Strengthened enforcement enhances marine sanctuary performance

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Abstract
© 2015 The Authors. Marine sanctuaries are areas where the extraction of biota is not permitted. Although most marine sanctuaries have a positive influence on biotic communities, not all sanctuaries are meeting their conservation objectives. Amidst possible explanations (e.g., size, age and isolation), insufficient enforcement is often speculated to be a key driver of marine sanctuary underperformance. Despite this, there are few studies directly linking quantitative enforcement data to changes in biotic communities within marine sanctuaries. Here, we used an asymmetrical-BACI experimental design from 2006-2012 to test whether new enforcement initiatives enhanced abundances of target fishes and threatened species in an existing large sub-tropical marine sanctuary relative to areas open to fishing. Implementation of the new enforcement initiatives in 2010 was associated with a 201% increase in annual fine rate and a significant increase in target fish and elasmobranch abundance, as well as sightings of a critically-endangered shark, in the marine sanctuary relative to areas open to fishing. Overall, these results demonstrate that strengthening enforcement can have a rapid positive influence on target fish and perhaps threatened species in a subtropical marine sanctuary. From this, we contend that increased enforcement guided by risk-based compliance planning and operations may be a useful first step for improving underperforming marine sanctuaries.

Keywords
sanctuary, marine, enhances, performance, enforcement, strengthened

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Strengthened enforcement enhances marine sanctuary performance

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HIGHLIGHTS

- We used a BACI design to test whether greater enforcement improved marine sanctuary performance.
- New enforcement initiatives resulted in a 201% increase in annual fine rate.
- Greater enforcement resulted in more target fish in the marine sanctuary compared to fished areas.
- Strengthened enforcement can help underperforming marine sanctuaries meet conservation goals.

ABSTRACT

Marine sanctuaries are areas where the extraction of biota is not permitted. Although most marine sanctuaries have a positive influence on biotic communities, not all sanctuaries are meeting their conservation objectives. Amidst possible explanations (e.g., size, age and isolation), insufficient enforcement is often speculated to be a key driver of marine sanctuary underperformance. Despite this, there are few studies directly linking quantitative enforcement data to changes in biotic communities within marine sanctuaries. Here, we used an asymmetrical-BACI experimental design from 2006–2012 to test whether new enforcement initiatives enhanced abundances of target fishes and threatened species in an existing large sub-tropical marine sanctuary relative to areas open to fishing. Implementation of the new enforcement initiatives in 2010 was associated with a 201% increase in annual fine rate and a significant increase in target fish and elasmobranch abundance, as well as sightings of a critically-endangered shark, in the marine sanctuary relative to areas open to fishing. Overall, these results demonstrate that strengthening enforcement can have a rapid positive influence on target fish and perhaps threatened species in a subtropical marine sanctuary. From this, we contend that increased enforcement guided by risk-based compliance planning and operations may be a useful first step for improving underperforming marine sanctuaries.

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1. Introduction

Global concern for marine conservation has driven an unprecedented increase in the establishment of marine protected areas (MPAs) (Edgar et al., 2014; Halpern et al., 2010). A small percentage of these MPAs are marine sanctuaries (or marine reserves), in which the extraction of living resources is not permitted (Gaines et al., 2010). Marine sanctuaries have an important role in conserving biodiversity (Edgar et al., 2014), and may also contribute to sustainable fisheries (e.g., Harrison et al., 2012). Although marine sanctuaries generally have a positive influence on marine environments, not all sanctuaries meet their conservation objectives (Guidetti et al., 2008).

In order to maximize the conservation benefit of marine sanctuaries, researchers have distilled a number of key attributes associated with positive environmental outcomes (e.g., size and degree of isolation, Edgar et al., 2014, or habitat quality, intensity of surrounding exploitation, Roberts, 2000). There is, however, growing recognition of the necessity of compliance with regulations to ensure long-term conservation benefits (Byers and Noonburg, 2007; Guidetti et al., 2008; Kelaher et al., 2014). It has been postulated that enforcement and compliance is essential to ensure positive ecological outcomes; otherwise an MPA may be protected in name only (Claudet and Guidetti, 2010; McCook et al., 2010).

