,866 surveys in the Caribbean and 6,678 in the IndoPacific (with 648 from Australia) (Figure 18).

The average abundance of long-spine (*Diadema*) urchins for the IndoPacific ($19.7/100m^2$) was higher than their Caribbean counterparts ($11.5/100m^2$) and much higher than Australian averages for the GBR ($1.8/100m^2$) and SEQ ($2.2/100m^2$). Long-spine urchins were found on more IndoPacific sites (69%) and Caribbean sites (66%) than in Australia (average 40%). The abundances of Caribbean *Diadema* were comparable with other studies (Kramer 2003, Creary *et al.* in Wilkinson 2008), but given the mass mortality of *Diadema* in the Caribbean in 1983/84 (Hughes 1985), the expectation was abundances would be lower here than other regions.

The lower abundance of *Diadema* in Australia may be related to different species communities and grazing dynamics on Australian reefs, with herbivorous fish likely playing a key role (Sammarco 1985, Cheal *et al.* 2010). The abundances of *Diadema* in Australia may also relate to highly nocturnal feeding patterns, which results in underestimations of individuals during daytime surveys, even with careful search patterns (Young & Bellwood 2011). This tendency may be more pronounced on reefs with relatively intact predator communities, compared to disrupted reefs where *Diadema* can forage during the day with limited threat from predators (Cowen 1983, McClanahan & Muthiga 1988). The first set of global Reef Check surveys in 1997 (n=312 surveys) recorded zero counts of *Diadema* at more than 40% of both IndoPacific and Caribbean sites (Hodgson 1999).

Abundances of giant clams were comparable for the IndoPacific and Great Barrier Reef (found in abundances of $5.3/100m^2$ and $5.6/100m^2$, recorded on 70% of IndoPacific sites and 84% of GBR sites). Generally, heavy harvesting pressure has influenced IndoPacific giant clam populations and local extinctions have been documented (Teitelbaum 2008). Previous studies in the IndoPacific have found clam densities to be as high as $3\text{-}19/100m^2$ in protected areas (Tan *et al.* 1998), with other subregions as low as 0.1 to $0.3/100m^2$ in areas with heavy fishing pressure (Alcala 1986, Guest *et al.* 2008). Giant clams are not found in the Caribbean.

Pencil urchin data showed similar abundances for the Caribbean ($1.2/100m^2$) and SEQ ($1.0/100m^2$) and abundances were much lower for the IndoPacific and GBR. Crown of Thorns Starfish (COTS), lobster and triton were found in relatively low abundances (less than $0.2/100m^2$) across the global regions. The average abundance of COTS was lower on Great Barrier Reef sites ($0.1/100m^2$) than the IndoPacific ($0.18/100m^2$) and found on fewer sites (11% on the GBR compared to 26% of IndoPacific sites). This is an indication that RCA monitoring sites have not had major COTS impacts during survey periods, which may be partially attributable to COTS management by dive tourism operators.

The Caribbean had higher average abundances of banded coral shrimp ($0.5/100m^2$, found on 44% of sites compared to 18% IndoPacific) and lobster (0.2/100m, found on 38% of sites compared to 12% of sites in the IndoPacific and 14% in Australia). Triton were low across all regions ($0.04/100m^2$ or less), found on a maximum of 11% of sites in the Caribbean, 9% of IndoPacific sites, 7% of GBR sites, and absent in SEQ.

# FINDING INDICATOR FISH

This report presents data from 8,186 fish surveys conducted from 2001 to 2013, encompassing 1,866 surveys in the Caribbean and 6,320 in the IndoPacific (with 290 from Australia) (Figure 19). Of the nine Reef Check global fish indicator categories, butterflyfish, parrotfish, snapper, grouper, sweetlips and moray eels were globally distributed. The bumphead parrotfish, humphead wrasse, and barramundi cod are IndoPacific indicators, as they are not found in the Caribbean.

Sweetlips were found in much higher abundances in the Caribbean (7.9/100m²) than the IndoPacific (0.4/100m²) or Australia (0.2/100m² and 0.3/100m² for GBR and SEQ). Sweetlips were also recorded more frequently in the Caribbean (88% of sites) compared to the IndoPacific (43%), SEQ (53%) and GBR (41%). Higher sweetlip abundance and frequency in the Caribbean was comparable to findings from the 1997 surveys (Hodgson 1999).

Butterflyfish were relatively common across all regions, with the highest abundances found in the IndoPacific (5.8/100m²) and lower abundances found in Australia (3.9 and 2.0/100m² GBR and SEQ respectively). Butterflyfish were recorded more frequently on sites in the IndoPacific (95%) than the Caribbean (85%), GBR (84%) or SEQ (66%). Results are comparable to the 1997 Global Reef Check surveys, where most IndoPacific sites had butterflyfish in abundances of 4-6/100m² and more than half of the Caribbean sites had abundances of less than 2/100m² (Hodgson 1999).

Parrotfish were found in higher average abundances in the Caribbean (3.6/100m²) and on more sites (90%) when compared to the IndoPacific (2.8/100m², 69% of sites). Parrotfish were found in lower abundances and frequency on the GBR (1.9/100m², 64% of sites) and lowest in SEQ (0.4/100m², 53% of sites). Snapper were found in slightly lower abundances in the Caribbean (2.1/100m²) and Australia (2.2/100m² and 1.2/100m² for GBR and SEQ) compared with the IndoPacific (2.6/100m²). Snapper were recorded on more sites (76%) in the Caribbean than the IndoPacific (59%), GBR (59%) or SEQ (72%). Grouper were recorded in abundances of less than 0.4/100m² across all regions (19%-57% of sites). Grouper abundances are similar to findings from 1997 surveys (Hodgson 1999).

Moray eels were recorded in abundances of 0.1/100m² or less across all regions (found on 9-33% of sites). Bumphead parrotfish, humphead wrasse and barramundi cod were recorded in low average abundances (0.1/100m² or less) and low frequency (0-16% of sites) across the IndoPacific and the GBR. In the 1997 Reef Check surveys, bumphead parrotfish were recorded on more sites (33%), humphead wrasse (14% of sites) and barramundi cod (2% of sites) were recorded in similar abundances (Hodgson 1999). Although still low, humphead wrasse abundances were notably higher on the GBR than in the IndoPacific.

