
Australasian Journal of Environmental Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tjem20

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Published online: 21 Mar 2014.

*Australasian Journal of Environmental Management,* 2014
http://dx.doi.org/10.1080/14486563.2014.881307





# No-anchoring areas reduce coral damage in an effort to build resilience in Keppel Bay, southern Great Barrier Reef

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The natural resilience of coral reefs and their ability to resist and recover from disturbance may be supported by managing user access, including regulating the anchoring of vessels. The process of targeting site-based local management actions and evaluating success is central to the adaptive management process. We describe an example of such a process from Keppel Bay in the southern Great Barrier Reef. No-anchoring areas were selected based on evidence of severe anchor damage relative to other sites. The four locations selected are areas of high visitation where interpretive signage and the effort to support reef resilience create additional benefits of community outreach. Surveys indicate reduced anchor damage inside all four no-anchoring areas from ~80 instances per 1000 $m^2$ in 2008 to fewer than ten in 2012. Anchor damage also declined between 2010 and 2012 at three of the four control reefs near the no-anchoring areas. This case study is unique and foundational in that this was the first time that supporting reef resilience was explicitly used as the motivation for local-scale management in the Great Barrier Reef. Follow-up engagement with community and stakeholder groups suggests the process has led to an increase in reef awareness and stewardship.

**Keywords:** anchoring; coral reefs; Great Barrier Reef; environmental management; Keppel Bay; resilience

## Introduction

Coral reefs are dynamic ecosystems that have evolved to recover from disturbances (Nystrom et al. 2000). This natural capacity to withstand and recover from disturbances is collectively referred to as 'resilience' (Holling 1973; Carpenter et al. 2001; Walker et al. 2002), often described as the maintenance or return to a stable state (Nystrom et al. 2008). Disturbance frequencies are expected to increase in coral reef areas as the climate changes (Trenberth 2012; Climate Commission Secretariat 2013). In the Great Barrier Reef (GBR) Marine Park, intense tropical cyclones and coral bleaching events are projected to become more frequent (Hoegh-Guldberg et al. 2007; Donner et al. 2009; Knutson et al. 2010). Ocean acidification will reduce calcification and growth rates resulting in net erosion of

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some reefs (Silverman et al. 2009). Sea levels are rising (CSIRO & BoM 2007; Lough & Hobday 2011) and changed rainfall patterns are expected to result in more flooding (Climate Commission Secretariat 2013). Collectively, these environmental conditions stress corals, but the causes of many of these stressors are largely beyond the scope of local management actions. Reef managers must therefore work to support the natural resilience of reef ecosystems by reducing anthropogenic impacts while allowing for sustainable use; this is the mandate of the GBR Marine Park Authority (GBRMPA).

Since its establishment in 1975, the GBRMPA has implemented several strategic initiatives to support the resilience of ecosystems within the GBR Marine Park. For example, the GBR Marine Park Zoning Plan 2003 protects representative biodiversity and there are ongoing efforts to improve water quality under the joint Queensland and Australian governments' Reef Water Quality Protection Plan (Reef Plan). In some areas of the GBR Marine Park, regional Plans of Management and Special Management Areas (SMAs) complement ecosystem-wide initiatives. Plans of Management and SMAs govern activities in areas of highly concentrated use and visitation like Cairns and the Whitsunday Islands. Local-scale actions are also being implemented to reduce known stresses caused by specific human activities. We describe such a local-scale action from the Keppel Bay area of the southern GBR that aimed to reduce anchor damage at some highly visited sites by establishing no-anchoring areas (NAAs). The process used to select the sites for the NAAs was unique and participatory. Supporting reef resilience was the explicit motivation for the action and was communicated as such to stakeholders and community members participating in the process.

The Keppel Islands are a group of 16 continental islands 15 km off the coast of Yeppoon in the southern GBR. The fringing coral reefs surrounding these islands have moderate to low diversity of fish and coral communities (Thompson et al. 2011), high average coral cover (Figure 1a, GBRMPA 2009), and consist of corals with growth rates higher than seen elsewhere in the GBR (Diaz-Pulido et al. 2009). Corals were stressed due to severe bleaching that followed anomalously warm sea surface temperatures in 1998, 2002 (Elvidge 2004) and 2006, and some died as a result (GBRMPA 2007). Most reefs demonstrated strong recovery after these bleaching events, but since 2008 have been repeatedly exposed to major flood plumes. The nearby Fitzroy River flooded in 2008, 2010 and 2011, and the low salinity flood plume caused many corals to bleach and some to die. Corals were also stressed during this time by high turbidity caused by the extreme rainfall events that caused the floods (Thompson et al. 2011). In addition, since 2000, the Keppel Bay region has experienced a 140 per cent growth in tourism coupled with a 33 per cent increase in recreational boat use (GBRMPA 2008a, 2008b).