An essential goal of effective marine sanctuary management is, therefore, to maximize compliance with regulations. Stakeholder incentives, careful planning, education and outreach programs contribute to this goal (Read et al., 2011). However, it is the deterrent created by effective legislation and enforcement that often drives high levels of compliance (Shimshack, 2007). Effective enforcement of marine sanctuary regulations routinely involves risk-based prioritization of illegal activities and tactical enforcement strategies aimed at optimal deployment of available resources (e.g., NSW Marine Parks Authority, 2009). Ultimately, the deterrent effect relies on those being regulated believing that there is a reasonable probability of being apprehended and, if caught, that the penalty will outweigh the benefits of non-compliance (Rossiter and Levine, 2014; Shimshack, 2007).

We evaluated the influence of strengthened enforcement of the Cape Byron Marine Park (CBMP) (22,000 hectare multi-use marine park on the North Coast of New South Wales (NSW), Australia) on the performance of the largest marine sanctuary (Cape Pinnacle sanctuary, IUCN Protected Area Categories II) inside the park. The zoning plan for the CBMP commenced on the 1st of May 2006, after which activities withinthepark(e.g.fishing,commercialuse,developmentandrecreational(CapePinnaclesanctuary,IUCNProtectedAreaCategoriesII)insidethepark.ThezoningplanfortheCBMPcommenced

2. Materials and methods

2.1. Study site and experimental design

Three locations were sampled to test the hypothesis that abundances of target fish and threatened species in the marine sanctuary at Cape Pinnacle (28° 37′ 12″S, 153° 38′ 24″E) were enhanced relative to fished areas after the implementation of new enforcement initiatives. The locations were established in the only areas with substantial deep reef habitat (25–40 m in depth) in the Cape Byron region (Jordan et al., 2010). As well as the Cape Pinnacle sanctuary, two reference locations were sampled in areas open to fishing (Billinudgel (28° 30′ 36″S, 153° 34′ 12″E) and North Julian reefs (28° 35′ 24″S, 28° 35′ 24.00″S)). At each location the fish assemblages were sampled six times from 2006 to 2009 (3 May 06–12 June 06, 11 Dec 06–17 Jan 07, 7 Dec 07–14 Mar 08, 9 Aug 08–2 Sep 08, 19 Jan 09–06 Feb 09 and 29 Oct 09–15 Dec 09). By mid-2010, the new enforcement initiatives had taken effect, after which the fish assemblages in each location were re-sampled twice more (27 Jun 11–01 Sep 11 and 01 Aug 12–11 Sep 12).

The combination of a marine sanctuary and two reference locations sampled before and after the new enforcement initiatives allowed for an asymmetrical BACI comparison to evaluate the influence of strengthened enforcement on fish
assemblages. For these analyses, a significant BACI interaction term indicates that there is a relevant change in an impacted area concomitant with an environmental disturbance or management intervention that is not observed in replicated reference locations. Importantly, for BACI comparisons it is not essential that the reference locations are similar, but instead represent the general population of reference locations in the broader study area (Underwood, 1993; Kelaher et al., 2003). In this case, the locations of Billinudgel and North Julian reefs represented the only deep reef habitats open to fishing around Cape Byron, and there were no other appropriate options for further independent reference locations (Kelaher, 2013).

2.2. Sampling of fish assemblages and compliance information

Hypotheses about changes in fish assemblages from before to after the implementation of new compliance initiatives were assessed using baited remote underwater video (BRUV). In many situations, BRUV units are preferred over other sampling techniques because they are a non-destructive sampling technique appropriate for high conservation areas (Klanges et al., 2014), they provide a permanent visual record of surveys (Gladstone et al., 2012), they can be deployed in environments unsuitable for conventional diver-based assessments (Gladstone et al., 2012), and they provide useable estimates of the relative abundance of economically-important species (Lowry et al., 2012).

In each location, BRUV units were deployed at approximately 50–100 m intervals onto reef habitat at depths between 25 and 40 m. BRUV units were deployed at each location until 6–12 adequate replicates with 30 min bottom times were obtained, with replicates being discarded without analysis if they had poor camera angles or an obscured field of view. The number of replicate deployments was based on optimization analyses conducted by Dasey (2010) and BRUV units deployed for 30 min provide a reliable and representative estimates of fish assemblages on NSW reefs (Harasti et al., 2015). Each BRUV unit had a flexible frame containing a video camera pointed at a bait container mounted horizontally at the end of a 1.5 m long bait arm. For each BRUV deployment, the bait was replenished with ~500 g of pilchards (Sardinops spp.); an optimal bait for NSW reef fish (Wraith et al., 2013).