Declines in the abundance of large food fish have been documented on a global scale (Pandolfi *et al.* 2003, Cheung *et al.* 2007, Fenner & Russell in Wilkinson 2008). Further research around historical comparisons and expanded assessments would be beneficial.

# REEF IMPACTS ACROSS THE GLOBE

Reef Check impact surveys yield data about visual evidence of reef impacts, focusing on human impacts that could be mitigated through management activities. This report presents data from 8,697 surveys from 2001 to 2013 (1,908 conducted in the Caribbean and 6,789 conducted in the IndoPacific (Figure 20).

Australia's GBR had the highest prevalence of coral bleaching (50%), followed by the Carribbean, SEQ, and the IndoPacific. However, bleaching impacted relatively low levels of the coral population (average 2.6% of the population on the GBR). Severity of coral bleaching was highest at Carribbean sites (5.6% of coral population on average) and lowest at IndoPacific and SEQ sites (1.7% of the coral population on average).

Coral damage from anchors was found in all regions, but mostly in low levels (1-4 counts/100m²). It was most common across IndoPacific transects (14%) and comparable (5.5-6.4% of transects) across all other regions. Coral damage from blast-fishing was a notable impact on IndoPacific sites, recorded on 6.7% of transects in low abundances (1-4 counts/100m²).

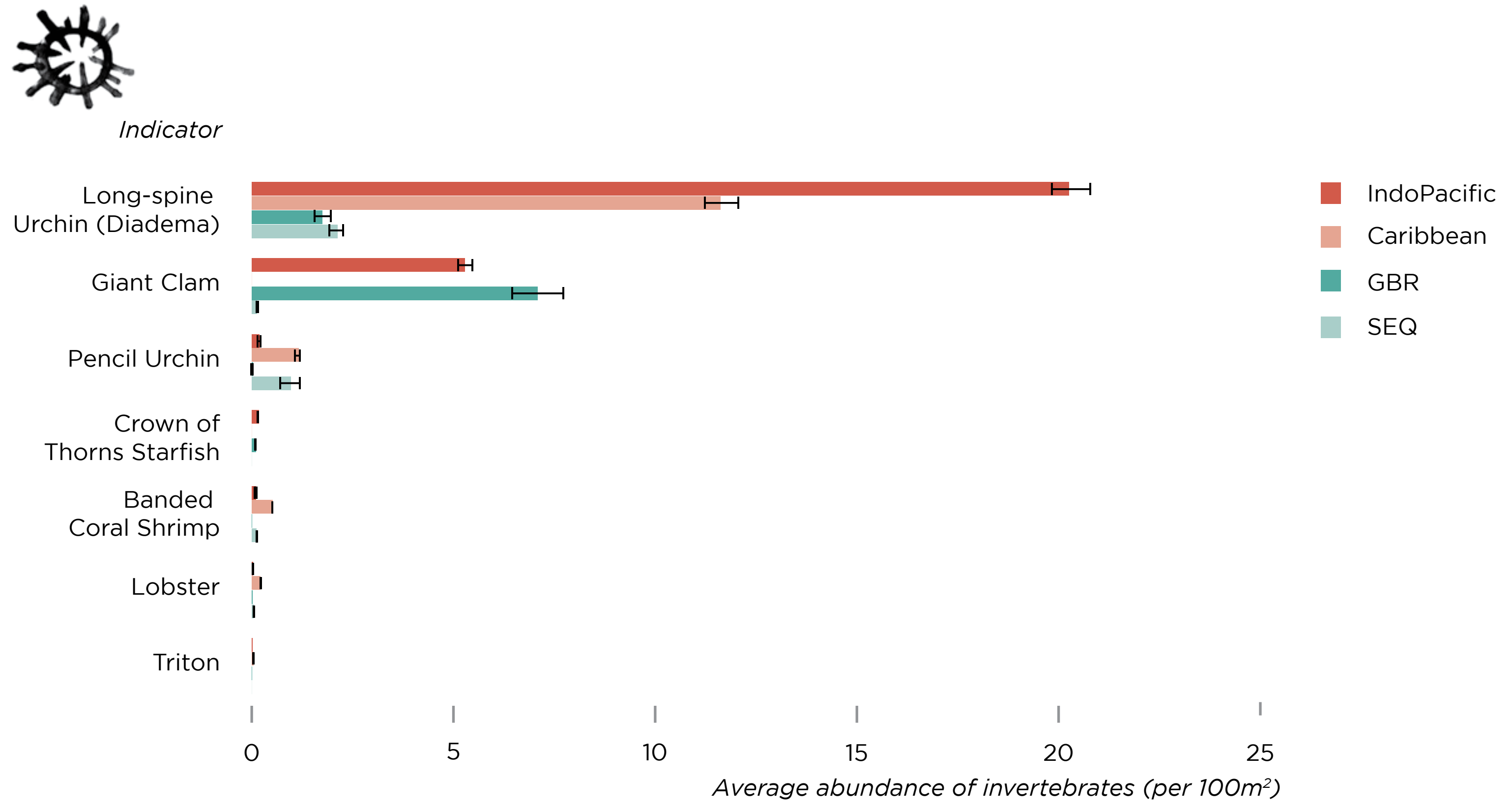



Figure 18. Regional average abundance of invertebrates (per 100m²) recorded on 8,544 surveys conducted by volunteers from 1997 to 2013 comparing the IndoPacific, Caribbean and Australia (subdivisions of Great Barrier Reef and South East Queensland). Error bars represent one standard error of the mean.

