



## Co-authors<sup>1</sup>

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## Introduction

Maritime area	1,302,114 km <sup>2</sup>
Land area	18,904 km <sup>2</sup>
Mean land elevation	210 m
Coral reef extent	6,704 km <sup>2</sup>

Located in the south central Pacific, the Republic of Fiji comprises 332 islands and 522 islets with a total land area of 18,904 km<sup>2</sup> and an exclusive economic zone of 1.3 million km<sup>2</sup>. Fiji's coral reefs cover approximately 6,704 km<sup>2</sup>, which represent 10.27% of the total coral reef extent of the GCRMN Pacific region, and 2.68% of the global coral reef extent. A wide variety of coral reefs are found in Fiji including fringing, platform, pinnacles, submerged, barrier, oceanic ribbon, atolls, near-atoll, and drowned reefs. At least 342 species of scleractinian corals, and 1075 reef-associated fish species have been documented in Fiji (Mangubhai et al., 2019).

Around 100 of Fiji's islands are inhabited, with more than 50% of Fiji's the population (total estimated population 864,132) residing in urban areas (477,500) (Fiji Bureau of Statistics, 2021). Indigenous Fijians (iTaukei) contribute to around 62% of the total population, followed by Indo-Fijians (34%), and other ethnic groups (4%). We estimated the human population of Fiji living within 5 km from coral reefs to be 468,453 inhabitants, in 2020. This represents 50.52% of the total human population of Fiji living within 5 km from coral reefs. We estimated that the human population living within 5 km from coral reefs has increased by 10.84% between 2000 and 2020.

Fiji's land-sea tenure system is deeply rooted in customary ownership, where iTaukei communities have ownership rights over land and access rights to adjacent marine areas (Veitayaki, 2000). Nearshore coral reefs fall within iTaukei customary fishing grounds (qoliqoli) which extend from the foreshore to the outer edge of the reef, are subject to a dual system of management under both customary and statutory laws, whereby communities have access rights and stewardship over their resources and the ownership of the seabed and overlying resources rests with the State (Sloan and Chand, 2016). There are 411 registered qoliqoli areas in Fiji covering approximately 30,011 km<sup>2</sup>, with several coastal communities sharing access rights to the same fishing grounds. The state retains authority over the seabed and marine resources, and therefore all commercial uses of marine waters (including in qoliqoli areas), requires a licence. This dual management system presents challenges for regulating inshore fisheries and in balancing resource use, biodiversity conservation and protecting customary rights.

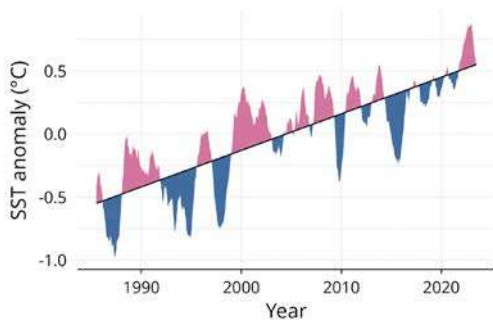
## Threats

### Thermal regime

The long-term average of SST on coral reefs of Fiji between 1985 and 2023 was 27.51°C (Supplementary Figure 1). SST over coral reefs of Fiji have increased by 1.06°C between 1985 and 2023, which corresponds to a warming rate of 0.028°C per year (Supplementary Figure 1). In Fiji, the highest SSTs occur in December to March each year (Supplementary Figure 2).

<sup>1</sup> The term co-authors encompasses both individuals who contributed to writing the chapter and those who provided data. Therefore, inclusion in this list does not necessarily imply endorsement of the chapter's content. Specific contributions are detailed in the Author Contributions section.

Widespread coral bleaching and associated mortality (estimated 40–80% of corals) were documented across the archipelago in the 2000 during a La Niña event (Cumming et al., 2006). Smaller, more localised bleaching events have often been reported regularly since during the warmest months (February–April), without strong evidence of significant bleaching-related mortality (Mangubhai et al., 2019). In 2019, SSTs in Fiji ranged from 27–31°C between the months of January to May, with the highest levels of coral bleaching were recorded in March and April, primarily in the Yasawa (40%), Taveuni (>40%) and Beqa (>40%), and 5–20% recorded along the Coral Coast (WCS 2019). However, bleaching did not persist and most corals had returned to normal by May and June as SSTs dropped.