BRUV footage was analysed in the laboratory using a field of view 2 m behind the bait container, which represented a standardized area of 9.4 m². For each replicate BRUV deployment, species richness, total max n, and max n of each fish species was determined from video analysis. Max n for a species was the maximum number of individuals in any frame and total max n was the sum of max n’s for each deployment (Cappo et al., 2004). Max n for target and non-target species was the sum of the max n’s for each species in that group at each deployment.

Data on enforcement actions in the CBMP were obtained from the NSW Department of Primary Industries Nautilus database. Data were extracted on the number of fines issued by marine park staff under the NSW Marine Parks Act 1997 and Regulations from 2006 to 2012. Data on the number of offshore patrols were obtained from the vessel log books of the CBMP.

2.3. Analysis of data

BACI analyses included three factors: before versus after the implementation of new enforcement initiatives (BA, orthogonal and fixed), locations (Lo, orthogonal and random) and times of sampling (T, nested within BA and random). Within the factor of location, a planned contrast was done between the Cape Pinnacle sanctuary (S) and fished areas (F) (SF term) to create the BA × SF term (equivalent to a BA × CI term). Seasons were not incorporated into analyses because this was not a major driver of temporal variation on deep (>20 m) subtropical reefs (Online appendix A). Hypotheses were tested using permutational multivariate analysis of variance (permanova) (Anderson, 2001), which is robust to highly variable ecological data commonly obtained from marine communities (Kelaher, 2002; Bishop and Kelaher, 2008). Euclidean distance was used to generate similarity matrices.

Hypotheses were tested for the richness and total max n of fish assemblages, as well as the max n of target and non-target species. Target species were defined as those listed in the NSW Status of the Fisheries Report (Rowling et al., 2010) or in the Stock Status of Queensland’s Fisheries (Queensland Government, 2011). All remaining species were considered non-target species. Hypotheses were also tested about the max n of elasmobranchs because of their vulnerability to fishing pressure due to relatively low population growth rates and weak density-dependent compensation in juvenile survival (Dulvy et al., 2014). Analyses were also carried out on the max n’s of five individual fish species (Venus tusk fish (Choerodon venustus), Pearl perch (Glaucosoma scapulare), Moses perch (Lutjanus russelli), Snapper (Chrysophrys auratus) and Tarwhine (Rhabdosargus sarba)). Each of these species is valued by recreational and commercial fishers and is under significant fishing pressure (Rowling et al., 2010; Queensland Government, 2011). These important species demonstrated the different types of observed responses (positive, negative and no change) to strengthened enforcement.

The study area contained critically-endangered Grey nurse sharks (Carcharias taurus), and vulnerable Great white sharks (Carcharodon carcharias) and Black cod (Epinephelus daemelii). Although rare, Grey nurse sharks and Black cod were observed often enough to use binomial probability tests (Sokal and Rohlf, 1995) to evaluate whether they were seen in the Cape Pinnacle sanctuary more than could be expected by chance.

3. Results

In the year following the commencement of the Cape Pinnacle sanctuary, there were 48 offshore patrols but no fines issued in the CBMP (Fig. 1). This coincided with an important advisory period where community awareness was the major
Fig. 1. Average (±1 SE) number of fines and offshore patrols in the Cape Byron Marine Park from 2006 to 2012. The dashed lines indicate the period in which the new enforcement initiatives were implemented.

compliance objective. From 2007 to 2009, there was an average of 29.0 offshore patrols/yr and 8.3 fines/yr in the CBMP. After the implementation of the new enforcement initiatives, the number of offshore patrols/yr reduced marginally, but the fine rate tripled to 25.0 fines/yr. The slight reduction of patrols may be due to a number of factors, such as the increased administrative burden resulting from the larger fine rate.

Following the implementation of the new enforcement initiatives there was a significant increase in target fish species in the Cape Pinnacle sanctuary relative to reference areas (BA×SF, P < 0.05, Table 1, Fig. 2). From before to after the new enforcement initiative implementation, the average max n of target species increased by 81% in the Cape Pinnacle sanctuary and decreased by 10% in the reference locations. This result was driven by a significant relative increase in the max n of highly valued fishes, including Moses perch (L. russelli), Pearl perch (G. scapulare), and Snapper (C. auratus), in the Cape Pinnacle sanctuary from before to after the implementation of new enforcement measures (BA×SF, P < 0.05, Fig. 2). There were exceptions, however. Changes in the max n of Tarwhine (R. sarba), for example, did not correspond to the implementation of new enforcement initiatives (BA×SF, P = 0.69, Table 1, Fig. 2). Furthermore, the max n of Venus tusk fish (C. venustus) exhibited a significant BA×SF interaction, but in a negative direction (Table 1, Fig. 2).