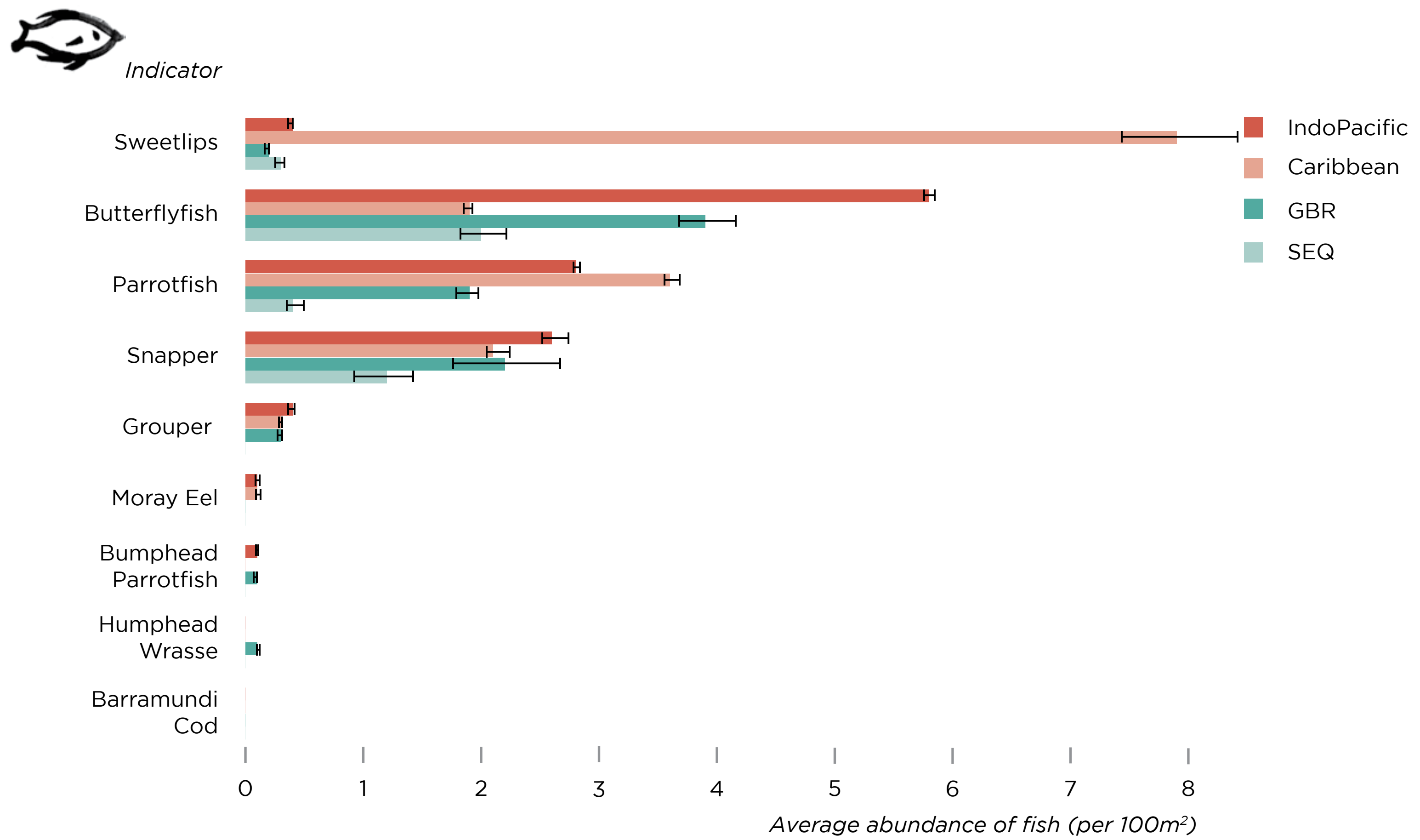



Figure 19. Regional average abundance of fish (per 100m²) recorded on 8,186 surveys conducted by volunteers from 1997 to 2013 comparing the IndoPacific, Caribbean and Australia (subdivisions of Great Barrier Reef and South East Queensland). Error bars represent one standard error of the mean.

**Reef Impacts continued...**

Low levels of physical coral damage from unknown causes was most common on the GBR (48% of sites) and SEQ sites (35%). Higher levels of damage (>5 counts/100m²) were found in similar abundances across the global regions (3-7% of sites).

Low levels of fishing gear prevalence (1-4 counts/100m²) were similar for SEQ and the broader IndoPacific (10.8% and 10.2% of transects respectively). The GBR had the lowest level of fishing gear (1% of sites), likely a reflection of the high number of protected areas monitored in this region.

Low levels of general rubbish (1-4 counts/100m²) were somewhat more prevalent across surveys, with the highest frequency recorded in the broader IndoPacific (15.6% of transects), comparable levels in SEQ and the Caribbean and the lowest on the GBR (7% of transects).

Reef Check global programs estimate the percent of corals impacted by two specific types of coral disease, black band and white band (coral disease not shown on graph). Australian data is excluded from the IndoPacific figures, as coral disease is recorded differently. Across surveys, black band disease was recorded on 25% of Caribbean sites and 3% of IndoPacific sites. White band was recorded on 30% of Caribbean sites and 12% of IndoPacific sites. A review of Australian survey data shows 48% of surveys in SEQ with coral disease records and 29% of GBR surveys. At first glance, this seems to potentially indicate higher coral disease counts than global surveys, however, Australian surveys record all coral disease, not just white and black band. Most coral disease records in SEQ suggest the coral disease category of white syndrome is most prevalent, which is a disease not recorded by Reef Check global surveys.

Coral disease has significantly affected coral reefs in the Caribbean (Gardner *et al.* 2003) and poses a growing threat to Australia's reefs (Willis *et al.* 2004). The abundance and distribution of coral disease appear to be increasing (Sutherland *et al.* 2004) and are likely more common on stressed reefs (Lesser *et al.* 2007).