▲ **Figure 2.4.1.** Average Sea Surface Temperature (SST) anomaly from 1985 to 2023 over coral reefs of Fiji. The black line is the long-term trend in SST anomaly, values below this line are negative SST anomalies (*i.e.* cooler than long-term trend), and values above this line are positive SST anomalies (*i.e.* warmer than long-term trend). Average Sea Surface Temperature (SST) anomaly with null-SST anomaly (*i.e.* 0) as a reference line, instead of the long-term trend in SST anomaly, are provided in Supplementary Figure 3.

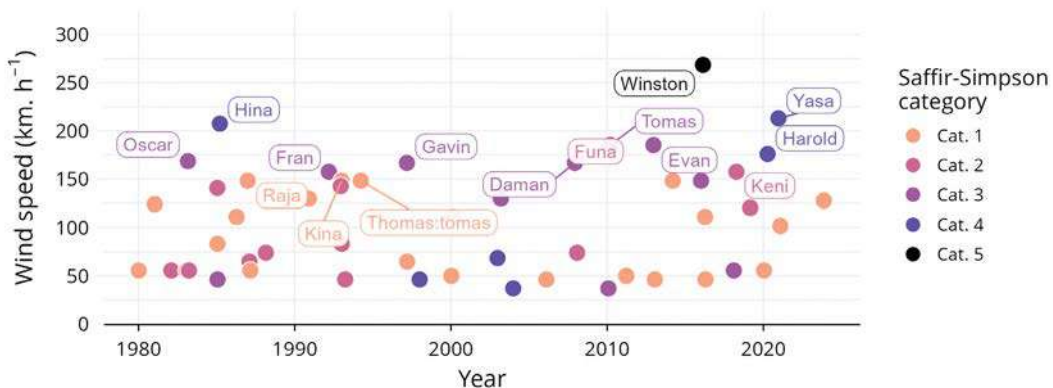
Fiji's reefs have generally displayed high resilience to disturbances, and reduced bleaching impact may be in part explained by the warmer months coinciding with the cyclone season, which can act to dissipate temperature stress (Mangubhai et al., 2019). For example coral bleaching was documented in 2016 in the weeks leading up to Tropical Cyclone Winston, with in situ temperatures on inner reef flats along

the Coral Coast reaching a high of 35°C (Mangubhai, 2016). Rapid assessments in the Vatu-i-Ra Seascape in March 2016 indicated that the average percentage of bleached corals was highest at Gau (20.2±8.6%) and reefs in the Eastern Bligh Waters (7.0±4.8%). Immediately following the cyclone, SSTs in Fiji dropped by 1–2°C and satellite imagery showed hot spots and temperature anomalies dissipating.

## Cyclones

Between 1980 and 2023, a total of 112 tropical storms passed within 100 km distance from a coral reef of Fiji, and of these 29 were characterized by sustained wind speed greater than 100 km.h<sup>-1</sup> (Figure 2.4.2). The cyclone with the highest sustained wind speed over the studied period was the cyclone Winston, in 2016, which passed 0 km from a coral reef with sustained wind speed of 269 km.h<sup>-1</sup>.

Tropical cyclone Winston - a category 5 storm on the Saffir-Simpson scale - generated waves up to 30 standard deviations higher than routine wave conditions in some areas (Price et al., 2021) and caused significant damage to corals and the reef matrix down to 30 m depth in 2016 (Mangubhai, 2016). Some reefs lost up to 90% of their hard coral following the cyclone, primarily driven by losses of branching and tabulate *Acropora* spp., but substantial recovery was documented already by 2020 (Ford et al., in review). Tropical cyclone Yasa that made landfall in 2020 was a slow-moving category 4 storm that also resulted in extensive damage to some areas of reef (e.g. in the Somosomo Strait), with evident dislodgement and breakage of corals and increased rubble following the cyclone (Aitken et al., 2021). The other recent category 4 cyclone was Harold, which occurred in 2021 during the COVID-19 lockdown. While there is no documentation of the impact of this cyclone on coral reefs, anecdotal reports suggest it had a significant impact on southern reefs (e.g. around Kadavu Province).