In terms of fishes with higher risks of overfishing, elasmobranchs were positively associated with implementation of new compliance measures (BA×SF, P < 0.05, Table 1, Fig. 3). Furthermore, 11 out of 12 sightings of the critically endangered Grey nurse shark (C. taurus) were in the Cape Pinnacle sanctuary, which is more than can be expected by chance (Binomial probability test, P < 0.01). Moreover, 11 of the 12 sightings were made after the implementation of new enforcement initiatives. The 10 sightings of vulnerable Black cod (E. daemelii) were all in the Cape Pinnacle sanctuary, with none in fished areas, which is more than can be expected by chance (Binomial probability test, P < 0.01). Of the 10 sightings, 6 occurred in the two times of sampling following the implementation of new enforcement initiatives. There was only one observation of a Great white shark (C. carcharias).

The implementation of the new enforcement initiatives did not cause significant changes in the richness of fish species or in the overall abundance of non-target species (Table 1, Fig. 3). When target and non-target species were combined (total max n), there was a non-significant trend towards a BA×SF interaction (P = 0.08, Table 1, Fig. 3) and a significant main effect demonstrating more fish in the Cape Pinnacle sanctuary than in areas open to fishing (SF, P < 0.05, Table 1, Fig. 3). When the temporal trend is considered, there were on average more fish in locations open to fishing than in the Cape Pinnacle sanctuary for the first two times of sampling (Fig. 3). For the remaining six times of sampling, this pattern was reversed suggesting that the positive influence of sanctuary protection was evident about one year after its establishment. Nonetheless, the most substantial changes in total max n occurred after the improvements to enforcement.
resulted in positive results. As a clear example, the relative difference in total maximum abundance in the Cape Pinnacles sanctuary prior to the new enforcement initiatives being implemented (Online appendix B).

sometarget species (e.g., Red morwong (Mulloway) increased throughout without the implementation of the new enforcement initiatives. Indeed, the total maximum abundance of prey species (e.g., fish and elasmobranchs) would be expected that the difference in fish abundances in the Cape Pinnacles sanctuary relative to fished areas would have increased through time without the implementation of the new enforcement initiatives. Indeed, the total maximum abundance of Grey nurse shark sightings may be associated with the increased abundance of prey species (e.g., fish and elasmobranchs). Although some caution is needed due to low sighting rates and temporal variation in site occupation, our results support the view that well-placed and well-enforced marine sanctuaries can play an important role in conserving critically endangered and vulnerable species (e.g., Lynch et al., 2013).

As well as common target species, the strengthened enforcement of the CBMP was associated with a significantly larger number of sightings of critically-endangered Grey nurse sharks (C. taurus) in the Cape Pinnacles sanctuary. The total size of the east Australian Grey nurse shark population is estimated to be between 1000–1500 individuals (Ahonen and Stow, 2010; Cardno Ecology Lab, 2010) and declining (Otway et al., 2004), despite extensive conservation measures (e.g., protected areas to safeguard aggregation sites, fishing bans and diver advisory programs). For the Cape Pinnacles sanctuary, the high proportion of Grey nurse shark sightings may be associated with the increased abundance of prey species (e.g., fish and elasmobranchs). Although some caution is needed due to low sighting rates and temporal variation in site occupation, our results support the view that well-placed and well-enforced marine sanctuaries can play an important role in conserving critically-endangered and vulnerable species (e.g., Lynch et al., 2013).

As our sampling commenced when the Cape Pinnacles sanctuary and the CBMP compliance program were first established, it would be expected that the difference in fish abundances in the Cape Pinnacles sanctuary relative to fished areas would have increased through time without the implementation of the new enforcement initiatives. Indeed, the total maximum abundance of Grey nurse sharks (C. taurus) and Silver sweep (Scorpis lineolata) showed greater relative abundance in the Cape Pinnacles sanctuary prior to the new enforcement initiatives being implemented (Online appendix B). Despite this, the timing and magnitude of changes in target species abundances between the Cape Pinnacles sanctuary and fished areas, supported by significant BA × SF interactions, provides convincing evidence that this management intervention resulted in positive results. As a clear example, the relative difference in total maximum abundance of Grey nurse sharks (L. russelli) between the Cape Pinnacles sanctuary and fished areas increased by 467% from before to after implementation of enhanced enforcement. This is almost three times the global average, including much older and larger marine sanctuaries (167%, n = 118 sanctuaries, Lester et al., 2009). Notwithstanding our clear results, future studies including more marine sanctuaries subject to modified enforcement strategies or changes in fish assemblages monitored over longer periods could improve the generality of conclusions.

