

## Progress towards conserving Tonga's coral reefs

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The Kingdom of Tonga's fifth national report to the Convention on Biological Diversity (Anon. 2014) and the report on the status of coral reefs of the Pacific for 2011 (Chin et al. 2011) both list Tonga's coral reef and reef fish fisheries as data deficient, unknown or not considered. While the area of coral reef in Tonga is extensive and many people are reliant on its reef fish fishery, "there has been little scientific monitoring and assessment of most reef areas and many have not been mapped or surveyed" (Chin et al. 2011:197).

In 2002, amid growing concerns over the security of Tonga's marine resources, the Tongan government implemented two-part, community-based marine management under the Special Management Area (SMA) programme. First, through legislative action, each SMA community is granted exclusive access to fishing grounds adjacent to their village. Second, in exchange for this access, a subset of the area must be designated as a permanent no-take zone, termed a fish habitat reserve (FHR). The incentive of exclusive access to fishing grounds in exchange for creating no-take areas has made the SMA programme extremely popular with Tongan coastal communities and, as a result, it has expanded rapidly in recent years. As of December 2019 approximately 50 SMAs have been implemented, 42 of which only since 2014.

While the expansion of the SMA programme has clearly been successful, the paucity of data on Tonga's marine environment made it difficult to determine whether its objectives were being achieved. Ultimately, the success of the SMA programme relies on improving coastal fisheries resources and conservation outcomes, not on creating more SMAs. Determining whether the SMA programme is achieving its aims relies first on having a clear understanding of the state of coastal fisheries resources, and second on being able to attribute changes in these resources to management and not other confounding factors.

Impact is defined as the intended or unintended consequences that are directly or indirectly caused by an intervention (Pressey et al. 2015). Determining impact, however, can be challenging as it involves estimating the counterfactual condition of no action or a different action. Accurately determining impact consists of identifying to what extent observed conditions are the results of the intervention (e.g. SMAs and FHRs), and to what extent environmental or social contextual factors are masking intervention failure or exaggerating successes. Conservation policies and actions, however, are rarely

evaluated for their impact (Pressey et al. 2015); few management areas have been evaluated for their past impact and even fewer proposed management areas for their potential future impacts. This trend is equally clear in fisheries management and protected area research in the South Pacific.

From 2016 to 2019 the first stage of a national monitoring programme of Tonga's coral reefs and reef fish fishery was implemented. This project aimed to provide Tonga with crucial information in order to improve the management of its coastal fisheries resources and overall health of its coral reef ecosystem. Ecological surveys of reef fish and benthic community composition were conducted at 270 sites across Tongatapu, Ha'apai and Vava'u, both inside and outside of existing or proposed management areas (Fig. 1).