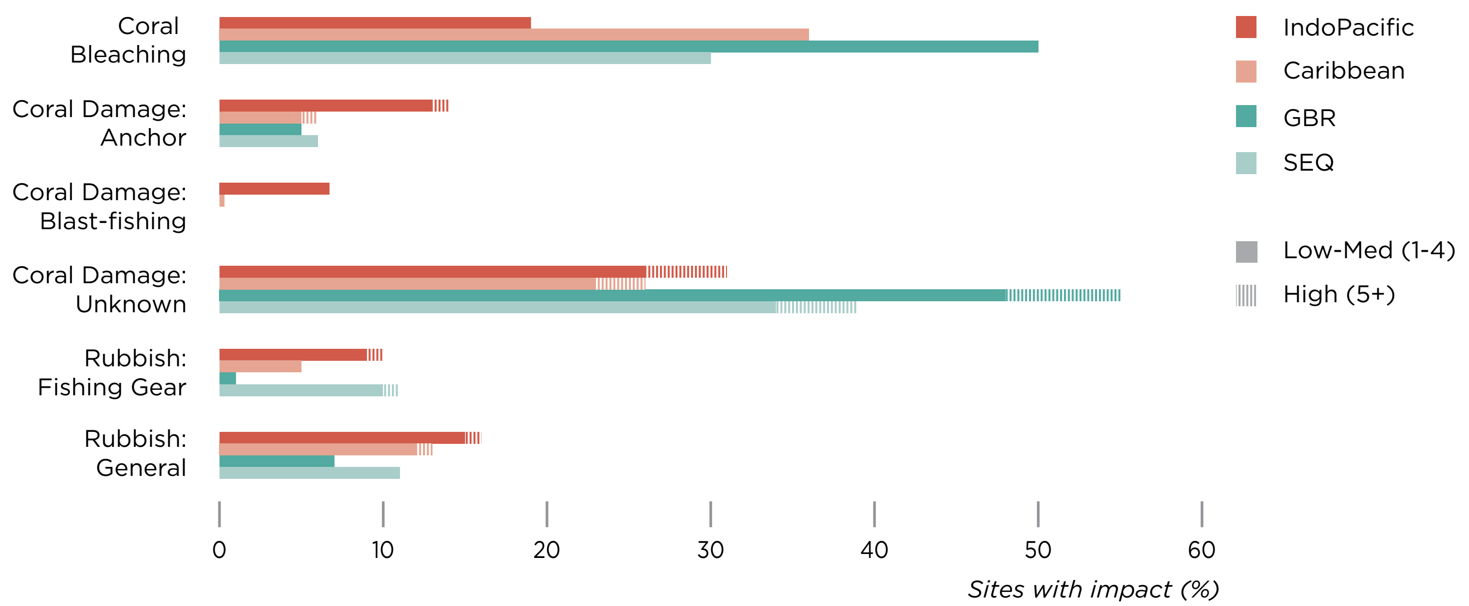



Figure 20. Percentage of sites with documented reef impact, as recorded on 8,697 impact surveys conducted by volunteers from 1997 to 2013 comparing the IndoPacific, Caribbean and Australia (subdivisions of GBR and SEQ). For all categories excluding coral bleaching, the stacked bars show percentage of sites with 1-4 impact counts/100m² (solid bars) and 5 or more impact counts/100m² (dashed bars). Coral bleaching is only recorded as a presence/absence on sites.



# Case study 4 SUMMARY & KEY POINTS

Gaining global perspective on how Australian reefs compare to those around the world offers a unique opportunity to consider our successes and challenges in regards to reef management. In some ways, RCA's monitoring sites seem to be faring well, with relatively high coral cover and relatively low levels of nutrient indicator algae. Yet, abundances of many food fish and invertebrates warrant more detailed assessment to better understand possible historic or current over harvesting.

Reefs in Australia and throughout the world are showing signs of stress. Reef impacts that are already more commonly recorded, such as physical coral damage and coral bleaching, are likely to increase with effects from global climate change (Hoegh-Guldberg 1999, Hughes *et al.* 2003, Burke *et al.* 2011).

This is one of the many reasons why the regulated management of Australia's reefs is so imperative. Building reef resilience can help to mitigate larger looming reef threats (Hughes *et al.* 2003, Selig & Bruno 2010). RCA's engagement with the dive tourism industry, schools and the broader community can be a major catalyst for good behaviour by visitors to Australian reefs and build accessible knowledge to help the public engage with reef health issues and actions.

**Key points:**

- Hard coral cover across GBR sites was comparable to the broader IndoPacific region. Interestingly, hard coral cover in the SEQ subtropical reef region was comparable to hard coral cover in the Caribbean.
- The overall average global hard coral cover across all Reef Check monitoring sites from 1996-2013 was 28%, slightly down from the 2002 Reef Check report of 31% cover. The average hard coral cover across sites is higher than other global studies and likely reflects Reef Check's protocol of selecting monitoring sites with high coral cover.
- Overall, most year to year changes in hard coral cover were less than 10%, however, many inter-annual changes were positive in Australia and negative in the Caribbean, suggesting reduced recovery in Caribbean reef systems.
- The average abundance of long-spine (*Diadema*) urchins was highest in the IndoPacific and lowest in Australia. The result was surprising given documented declines in Caribbean *Diadema* populations, but may show differences in regional species communities, as well as grazing and predation dynamics.
- Butterflyfish were relatively common across all regions, with the highest abundances in the IndoPacific. Sweetlips and parrotfish were found in higher abundances in the Caribbean. Bumphead parrotfish, humphead wrasse and barramundi cod were recorded in low average abundances across the IndoPacific and GBR. While humphead wrasse abundances appear low, Australian averages are notably higher than other global regions.
- Australia had a higher number of surveys with coral bleaching reports than the IndoPacific, but population level impacts were low in both regions (higher in the Carribbean). Low levels of physical coral damage (unknown causes) was most common on the GBR. Abundances of fishing gear were similar for SEQ and the broader IndoPacific. The GBR had the lowest level of fishing gear, which is likely a reflection of the high number of protected areas monitored in this region.
- The Reef Check data comparisons indicate interesting preliminary findings that generate both answers and more questions regarding the global state of reefs. Reef Check surveys offer a unique tool to compare how Australian reefs compare to those around the world. This snapshot warrants further analysis to investigate long-term trends and link changes with potential causes to improve understanding and help contribute to meaningful discussions about how as a global community we can take action to find solutions.