▲ **Figure 2.4.2.** Maximum sustained wind speed of tropical storms passing within 100 km of a coral reef between 1980 and 2023 in Fiji. Colors correspond to the cyclone’s Saffir-Simpson category along its entire track. However, the values of sustained wind speed are extracted from the nearest tropical storm position from a coral reef. For this reason, some sustained wind speed values are below the lower threshold of category 1 Saffir-Simpson scale (*i.e.* 119 km.h<sup>-1</sup>). Note that cyclones passing more than 100 km away from coral reefs of Fiji are not represented, although they may have had an impact.

## Other Threats

Fiji’s coral reefs face a range of compounding and intersecting local threats stemming from anthropogenic activities, including pollution (land and sea-based), sediment, nutrient and chemical runoff, destructive fishing (e.g. duva, a traditional poison), overfishing and poorly planned coastal development (Mangubhai et al., 2019). These stressors can directly damage coral structures, disrupt ecosystems, and impact water quality, leading to reduced coral health and reef resilience (McLeod et al., 2019).

Benthic cyanobacterial mats are an issue on several of Fiji’s reefs, covering up to 50% of the substrate at some reefs during surveys (Ford et al., 2021), with a large study of 150 sites in Fiji revealing that 20% have >10% cyanobacterial coverage (Ford et al., unpubl. data). The mats have been linked to rising temperatures and declining water quality (Ford et al., 2018) and can negatively impact corals, coral recruitment, and herbivory processes (Ford et al., 2021), thus likely reducing system resilience. Many survey protocols do not record mats, lumping them together with other groups or recording the abiotic substrate underneath them, limiting large-scale and long-term comparisons in their coverage.

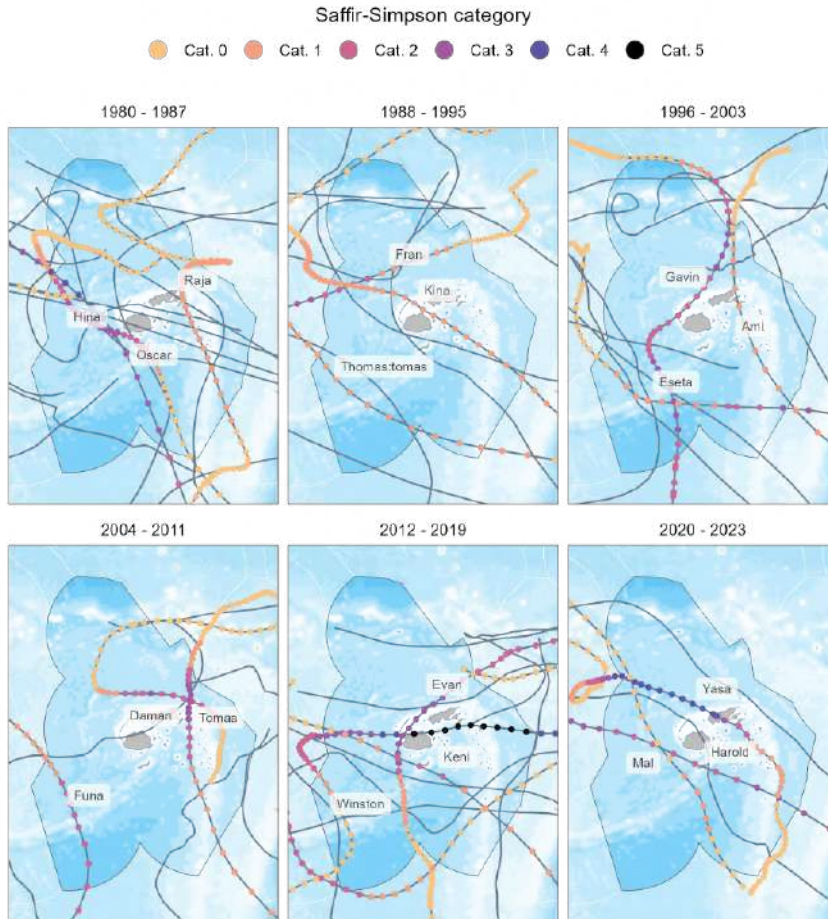
Corals are vulnerable to predators such as crown-of-thorns starfish (COTS) (*Acanthaster planci*) and