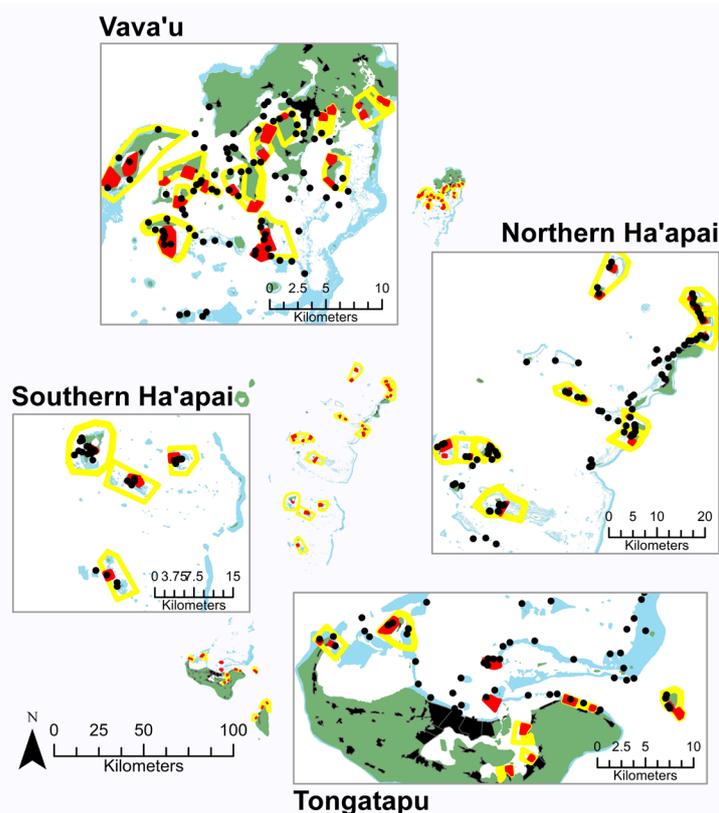


Figure 1. Maps of Tonga's main island groups outlining the current extent of both the Special Management Area programme and the ecological surveys used for this study. Yellow outlines are the Special Management Areas, where only registered members of the community can fish. Red outlines are Fish Habitat Reserves, which are permanent no-fishing zones. Black circles are survey sites and each black outline on land is a village.

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These surveys enabled the production of maps of target species density (Fig. 2) and biomass, reef fish species richness, and coral cover.

In addition, 17 socioenvironmental data layers were built or compiled covering the entirety of Tonga's coral reef ecosystem. These data were not only useful for determining the overall status of Tonga's coral reefs and reef fish fishery, but has also enabled a comprehensive impact evaluation of the SMA programme to be completed. An explicit aim of this project has, therefore, been to use the Tongan SMA programme as a case study for advancing the field of impact

evaluation in the community context as well as in the South Pacific. Specifically we: 1) looked back to assess the impact of the oldest established management areas in the country, and 2) used predictive techniques to look forwards at the potential long-term impacts of new or proposed management areas. While some of this work is still unpublished, it is anticipated that it will all be available by mid-2020 (Table 1). A national report is also in preparation, which will provide an overview of the findings written for the general public as well as detailed information on the ecological status of 49 individual SMA communities (Table 1).