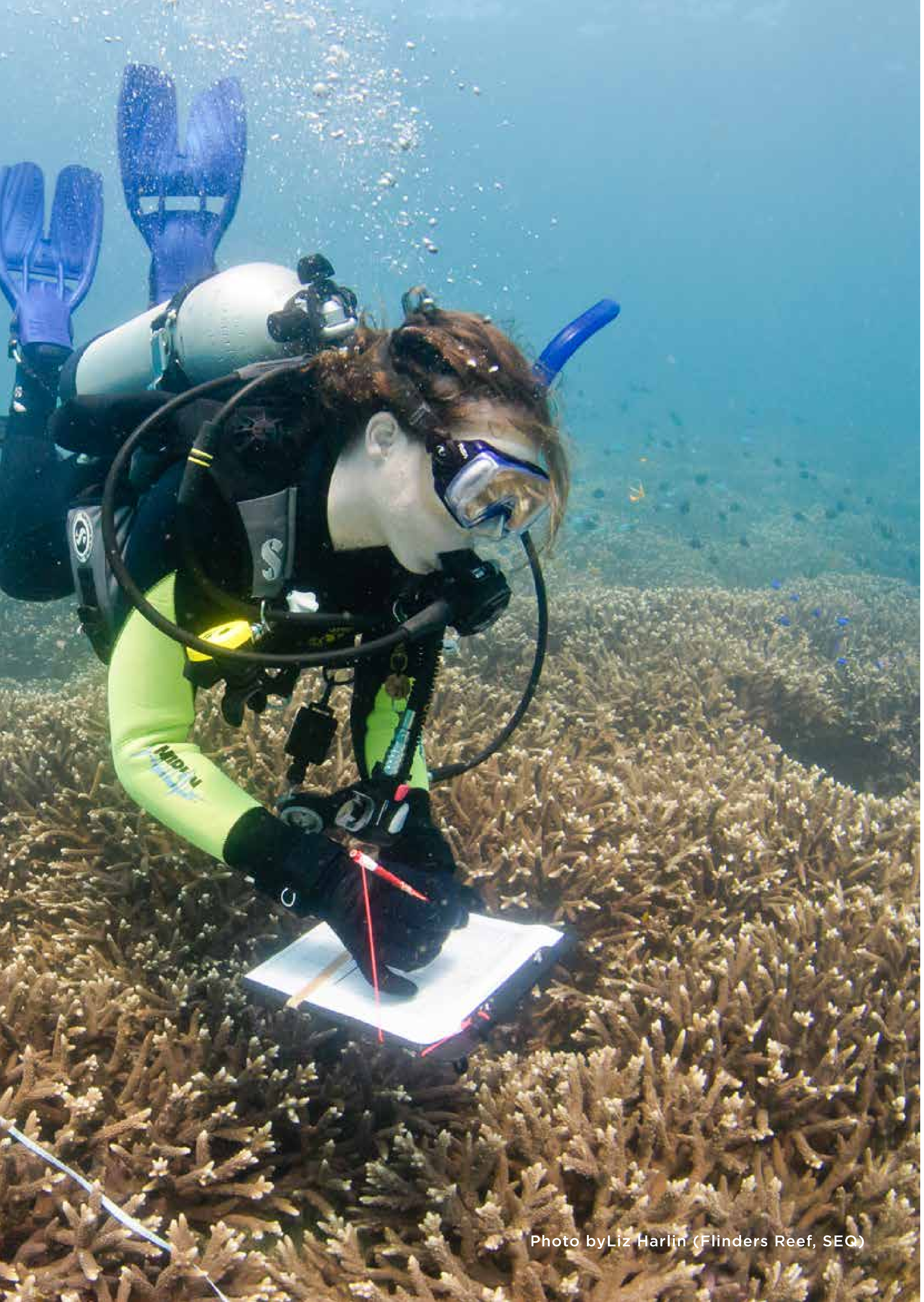


Photo byLiz Harlin (Flinders Reef, SEQ)

# Science project highlights

It's impossible to capture a legacy of a decade of programs in several pages, but here are a few highlights from Reef Check Australia programs. This is only a fraction of the programs and science stories from over the years.

For additional stories and information, please visit www.reefcheckaustralia.org.

## SUPPORTING SEA COUNTRY MANAGEMENT

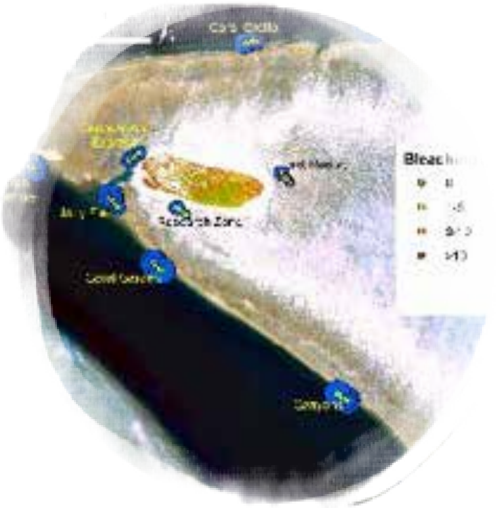
In 2013 & 2014, Reef Check Australia partnered with SEQ Catchments and The University of Queensland's Biophysical Remote Sensing Group to deliver snorkel-based reef health monitoring courses for participants from Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC). QYAC manages the native title interests of the Quandamooka area to support land and sea country management. QYAC participants applied their new skills helping to establish three new shallow reef monitoring locations in Moreton Bay. The groups continue working together, to build further understanding about local rocky reefs with applications for sea country management. Quandamooka Yoolooburrabee Aboriginal Corporation's Darren Burns sees Quandamooka's involvement in reef monitoring as an important step towards fostering management capacity, saying "It has provided an opportunity to demonstrate how Traditional Owners can and should be involved in science-based monitoring and evaluation on their traditional country."

## FRASER COAST CORALS

The Great Sandy Marine Park is just south of the GBR Border! Research indicates that these reefs appear to have more similarities with those north on the Great Barrier Reef than their nearby neighbours in Moreton Bay (Zann *et al.* 2012), yet there is limited regular reef monitoring. RCA worked with local partners including Burnett Mary Regional Group, Queensland Parks and Wildlife and two local University of Queensland researchers to establish five monitoring sites in 2012. Several years of surveys show that Woongarra Coast reefs appear to be dominated by soft corals where the reefs of Hervey Bay host more hard coral communities. All of these reefs are subject to siltation from nearby river systems, and were exposed to heavy flooding events in 2011 and 2013 (Butler *et al.* 2013 & 2015). Therefore ongoing monitoring to build on mapping and reef composition data is vital for understanding resilience and recovery in this unique reef area.