Higher incidences of anchor damage generally occur in areas popular with boaters (Dinsdale & Harriott 2004). Anchor damage was observed at a third of the sites surveyed in Keppel Bay in 2007 shortly after the 2006 major coral bleaching event (see Figure 1b for example; GBRMPA 2008a). Boaters in the area usually use Danforth (or 'reef-pick') and mushroom-style anchors, and the boats are mostly 6–12 m powerboats and 8–15 m sailboats. The Danforth reef-pick holds fast but often pulls coral and other invertebrates off the substrate when pulled out of the water. Mushroom anchors are less common but even more damaging, as these bounce up and down on the reef as the boat above moves with the surface water motion. Physical damage to corals caused by anchors can be identical to that caused by severe storms like cyclones, albeit on a far smaller scale. Physical damage to corals can increase susceptibility to disease and bleaching, and can lengthen recovery timeframes following disturbances (Hawkins et al. 1999). Expected

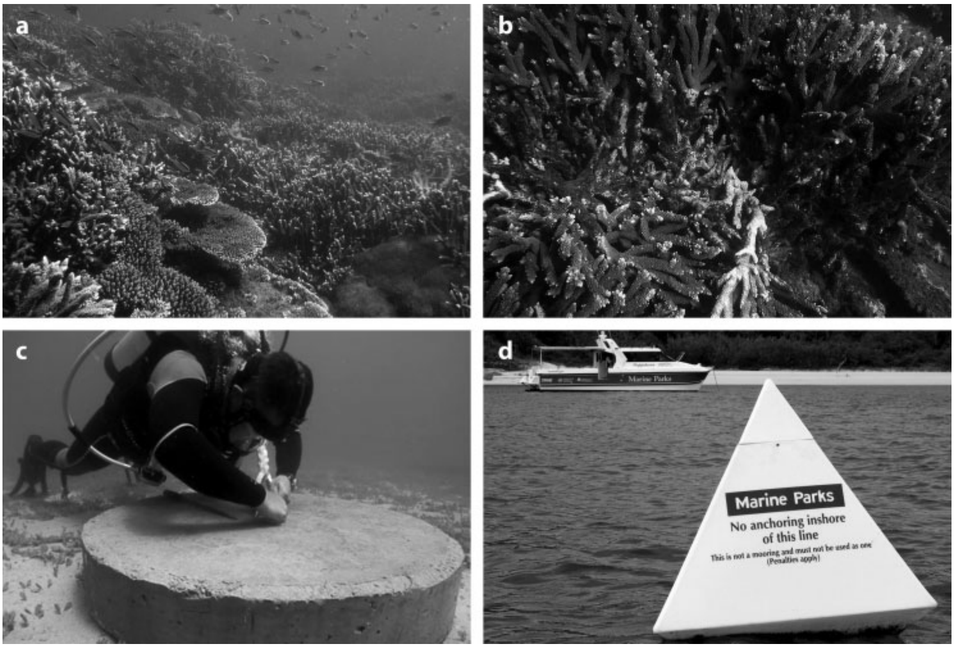


Figure 1. (a) Photo series of the diverse high coral cover reefs characteristic of the Keppel Bay area (from Sloping Island); (b) damage to a branching *Acropora* colony caused by anchoring at Humpy Island; (c) installation of the NAA markers underwater at Humpy Island; (d) buoys used to mark the boundaries of the NAAs at Big Peninsula. Photos copyright GBRMPA.

ongoing increases in use suggests anchoring will continue to add stress to the already vulnerable fringing reefs in Keppel Bay.

The GBRMPA has been examining strategies to enhance the resilience of vulnerable coral reef ecosystems. In 2008, a working group that included local managers, community members and regional natural resource management bodies decided that NAAs would be trialled in the Keppel Bay area. The NAAs deter boaters from anchoring, reducing physical stress on corals in the area and supporting the capacity of corals to recover from other disturbances (Day 2002).