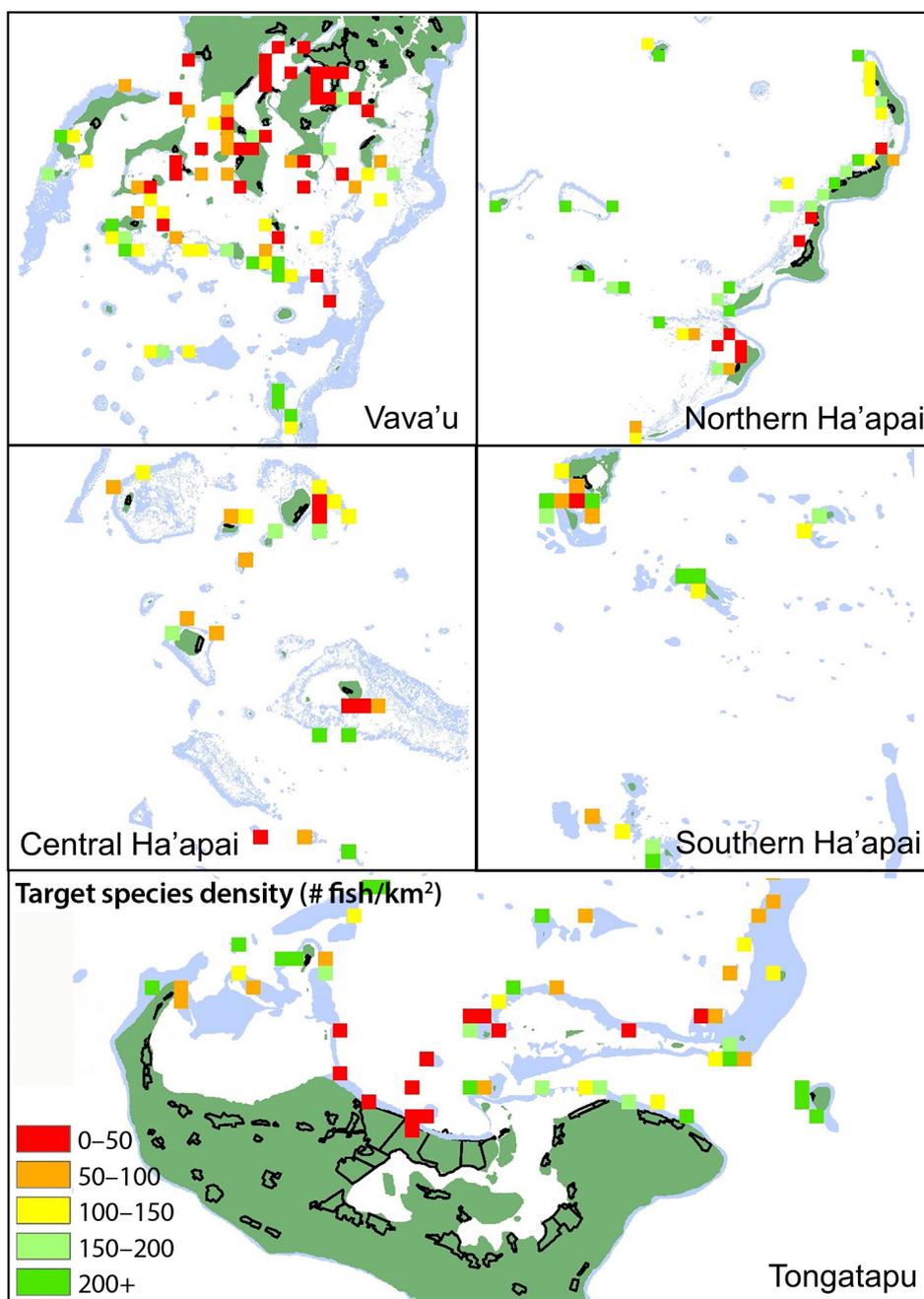


Figure 2. Target species density in surveyed areas.

Table 1. List of completed or ongoing projects with a focus on Tonga's coral reefs, reef fish fishery or Special Management Area programme.

Project	Publishing status	Objectives	Main findings
Ecological and socioeconomic impacts of marine protected areas in the South Pacific: assessing the evidence base	2019	To determine: <ol style="list-style-type: none"> <li>i) The overall ecological and socioeconomic impacts of marine protected areas in the South Pacific.</li> <li>ii) What factors are associated with positive, neutral and negative impacts in the region.</li> <li>iii) To what extent the protected area evaluation literature from the region has incorporated counterfactual thinking and robust impact evaluation techniques.</li> </ol>	Based on 52 identified studies, 42% of measured ecological impacts and 72% of socioeconomic impacts were positive. The proportion of positive impacts was comparable between community-based and centrally governed management areas. There was little evidence of long-term recovery inside periodically harvested closures. Most studies (59%) did not provide any clear consideration of factors beyond the presence of management areas that could have confounded their results. We conclude that counterfactual thinking has yet to be embraced in impact evaluation studies in the region.
Tongan socioenvironmental spatial layers for marine ecosystem management	In review	To provide an open source socioenvironmental dataset covering Tonga's near-shore marine ecosystem. Compiled from various global layers, remote sensing projects, local ministries and the 2016 national census.	The dataset consists of 11 environmental and 6 anthropogenic variables summarised in ecologically relevant ways, spatially overlaid across the nearshore marine ecosystem of Tonga. The environmental variables selected include: bathymetry, coral reef connectivity, distance from deep water, distance from land, distance from major terrestrial inputs, habitat, land area, net primary productivity, salinity, sea surface temperature, and wave energy. The anthropogenic variables selected include: fishing pressure, management status, distance to fish markets, distance from villages, population pressure, and a socioeconomic development index based on population density, growth, mean age, mean education level, and unemployment.
Coral reef annihilation, persistence and recovery at Earth's youngest volcanic island	2019	To examine the destruction, persistence and initial recovery of reefs associated with the hydromagmatic eruption that created Earth's newest landmass, the Hunga Tonga–Hunga Ha'apai volcanic island in the Tongan archipelago.	Despite extreme conditions associated with the eruption, impacts on nearby reefs were spatially variable. Importantly, even heavily affected reefs showed signs of rapid recovery driven by high recruitment, likely from local refuges. The remote location and corresponding lack of additional stressors likely contribute to the resilience of Hunga's reefs, suggesting that in the absence of chronic anthropogenic stressors, coral reefs can be resilient to one of the largest physical disturbances on Earth.
Towards reducing misrepresentations of national achievements in marine protected area targets	2018	To highlight the large-scale misrepresentation, by up to two orders of magnitude, of national marine protected area coverage from two Pacific Island nations in multiple online databases and subsequent reports, including conclusions regarding achievements of Aichi 11 commitments.	Tonga's marine protected area coverage in the World Database on Protected Areas (WDPA) was falsely listed as 10,133.82 km <sup>2</sup> due to the inclusion of a massive 10,000 km <sup>2</sup> paper park, the Ha'apai Conservation Area. In addition, the Phoenix Island Protected Area, one of the largest MPAs in the world (397,447 km <sup>2</sup> ) was also listed twice in the WDPA.
Incentivising marine management: mechanisms driving the successful national expansion of Tonga's Special Management Area programme	In prep	To identify key characteristics of the SMA programme that have enabled it to successfully avoid two common pitfalls in the expansion of protected areas globally: i) the difficulty of incentivising groups to also manage resources when their livelihoods depend on them, and ii) that many protected areas are situated residually, or in areas with limited value for extractive activities.	Providing immediate incentives (e.g. SMAs as exclusive access zones) that also foster long-term care for natural resources, encourage groups that otherwise may be against management and conservation to implement no-take protected areas (e.g. FHRs). Then ensuring that protected areas occur within the boundaries of these exclusive access zones entices groups to protect areas of greater extractive value than they would likely do so otherwise.