## HEADING TO HERON ISLAND

Understanding the ecology of relatively pristine reefs provides an important baseline for reef health. With the support from The University of Queensland's Biophysical Remote Sensing Group, Heron Island Research Station and Heron Island Resort, 15 new Reef Check monitoring locations were established around Heron Island from 2011-2014. Reef Check volunteers surveyed transects that overlapped with annually visited geo-referenced benthic photo-transects dating back to 2001. The ongoing research project involves using field data for calibration and validation of benthic community maps derived from high spatial resolution satellite imagery (Phinn *et al.* 2012 and Roelfsema *et al.* 2010). Reef Check data is being used to provide additional data on reef condition for mapping applications, which expands on available data for this remote reef location and supports projects to monitor reef change remotely over large areas.

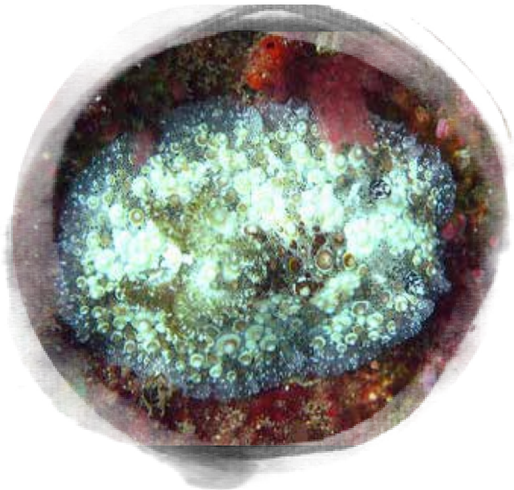


## DEBRIS AND OUR SEA

Marine debris is quickly gaining recognition as a critical issue for our oceans. Since 2012, RCA has been partnering with Tangaroa Blue Foundation on coastal and marine debris clean-up events. Tangaroa Blue coordinates the Australian Marine Debris Initiative, a network of volunteers, communities, organisations and agencies around the country monitoring the impacts of marine debris along their local stretch of coastline. One of our collaborative goals is to create improved understanding of the relationship between coastal and underwater debris, so we can develop innovative solutions to tackle this issue. RCA survey data from 2001 to 2013 was re-analysed to coordinate with Tangaroa Blue debris categories and then compared with nearby historical beach clean-up data. This direct data comparison is helping to build understanding and identify areas where more coordinated clean-up data would be beneficial to support on-ground actions into the future.

## NEW NUDIS!

RCA volunteers tell us one of the highlights of carefully looking at the reef in detail is their heightened ability to spot the small stuff. In 2012, we expanded Australia's taxonomic record of nudibranchs, spotting a *Hoplodoris estrelyado* on a survey at Currimundi Reef on the Sunshine Coast. The species has previously been recorded in the Indo-West Pacific (including Western Australia, Vietnam, Philippines, Indonesia, and the Marshall Islands), but had never been seen on the East Coast of Australia. This sighting was identified and confirmed by the dedicated citizen science team at www.nudibranch.com.au. This was the 525th species of nudibranch that their dedicated team has documented on the Sunshine Coast, supporting the belief that the SEQ region has one of the most diverse assemblages of nudibranchs in the world!



## SURVEYS POST SPILL

Sadly, oil spills and ship groundings can have a huge impact on our marine environment. In 2009, the Pacific Adventurer container ship was damaged by Cyclone Hamish and spilled 270 tonnes of oil into Moreton Bay Marine Park. Considered one of Queensland's worst environmental disasters, the spill threatened the habitats and inhabitants of beaches, rocky reefs and wetlands. SEQ Catchments invited RCA to contribute baseline information to understanding oil spill impacts on Moreton Bay's reefs. Data from 13 RCA sites (including 4 with baseline data prior to the spill) were used in the assessment of oil contamination impacts. The type and frequency of impacts recorded in 2007 and 2008 were statistically different from those recorded in 2009, particularly increased coral scars and *Drupella* snail scars, indicating potential alterations in reef health. Statistical comparisons of four baseline RCA monitoring sites did not reveal detectable impacts on substrate composition, which suggested the four baseline sites were not heavily impacted by the spill. However, events such as this can have long-lasting impacts and RCA continues to monitor Moreton Bay reefs. Photo credit Tangalooma Resort.

## GETTING PLACES ON THE MAP

In order to better manage and protect our reef resources, it is essential to have a solid dataset about reef location and condition. In 2010, Noosa Integrated Catchments undertook a comprehensive Sunshine Coast Marine Biodiversity study across key reef sites (DeVantier *et al.* 2010). RCA wanted to ensure that Reef Check surveys could build on this rich dataset, and offer a sustainable and complimentary regional project. Therefore Principle Investigator, coral ecologist, Dr. Lyndon DeVantier was asked to review RCA monitoring methods to ensure a best fit. It was found that significant overlap between protocols and categories would allow for a complementary approach to link the two studies, as well as recommendations for continued improvements to the RCA program. In 2012, we undertook a project to literally add Sunshine Coast reefs to the SEQ map. The RCA team worked with SEQ Catchments to identify spatial locations of established Reef Check monitoring locations on the Sunshine Coast. For the first time, these reefs were officially acknowledged for future natural resource management planning. This initiative has continued to build on the available knowledge about these unique reefs. These projects show the positive outcomes from multi-year funding from Sunshine Coast Council, who have supported RCA regional work since 2009.