Sites were selected for NAAs late in 2008 following an assessment of the relative resilience of reef sites in the Keppel Bay area. A resilience assessment and capacity building workshop was convened that included managers, scientists, local community members and stakeholders (Maynard et al. 2010). Attendees participated in assessing the resilience of 31 sites and reviewed the results to select suitable sites to trial NAAs. Four sites met the criteria of having: (1) low to medium resilience relative to other sites; (2) high levels of anchor damage; (3) high usage and good visibility to the public; and (4) high accessibility for managers and rangers to install and patrol the NAAs (Figure 1c, d). The selected sites are at Humpy and Barren Islands, and Big Peninsula and Monkey Beach on Great Keppel Island (Figure 2).

The process used for establishing the NAAs was driven by information from stakeholders and the community, and is an example of responsive and adaptive management. Here, we report on the effectiveness of the NAAs from in-water surveys of anchor damage conducted since 2008. We discuss the increasing importance of using

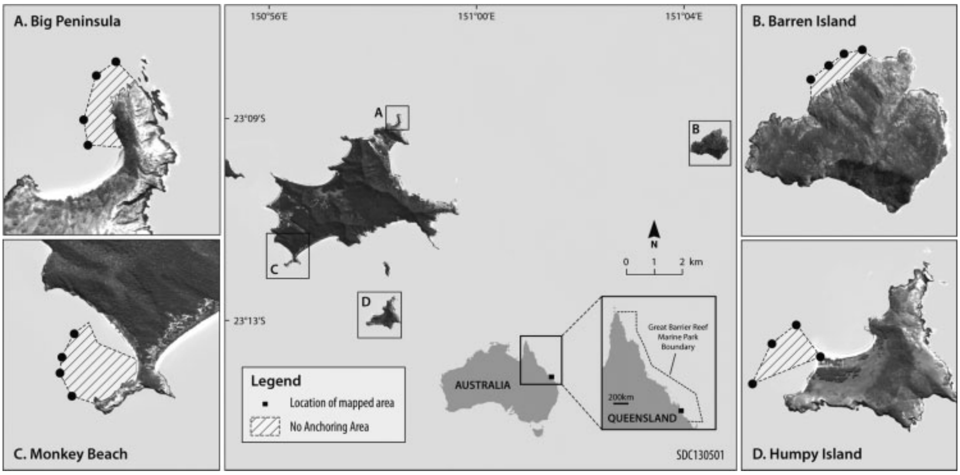


Figure 2. Map of the NAA locations within the Keppel Bay area of the southern Great Barrier Reef. No-anchoring areas are: (a) near the northern tip of Great Keppel Island at Big Peninsula; (b) on the northern shore of Barren Island; (c) at a popular sailing stop on the southwestern shore of Great Keppel Island at Monkey Beach; and (d) near a campground at Humpy Island.

local-scale actions to support reef resilience as disturbance frequencies increase under climate change. We also make the case that the participatory process with community members and stakeholders increased support for the NAAs once implemented, and has increased engagement and reef stewardship in the Keppel Bay area.

## Survey methods

Surveys of habitat within NAAs were undertaken in 2008 to establish baseline condition prior to the NAA markers being installed in 2009. Follow-up surveys were conducted for the NAAs and control sites in 2010, 2011 and 2012. In 2008, a fixed area was set of 100 m × 10 m and observers counted every instance of anchor damage within the 1000 $m^2$ survey area. During subsequent survey years, observers used the GBRMPA's reef health and impact survey (RHIS) protocol. The lead observer team had the same members during all years; when others participated they were trained by lead observers to the program standard. All team members could readily identify instances of anchor damage. The RHIS protocol enables observers to capture replicate assessments of reef condition (including impacts such as anchor damage) at multiple locations within each site. Control sites surveyed are adjacent to the NAAs at Humpy and Barren Islands and near Monkey Beach and Big Peninusla (at Miall and Sloping Islands).

Using the RHIS protocol requires observers to search for a consistent reef habitat to survey; sloping reef areas from 4–12 m for this study. Observers then randomly select a central point to start the survey by doing 20–30 fin kicks along the reef with their eyes shut. The surveys cover a circular area with a 5 m radius. The observer swims from the central point to four points using the north, south, east and west of a compass. Those points form the circle perimeter and observers survey the perimeter while recording their estimates of benthic cover and signs of impacts, including anchor damage instances. For all surveys and all survey years observers recorded anchor damage instances rather than damaged colonies. This is due to the difficulty in distinguishing colonies as many of these reefs are dominated by monospecific stands of branching *Acropora*. An 'instance' of anchor damage is a discrete observation of damage, such as a hole in the reef surrounded by broken branches or an area of broken branches (Figure 1b). A minimum of three RHIS surveys were undertaken inside and outside each of the NAAs during the 2010–2012 surveys.