Relative to studies on marine sanctuary (or reserve) planning principles (e.g., size, adjacent land use and isolation), there is much less quantitative evidence linking enforcement activity with marine sanctuary performance (Bergseth et al., 2013). To date, this has mostly taken the form of correlational analyses associating differences between fished areas and sanctuaries with some measure of enforcement (e.g., Kelsey et al., 2014). Alternatively, compliance information has been used to categorize marine protected areas into discrete levels (e.g., low, medium and high compliance), which is then used to compare sanctuary performance (e.g., Edgar et al., 2014 and Guidetti et al., 2008). In general, past work has highlighted the important role of enforcement in the efficacy of marine sanctuaries (Edgar et al., 2014; Guidetti et al., 2008; Kelsey et al., 2014),

Table 1

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<tr>
<th>Location = Lo</th>
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4. Discussion

Our study represents one of the first BACI experiments assessing the influence of strengthened marine park enforcement on fish assemblages in an existing marine sanctuary compared to similar habitats open to fishing. The enhanced enforcement, which included a 201% increase in annual fine rate, was associated with a substantial improvement in the conservation value of the marine sanctuary. For the most part, this was driven by an overall increase in target species and elasmobranchs, which is strongly indicative of decreased fishing pressure (Edgar et al., 2014). In the case of Venus tusk fish (C. venustus) the opposite pattern was shown, which is likely the result of changing ecological processes (e.g., competition, Micheli et al., 2004). Similar to studies on the implementation of new marine sanctuaries (e.g., Edgar and Barrett, 2012), some target species, non-target species and species richness did not show significant short-term changes in response to the strengthened enforcement.

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although this has been complicated by variation in age, size and other key factors among sanctuaries. Our BACI approach avoids these complications by attributing strengthening enforcement measures to a distinct enhancement of target fish in an existing marine sanctuary. Importantly, other studies would have concluded the level of enforcement in CBMP to be high even before the new enforcement initiatives were implemented (see Edgar et al., 2014). Our results, therefore, demonstrate that strengthened enforcement can have a positive influence on marine sanctuary performance, even when the existing enforcement level was already in the upper spectrum on a global scale.

The combination of a perceived risk of being apprehended and a substantial fine outweighing possible benefits acts as a significant deterrent to non-compliance (Rossiter and Levine, 2014; Shimshack, 2007). Here, the tripling of the fine rate combined with the increased enforcement capacity from two specialist compliance officers supported by two rangers produced a strong deterrent against non-compliance. In particular, the two well-trained compliance specialists allowed for greater tactical enforcement (e.g., intelligence gathering operations and night patrols) targeting high risk offenders and activities.
This can be critical because often fishers with the skill and equipment to illegally take large numbers of fish also know how to minimize their chances of being apprehended.

The introduction of standardized guidelines for issuing fines and reporting on compliance effort were also important components of the new enforcement initiatives. In particular, the standardized enforcement guidelines ensured that the minimum penalty for fishing in a sanctuary was a $500AUD fine or, given defined extenuating circumstances, issued an official written caution. This effectively removed the discretion of officers to issue verbal cautions, and helped to ensure fishers believed there were genuine consequences for illegal fishing. The detailed reporting of enforcement activity to a central compliance database was also an important step forward, as it facilitated quantitative analysis of enforcement performance providing a platform for adaptive management of strategically-targeted compliance activities. It also enabled compliance statistics to be correlated to marine sanctuary performance, linking management operations to conservation outcomes (Kelaher et al., 2014).

Once marine sanctuaries are established, it is often difficult to change attributes that may be important to performance, such as size, adjacent land use or degree of isolation. In contrast, it is relatively straightforward to improve enforcement if resources are available. Our results show that strengthening enforcement can have rapid positive influences on target fish in an existing marine sanctuary and may also benefit threatened species. If appropriate laws are in place, we contend that strengthened enforcement founded on risk-based tactical compliance planning may be a prudent first step to improve the likelihood that marine sanctuaries meet their conservation goals.

Acknowledgements

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2015.02.002.