*Drupella* snails (Mangubhai et al., 2019) and diseases such as white syndrome, ulcerative white spot syndrome and brown band diseases. However, other signs of stress response, such as pigmentation response and growth anomalies, are commonly sighted on Fijian reefs (Nand, 2020). A study from 38 sites across Fijian reefs in 2013 showed that disease prevalence rates varied across locations, reef types (barrier and fringing reefs) and habitats (fore reefs and reef flats). It also showed that barrier reef systems and forereefs (<10%) recorded higher signs of disease lesions on corals than fringing reefs and reef flats (<3%), respectively. Disease prevalence also varied with coral assemblage and locations (difference between dry and wet sides of the larger islands). Diseases in corals are important as a driver of reef degradation, and there is a need to invest resources to assess long-term trends, seasonal and spatial variations of disease prevalence and incidence across Fijian reefs. The correlation between coral disease and other disturbances such as tropical cyclones, flood events, pollution, sedimentation, coastal development, and tourism is poorly understood in the region (Beeden et al., 2015; Ruiz-Moreno et al., 2012; Haapkyla et al., 2013).

Pollutants including but not limited to sedimentation, nutrients, sewage, heavy metals, (micro)plastics, and pharmaceuticals have been increasingly well-

documented in coastal areas in Fiji, revealing concerning levels in sediments, water and biota at some areas, particularly those close to urban centres and rivers (e.g. Pratap et al., 2020; Dehm et al., 2021; Singh et al., 2009). Although coastal pollution is widely acknowledged as a national issue, there has been little to no research on the direct impacts of different pollutants on coral reefs in Fiji. However, research has suggested that some corals

near the urban centre of Suva remain adapted to their environment, exhibiting recruitment rates comparable to those in less polluted areas (Lal et al., 2018). Furthermore, comparisons with historical navigational charts suggest that the overall coral reef area has been maintained over time (Lawson et al., 2021), though community changes and degradation have likely occurred.