Trends in anchor damage through time are examined graphically: (1) across all NAA and control sites for all four survey years; and (2) for the NAA and control sites individually when averaging was possible (i.e. multiple surveys were conducted; 2010, 2011, 2012). For the first, counts of anchor damage instances from the 2008 and subsequent RHIS surveys were averaged for surveys completed inside the NAAs (2008, $n = 4$; 2010, $n = 21$; 2011, $n = 40$; 2012, $n = 24$) and for surveys at the control sites (2010, $n = 26$; 2011, $n = 22$; 2012, $n = 29$). For the second, counts of anchor damage were averaged at the site level from all surveys completed inside the NAA and at the control sites. For both approaches, anchor damage counts from RHIS surveys were converted to a per 1000 m$^2$ density value for comparison with the data collected in 2008 (circle survey area is 78.5 m$^2$ so damage counts multiplied by 12.74 = 1000 m$^2$). The switch was made to the RHIS protocol in 2010 because that year RHIS became the standard protocol used by managers and scientists participating in the GBRMPA's Eye on the Reef monitoring program. In 2010, the RHIS protocol and the 100 m × 10 m belt transect approach used in 2008 were compared. During swims on the first survey day, anchor damage counts from the two approaches were found to be within 10 per cent when converted to a 1000 m$^2$ value as described above. The approaches were considered to be comparable here for assessing the severity of anchor damage because the NAAs are very small (less than 0.25 km$^2$ in all cases) and because no location within the NAAs is a better anchorage than any other. Anchoring is random and well represented using both survey approaches.

## Results and discussion

Anchor damage declined following installation of the four NAAs. The average number of anchor damage instances across all NAAs per 1000 m$^2$ exceeded 80 in 2008 prior to installation of the marker buoys. By 2010, average anchor damage counts from surveys declined to less than 25 per cent of levels observed in 2008 (c. 20, Figure 3a) and fewer than ten instances were observed at any of the NAA sites in 2012 (Figure 3a). In all four NAAs average anchor damage by 2012 was less than 10 per cent of levels observed in 2008 (Figure 3b). By location (SE in brackets), from 2008 to 2012, the declines in average anchor damage instances observed are from 32 to 2.56 (± 2.56) instances at Barren Island, 64 to 0 instances at Humpy Island, 167 to 8.01 (± 8.01) instances at Big Peninsula and 51 to 16.03 (± 14.28) instances at Monkey Beach (Figure 3b). Most of the decline in anchor damage instances observed at the NAA sites takes place between 2008 and 2010. Overlapping error bars for levels of anchor damage observed between 2010 and 2012 indicate that differences in those years are not significant. Average anchor damage counts also declined at most control sites from 2010–2012 (not at Big Peninsula). The declines at the control sites (Figure 3) in anchor damage instances from 2010 to 2012 are from 83.33 (± 48.40) to 23.81 (± 10.99) at Barren Island, 31.34 (± 21.16) to 2.14 (± 2.14) at Humpy Island and from 51.28 (± 45.02) to 4.81 (± 3.37) at Monkey Beach. No decline was observed at the control site for the Big Peninsula NAA (from 19.23