Reef cleaning pro

## HOW LONG IS A PIECE OF FISHING LINE?

Lost or discarded (derelict) fishing gear can threaten marine life through entanglement and ingestion. Nylon fishing line and nets are extremely persistent in the marine environment, potentially remaining intact for decades or even centuries. Following the 2004 re-zoning of the Great Barrier Reef Marine Park (GBRMP), coral reef scientists at James Cook University (JCU) began recording discarded fishing lines while conducting fish and coral monitoring surveys in the Palm, Whitsunday and Keppel Island groups. Fishing lines were recorded on coral reefs in both areas that are open to fishing and within no-take marine reserves (green zones). From 2007 to 2008, RCA collaborated with JCU to investigate how derelict fishing line can be used as a proxy for estimating fisher non-compliance (poaching) levels in green zones. Over the course of the project, RCA volunteers collected more than 500 derelict fishing lines from 10 long-term monitoring sites in the Palm Islands. The research team monitored the re-accumulation of fishing lines at each of the sites over a 32 month period following the clean-up. Surprisingly, it was found that lines re-accumulated on green zone reefs at approximately one third (32.4%) of the rate observed on reefs that are legally open to fishing (Williamson *et al.* 2014). Although these inshore green zones have long been considered some of the best protected within the GBRMP, the results of this study indicate that poaching levels are higher than previously assumed. The findings support the ongoing monitoring of discarded fishing gear to gain insight about fishing effort and levels of non-compliance within no-take marine reserve areas.



## MONITORING MAGNETIC ISLAND

One of the reasons the Great Barrier Reef is so amazing is the huge diversity of different habitats. Inshore reefs are critical habitats and their accessibility makes them amazing convenient reefs for us to explore. Yet their proximity to shore also makes exposes these reefs particularly susceptible to the effects of human activities. Sedimentation from dredging or coastal development, as well as nutrient pollution from land-based activities are among the threats facing inshore reefs. The chronic water quality stressors to which inshore reefs are exposed can reduce their resilience to bounce back from irregular events like storms and cyclones. RCA has been involved in monitoring inshore reefs around Magnetic Island since 2003 with ongoing support from Townsville City Council's Creek to Coral program. Creek to Coral is a combined local and State Government initiative to maintain and enhance healthy waterways in the Dry Tropics region. With the combined efforts of the Great Barrier Reef Marine Park Authority and the Australian Institute of Marine Science, this initiative is working to increase the inshore reef area that is under surveillance. Nelly Bay Reef on Magnetic Island is one of the longest RCA monitoring sites (established in 2003). Unfortunately the story at this site isn't so uplifting, and since the 2007 we have seen steady hard coral declines. RCA continues to work with Townsville City Council to share the story of Townsville's inshore reefs with the local community to generate appreciation and awareness about these threatened habitats.

## WATCHING OUT FOR SHARKS

Sharks are vital to the health of our oceans. Sadly populations are in decline globally – and in Australia. Having been hunted almost to the point of extinction in the 1950s, the Australian east coast population of grey nurse shark is listed as Critically Endangered under the International Union for the Conservation of Nature's Red List of Threatened Species. Since 2011, RCA has been hosting the Grey Nurse Shark Watch photo identification program. We're honoured to host this citizen science project initiative, offering more opportunities for volunteers to engage in meaningful data collection that improves marine science and management efforts for this endangered species. Since the program started, more than 300 members have signed up to participate. Their data and images add to the national database, building information on grey nurse shark numbers, movements and distribution during different stages of their life cycle throughout their range in both the NSW and QLD marine regions. The program is critical for filling data gaps and increasing knowledge of the east coast population of this species (estimated to be 1000-1500 individuals).


Photo by Jodi Salmond (North Stradbroke Island, SEQ)

# More than monitoring

While volunteer citizen scientists form the heart of what we do and link us with the global Reef Check network, it takes more than data to make a change. We aim to engage the community celebrating, understanding and protecting our reefs and oceans. Here is a sample of a few key programs, projects and activities through the years.

For additional stories and information, please visit www.reefcheckaustralia.org.


## BEERAMUNDI

It doesn't get much better than combining two loved pastimes in the name of a good cause. In 2006, Townsville's beer lovers helped support RCA activities with a conservation-minded beer called Beeramundi. The new beer was named as part of a competition held in partnership between Reef Check Australia and the Townsville Brewing Company. The public was asked to come up with a name, and a slogan for the beer, and an educational concept that would help make reef conservation a conversational topic. The project was the brainchild of Roger Beeden, the name courtesy of Eion Howe. A team effort by Dean Miller, Alana Grech and James Moloney was responsible for the slogan "Saving the Reef one beer at a time". Cheers to the reef!

## COMMUNICATIONS FOR CORALS

We believe informed and passionate communities can make a difference for our reefs. To help boost accessible science information, we strive to share experiences, findings and information about important issues with the community. RCA has produced several community service announcements highlighting the GBR and Moreton Bay reef ecosystems and the efforts of RCA volunteers to build practical knowledge for conservation.

## WHAT'S YOUR REEF IQ?

To support meaningful change, we wanted to create accessible educational tools to help kids understand what they and their families can do to help protect the Great Barrier Reef. The idea for an innovative reef education program was born in 2007. The aim was to give kids a real understanding of what it's like to be a marine biologist and undertake reef research. The resources gave students a "real feel" for environmental monitoring and enhanced educators' capacity to deliver meaningful environmental education. Through the dedication and commitment of Malo Hoskins and Jo Roberts, an online interactive coral reef game was brought to life, along with a comprehensive suite of online educational resources.

The Reef IQ materials have been downloaded by more than 450 teachers, ranging from Townsville to Tanzania. The Reef IQ game went on to win the Best Use of Flash Animation Award in the Queensland Multimedia Award, whilst the joint workshops won the Community Group Award in the Townsville Environmental Excellence and Sustainability Awards.

## MORE REEFSEARCHERS FOR THE REEF

Reef Check has always been about providing community members with the tools to better understand and protect their local reefs. The REEFSearch identification and observation program was born from regular inquiries about how to get involved... without having to do a four day training course like RCA survey volunteers! Essentially, REEFSearch is Reef Check 101: an introduction to the how's and why's of reef ecology, reef monitoring and reef conservation. The self-guided program allows many more snorkellers, divers and reef walkers to learn and contribute. The REEFSearch pilot program was featured on Tourism Queensland's Best Expedition in the World in 2011, with trials all along the 1,600 kilometre journey up the length of the Great Barrier Reef from May to September 2011. The online REEFSearch Hub allows REEFSearchers to report their findings and photos, review trends for their region and investigate their information within their REEFSearch Groups. The program expands RCA capacity to get folks involved and helps us keep an eye on what's happening out there on the reefs by collecting more information across locations and time.