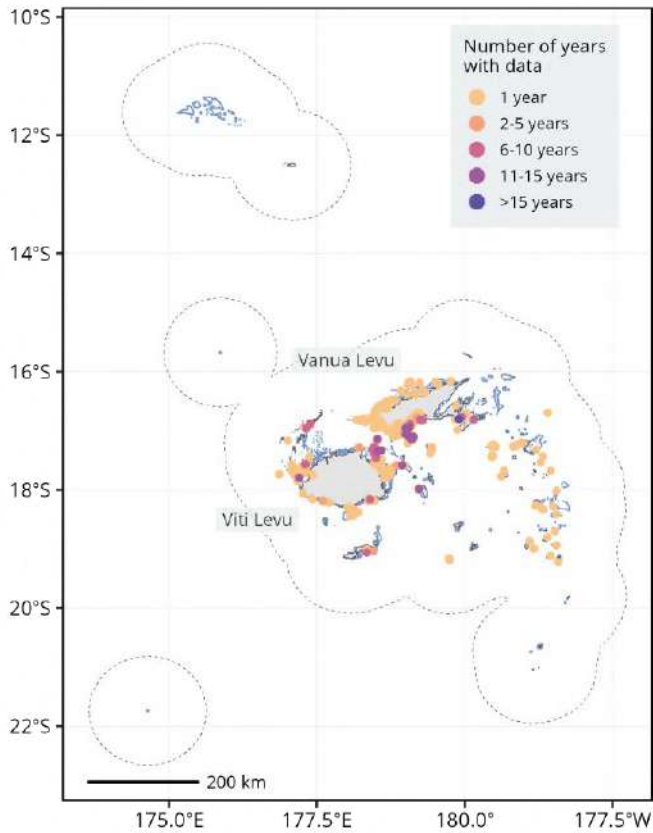


▲ **Figure 2.4.3.** Trajectories of cyclones passing within 100 km of a coral reef between 1980 and 2023 in Fiji. Points correspond to cyclone positions every 3 hours and are colored depending on the Saffir Simpson scale of the sustained wind speed. Grey points correspond to cyclone positions on which wind speed was not available. For readability, only the three most powerful cyclones are labeled and colored per time range (*i.e.* subplot). The trajectories of other cyclones are represented by gray lines only.

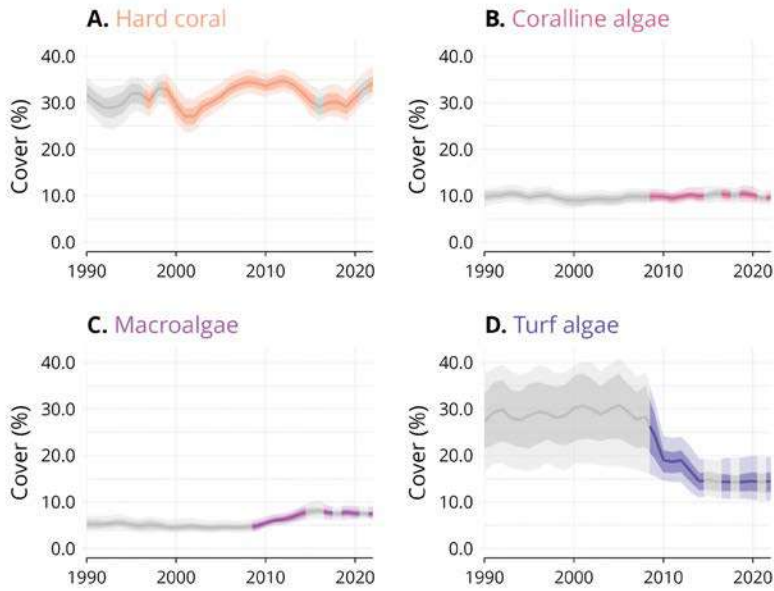
## Temporal trends in benthic cover

The estimation of trends in the benthic cover of hard coral, coralline algae, macroalgae, and turf algae in Fiji was achieved through the integration of 12 datasets (Supplementary Table 1). These datasets represent a total of 650 monitoring sites, on which 997 surveys were conducted between 1997 and 2023. Long-term monitoring has documented the

impact and recovery of coral reefs to bleaching, cyclone events and local stressors at different sites (see Figure 35.9 in Mangubhai et al., 2019). High rates of recovery have been documented post-bleaching (Mangubhai et al., 2019) and post-cyclones (Ford et al. *in review*).



▲ **Figure 2.4.4.** Spatio-temporal distribution of benthic cover monitoring sites across Fiji. Sites that were monitored for the longest period of time are represented on top of the sites monitored for fewer years. The scale bar provides distance at the equator and may not accurately represent distance over the entire latitudinal range of the economic exclusive zone. Dashed polygons represent a 100 km buffer around coral reefs. Note that only land and coral reef buffers of the country or territory are represented, not those of adjacent countries and territories. The distribution of coral reefs is shown in light blue.



▲ **Figure 2.4.5.** Modeled temporal trends for hard coral (A), coralline algae (B), macroalgae (C), and turf algae (D) cover from 1990 to 2022 in Fiji. The bold line represents the estimated average cover, lighter and darker ribbons represent 95% and 80% confidence intervals, respectively. Gray areas represent periods where no observed data were available. The raw data used to estimate these temporal trends are shown in Supplementary Figure 4.