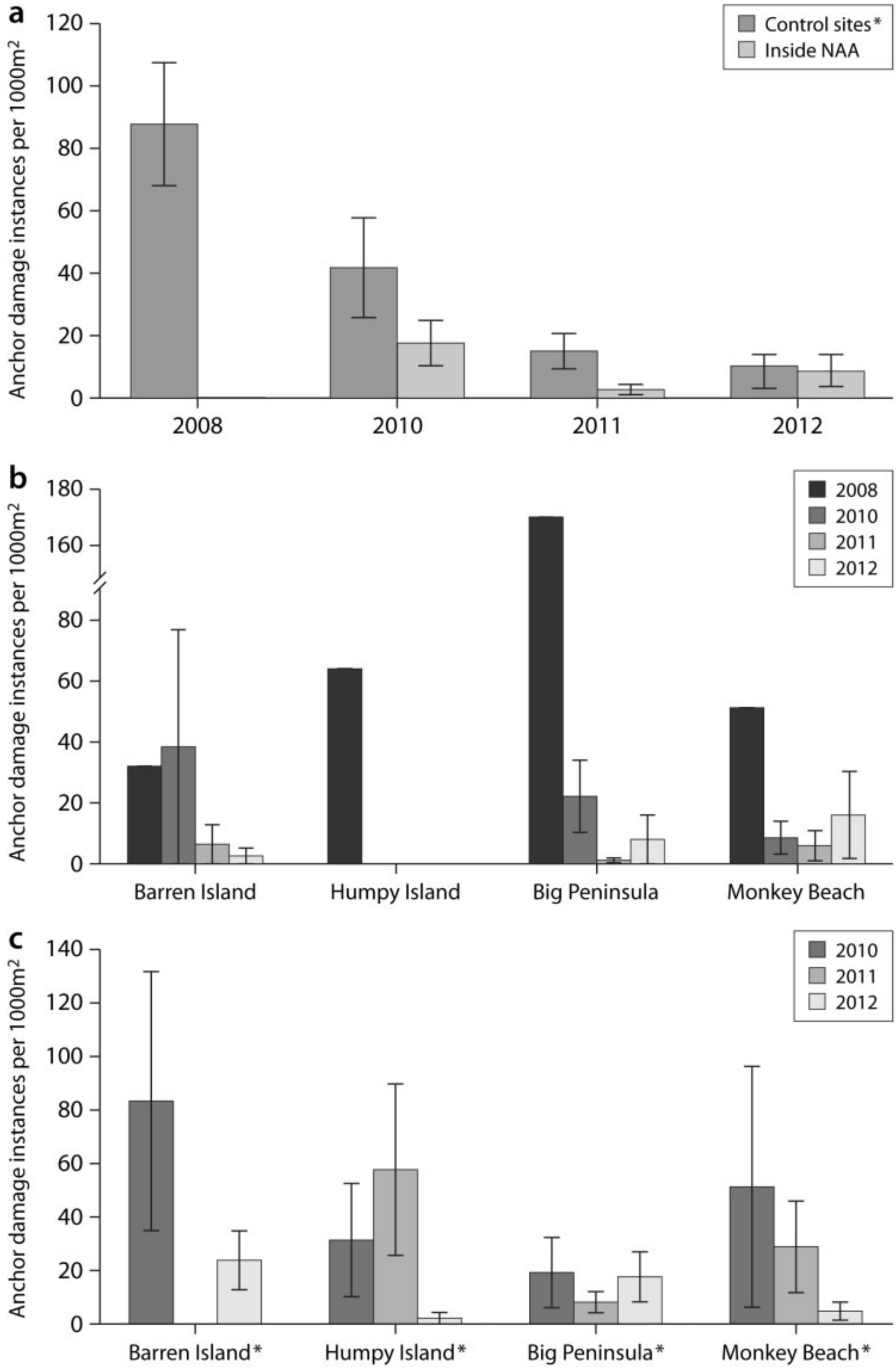


Figure 3. (a) Pooled data for all sites per survey year for pre-NAA sites in 2008 and post-NAA marker installation for 2010, 2011 and 2012; (b) data per survey year per site for NAA; (c) NAA control sites. Error bars are SE and are not shown for 2008 in (b) as those were single surveys.

(± 13.14) to 17.63 (± 9.36)). However, of all four of the control sites this site is furthest from the no-anchoring markers of the NAA so at this location the no-anchoring markers are least likely to deter boaters from anchoring. The data indicate the NAAs are effective in reducing damage to corals where installed, and also appear to reduce anchor damage at areas nearby.

Coral cover declined between 2010 and 2012 at all sites, but still exceeded 25 per cent in 2012 at all sites excepting Humpy Island where cover declined from 80 to 0 per cent during the study period (Thompson et al. 2011). The decline at Humpy Island in the average number of anchor damage instances can certainly be attributed to the loss of nearly all corals at this site. Evidence from the other NAA sites though suggests that if there were still corals at Humpy Island, they likely would have been damaged by anchors far less frequently from 2010–2012 than prior to the NAA being established in early 2009.