Community-based marine management yields positive impacts for coastal fisheries resources and biodiversity conservation	In prep	To conduct a rigorous ecological impact evaluation comparing the current ecological state of the 15 oldest community-based management areas in Tonga with their estimated counterfactual conditions. We use statistical matching of 11 ecological and socioeconomic variables and a national coral reef baseline dataset constituting 1628 transects.	A two-part approach to marine conservation, whereby communities are granted exclusive access to nearby reefs as an incentive to establish no-take zones, can yield positive impacts on a national level for both coastal fisheries resources and biodiversity conservation. No-take FHRs had significantly greater reef fish diversity as well as biomass, density and length of target species. There was, however, limited evidence of any difference between areas open to all fishing and the SMAs, where community members are allowed to fish.
Predicting impact to assess the efficacy of community-based marine reserve design	2018	Boosted regression trees were used to predict conservation impact to compare recently implemented community-based marine reserves in Tonga to a systematic configuration specifically aimed at maximising impact.	It was estimated that the community-based approach provides 84% of the recovery potential of the configuration with the greatest potential impact. This high potential impact results from community-based reserves being located close to villages, where fishing pressure is greatest. These results provide strong support for community-based marine management, with short-term benefits likely to accrue even where there is little scope for systematic reserve design.
Kingdom of Tonga Special Management Area report 2020	In prep	To provide both a broad overview and detailed synthesis of Tonga's marine resources and the status of the SMA programme. Specifically this document outlines: i) the overall status of Tonga's coral reefs and reef fish fishery, ii) the ecological impacts of the eight oldest SMAs, and iii) detailed baseline data on 41 new SMAs.	<ul style="list-style-type: none"> <li>i) Both fish abundance and diversity are improving in roughly half of the older FHRs in Tonga.</li> <li>ii) There is little evidence of any recovery inside Tonga's SMAs (outside the FHRs), where fishing is still allowed by the community.</li> <li>iii) The coral reefs and reef fish fishery in Vava'u are in noticeably worse condition than elsewhere in the country.</li> <li>iv) There is extensive evidence of damage to reefs from coral bleaching in Vava'u and northern Ha'apai.</li> <li>v) There is extensive evidence of cyclone damage in southern Vava'u and northern Ha'apai.</li> <li>vi) Poor water quality appears to have damaged or killed many reefs around lagoonal areas in both Vava'u and Tongatapu.</li> </ul>

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