The REEFSearch Marine Education Kit was released in 2013 to help bring corals to the classroom and has been used by schools and community groups across QLD and WA. The program was matched to national curriculum allowing schools to easily integrate marine biology and citizen science, allowing them to bring reefs to the classroom in a truly engaging and educational way.



## CONNECTING SCHOOLS WITH THEIR LOCAL REEFS

Empowering our future leaders to love, appreciate and protect reefs is critical. Reef Check Australia has partnered with a variety of schools over the years, encouraging students of all ages to get involved in better understanding of reefs and oceans.

RCA started working with Bwgcolman Community School on reef education projects in 2006. In 2008, students from Bwgcolman School on Palm Island were the first children to get in the water and trial the Reef IQ field activities on the beautiful coral reefs around their island home. In 2013, teachers undertook the first official Reef Check teacher training course to help deliver reef ecology knowledge to their students. All of these initiatives were designed to build capacity for students to be stewards of the reefs on their doorstep.

Cleveland District High School have encouraged students and teachers alike to embrace reef conservation using the REEFSearch program to set up long term observation sites on Lady Elliot Island and in Moreton Bay.  They have also helped show the world how easy the program is with popular kids TV shows SCOPE and Totally Wild.  With hundreds of students exposed to reef conservation programs such as this, we are able to extend the RCA reach in fostering more marine stewards to ensure the future of our reefs looks bright.

## KICKIN' THE PLASTIC HABIT WITH CALOUNDRA MUSIC FESTIVAL

Plastic is a menace for the marine environment, persisting in our oceans and beaches and wreaking havoc for marine life. Since 2012, Reef Check Australia has been one of the charities supporting the Caloundra Music Festival (CMF). In 2013 CMF became the very first festival in Australia to ban the sale of plastic water bottles. RCA teams were there talking about plastics issues for the ocean and hosting water refill stations for thirsty festival-goers! More than 20,000 people attend the festival annually, so this is a huge step in creating sustainable events and lifestyles for the Sunshine Coast Community! We're proud to be a part of this green festival and many others that help us engage the community in taking care of their reefs.

Photo by Undersea Explorer (GBR)

# Back to the beginning

## THE ORIGIN OF REEF CHECK AUSTRALIA

I have always believed in the value of engaging communities in environmental stewardship. Reef Check Australia began when a small group of marine biologists and dive tourism professionals got together to devise a program that engages the general public in monitoring key dive sites on the Great Barrier Reef. Since 1997, Reef Check volunteers have been monitoring the health of coral reefs and educating their friends and families about the importance of protecting these systems. Through Reef Check Australia, we sought to create a high quality, locally-applicable, standardised training and data collection platform for volunteer divers and a central location for data dissemination to those making management decisions.

Ten years on, it is humbling and inspiring to see Reef Check Australia emerge as an award-winning environmental charity that has engaged hundreds of volunteers in monitoring reefs all around Queensland, as well as contributing to a range of ocean conservation initiatives. Looking back, it is hard to imagine the early days when I organized Reef Check surveys out of internet cafes in Port Douglas! This organisation has been built out of passion, commitment and a spirit of collaboration.

As environmental challenges continue to grow for Australia, it has never been a more important time for the community to get involved with coral reef conservation--to stand up and demand that we take care of these important ecosystems that provide us with food, pleasure, life-saving medicines and protect our coasts. Thank you for your continued support of Reef Check Australia!

**Jos Hill**
*Executive Director of Olazul and Founder of Reef Check Australia*

# Thank you

Thank you to the network of passionate individuals and organisations that support RCA projects.

Reef Check Australia Industry Champions help make it possible for survey teams to access sites by providing extensive in-kind support and a platform for sharing survey findings. Industry Champions know these sites better than anyone and we are proud to work beside them for our reefs.

Reef Check Australia survey, office and project volunteers (2001-2014) have made this work possible through many hours of commitment to our oceans.

There are a huge number of advisors, funders and partners who have and continue to make our work possible.

Thank you and congratulations to you all! There are so many people here in spirit!

## INDUSTRY CHAMPIONS

1770 Reef Explorers
Adrenalin Dive
Affordable Charters
Aristocat
Beuchat Dive Centre
Bundaberg Aqua Scuba
Cairns Dive Centre
Calypso Reef Cruises
Cruise Whitsundays
Daydream Island Resort and Spa
Dive Noosa
Diving the Gold Coast
Down Under Cruise and Dive
Explore Whitsundays Sailing Adventures
Fantasea Cruising Magnetic
Go Dive Brisbane
Haba Dive & Snorkel
Hamilton Island H2O Watersports
Hayman Island Resort
Heron Island Research Station
Heron Island Resort
Keppel Bay Escapes
Lady Elliot Island Eco Resort
Magnetic Dive
Manta Lodge and Scuba Centre
Mantaray Charters
Mike Ball
Moreton Bay Research Station and Education Centre
Nautilus Scuba Supercat
New Horizon
Ocean Cat Charters
Orpheus Island Scientific Research Station
Palm Beach Dive Centre
Pleasure Divers on Magnetic Island
Poseidon Outer Reef Cruises
Pro Dive Cairns
Pro Dive Townsville
Quicksilver Charters
Reef Encounter
Reef HQ Aquarium
Reef Magic Crusies
Reef Safari Airlie Beach
Reef Safari Magnetic Island
Remote Area Dive
Salt Dive
Sea World, Gold Coast
Spirit of Freedom
Scuba World
Stradbroke Ferries
Straddie Watersports
Sunferries
Sunlover Reef Cruises
Sunreef Scuba Diving Services
Tropical Diving
TUSA Dive
Undersea Explorer
Underwater World SEA LIFE Mooloolaba
Wavelength Marine Charters
Whitsunday Dive Adventures



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Photo by Ian Banks (Flinders Reef, SEQ)

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