Anchor damage is likely to remain low at the four sites where NAAs were installed, as well as at the control sites close by, providing the markers (Figure 1d) are well maintained and that local communities continue to comply with their intent. Although small in scale, the benefit of NAAs is that they actively address a locally significant damaging process that can undermine reef recovery post-disturbance. A study of ecological recovery after the 2006 bleaching event in the Keppel Bay area showed that coral recovery was strong after 2006 due primarily to four factors: (1) the rapid regeneration of remnant coral tissue; (2) very high competitive ability of corals in the Keppel Bay area that allows them to out-compete macroalgae; (3) a natural seasonal decline in the dominant species of macroalgae; and (4) an effective marine protected area (Diaz-Pulido et al. 2009). Coral colonies not damaged by anchors are certainly more likely to be resilient than corals that are severely damaged.

Coral reefs in Keppel Bay have been impacted by flooding every year during recent years and, as a result, are now considered to be in a ‘poor’ state (Thompson et al. 2011). Some reef sites monitored by the Australian Institute of Marine Science marine monitoring program, like Humpy Island, were so severely impacted by the 2011 flood event that they have shown no signs of recovery (Thompson et al. 2011). For these reefs, recovery may depend upon larval supply from adjacent reefs (Hughes et al. 2000). However, recent monitoring data may indicate another reason for this poor recovery; limited settlement of larvae on the reef even when fecundity of adult corals is high. Monitoring shows that high larval settlement onto tiles is not translating into abundant juvenile corals on the natural substrata. Larvae are either avoiding settling onto the available natural substrata or are not surviving even though they are clearly present and viable (Thompson et al. 2011). It is likely that the recovery of coral reefs in Keppel Bay is dependent on a dual mechanism of larval recruitment and growth of surviving fragments, making protecting live coral critical. Efforts to continue to improve water quality are critical as many studies suggest larvae survivorship can be adversely affected by poor water quality (Fabricius 2005; Humphrey et al. 2008).

Community engagement benefits have arisen from the local-scale management action of establishing NAAs in Keppel Bay. The initial workshop meetings and follow-up meetings with the Local Marine Advisory Committee are part of an ongoing two-way exchange between managers and stakeholders about this project. Frequent opportunities have been created in recent years to discuss with community members the demonstrated effectiveness of the NAAs and the need for local-scale actions to support reef resilience. The local community has embraced the project, is clearly complying with the intent of the

NAAs and has been communicating about the project to others visiting Keppel Bay. The process of establishing the NAAs, their demonstrated effectiveness, the signage describing their intent and the ongoing engagement process have increased reef awareness and stewardship. Anchor damage is declining dramatically at areas within and near the NAAs, demonstrating marker buoys are positively changing boating behaviour.

Another benefit of the ongoing engagement with community members is the implementation of the Marine Aquarium Industry's Stewardship Action Plan (Provision Reef 2013) following the 2011 floods. Survey data collected while surveying for anchor damage was used to develop the boundaries for a voluntary moratorium on aquarium collection. The collectors themselves aim to limit the impact of the industry on reefs in the Keppel Bay area by not collecting when reefs are recovering from stress events, including flood-induced coral bleaching.

This project used relatively simple technology to target a locally damaging process – anchoring – to reduce damage to corals at high visitation sites in Keppel Bay. The success of these NAAs is demonstrated by the fact that there is now virtually no anchor damage to corals in these areas, and by the level of community participation in the process and their support for the initiative. The NAAs are effective in reducing anchor damage on coral communities and can positively influence their resilience to other disturbances, albeit at a small scale. This project provides a case study of resilience-based participatory local management that can be applied elsewhere in the GBR and in other reef ecosystems.

## Acknowledgements

This applied research and work was made possible by funding provided by the Climate Change Group of the Great Barrier Reef Marine Park Authority. The work presented has benefited greatly from ongoing support from both the Capricorn Coast Local Marine Advisory Committee and the Marine Aquarium Industry peak body Provision Reef. Field surveys were undertaken with logistical support from the Queensland Department of National Parks, Recreation, Sport and Racing via the Queensland Parks and Wildlife ranger station in Rosslyn Bay. Chris Maple and John Olds served as co-project leads of the fieldwork with the paper authors. Tyrone Ridgeway assisted with analysing the data on anchor damage instances from the 2010 survey year. Quennsland Parks and Wildlife Service rangers led the installation of the no-anchoring markers in 2009 with assistance from the GBRMPA's Field Management Unit. S.K. was supported by Mistra through a core grant to the Stockholm Resilience Centre and the Strategic Research Programme EkoKlim at Stockholm University. J.M. was partially supported by a grant from the LABEX CORAIL program via Université de Perpignan and CRIOBE/EPHE. Figures were developed in collaboration with D. Tracey primarily, as well as R. Banks and C. Malone.

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