Commonwealth of the Northern Mariana Islands

Coral Reef Resilience and Social Vulnerability to Climate Change

Summary

We present an analysis of exposure, resilience, and social vulnerability to climate change threats to the coral reefs of the Commonwealth of the Northern Mariana Islands (CNMI), relative to the rest of the U.S. Pacific. We focus primarily on the increases in ocean temperatures and the impact of coral bleaching on CNMI's coral reefs and the communities that depend on them.

Ocean temperatures will rise across the region, with little potential for refuge areas from warming. There are, however, important differences in reefs' resilience; the ability of a reef to resist or recover from the impacts of warming and continue to provide ecosystem goods and services. Our metrics of social vulnerability suggest that CNMI's human populations may face challenges relative to the rest of the U.S. Pacific, especially from housing and personal disruption.

Exposure

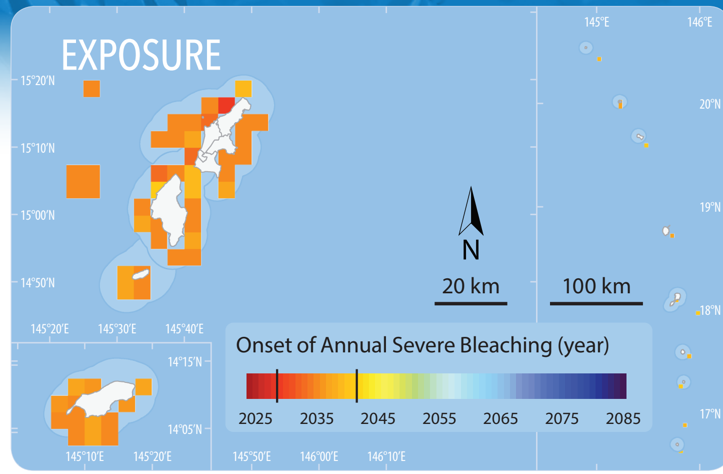
We report a coral reef sector's **Exposure** to warming as the projected year of onset of annual severe bleaching, under the 'business-as-usual' emissions scenario RCP 8.5. After this year, climate models suggest that high sea temperatures will trigger a severe coral bleaching event every summer. Reefs are expected to have lower biodiversity after this point, and habitat quality will decline, reducing the ecosystem goods and services reefs can provide. The onset of annual severe bleaching is projected for similar times across the region, with sector estimates ranging from 2029–2041, roughly 10 to 22 years from today (2019). If *Paris Accord* emissions reductions pledges become reality, corals will have 10–15 more years to adapt or acclimate to warming seas.

Resilience

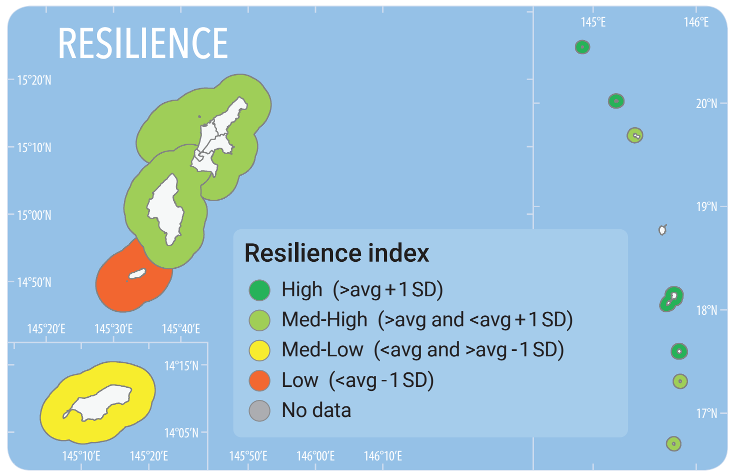
Reefs across the CNMI differ substantially in their **Resilience** to rising temperatures, both in their ability to resist increased temperatures and to recover from high temperature events. The Resilience index combines 8 resilience factors and shows that Saipan and Tinian have the highest resilience of the populated southern islands, while Aguijan has the lowest, due to higher macroalgal cover and a lower proportion of bleaching-resistant corals.

Social Vulnerability

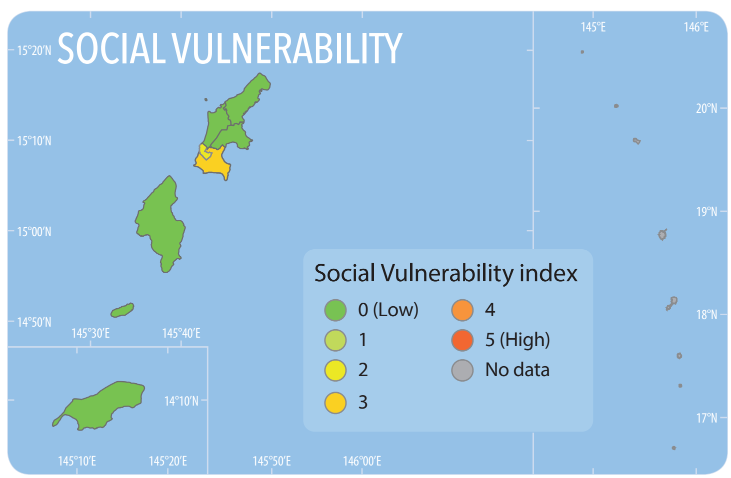
The five distinct indices of **Social Vulnerability** vary across CNMI and highlight that certain regions (i.e., Saipan Districts 1 and 2) may face challenges due to higher social vulnerability. These challenges depend on the district, with Saipan District 1 driven by our metrics for Personal Disruption, Population Composition, and Labor Force Structure, while District 2 by our metrics for Housing Characteristics, and Poverty.



Projected timing of the onset of annual severe bleaching under business-as-usual emissions scenario RCP8.5 (assumes climate policy is not effective at reducing emissions).



Aggregate index based on Bleaching resistance, Coral disease, Coral diversity, Coral juvenile density, Herbivorous fish biomass, Macroalgae cover, Fishing depletion, Temperature variability (see page 3).



Aggregate index based on Personal disruption, Population composition, Poverty, Labor force structure, and Housing characteristics (see page 6).

DATA USED

Exposure data come directly from ***van Hooidonk et al. (2016)****. All ecological data were derived from the* ***National Coral Reef Monitoring Program Datasets 2013–2015****, with factor selection and calculation following* ***McClanahan et al. (2012)*** *and* ***Maynard et al. (2015)****. Temperature variability data are from* ***Heron et al. (2016)****. All social vulnerability data were derived from the* ***American Community Survey****, analyzed following* ***Kleiber et al. (2018)****. For social data, all measures are compared to regional means in each of Hawai'i, American Samoa, and the Marianas Islands (Guam and CNMI).*

NOAA CORAL REEF CONSERVATION PROGRAM

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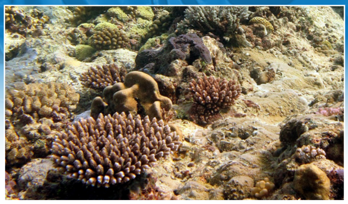
Coral Reef Resilience and Social Vulnerability to Climate Change






Coral reefs are one of our most important coastal ecosystems. They inspire us with their beauty, support diverse economies from fishing and tourism, protect our shorelines from storm waves, and house the greatest biological diversity of any marine habitat on earth.

However, coral reefs are in trouble. They face local threats, such as overfishing and pollution, and increasingly face threats that lie outside of local control, such as globally warming temperatures and acidifying seas. As temperatures rise, corals on reefs undergo bleaching, an acute condition that, if severe, can lead to large sections of coral reefs turning white and dying.

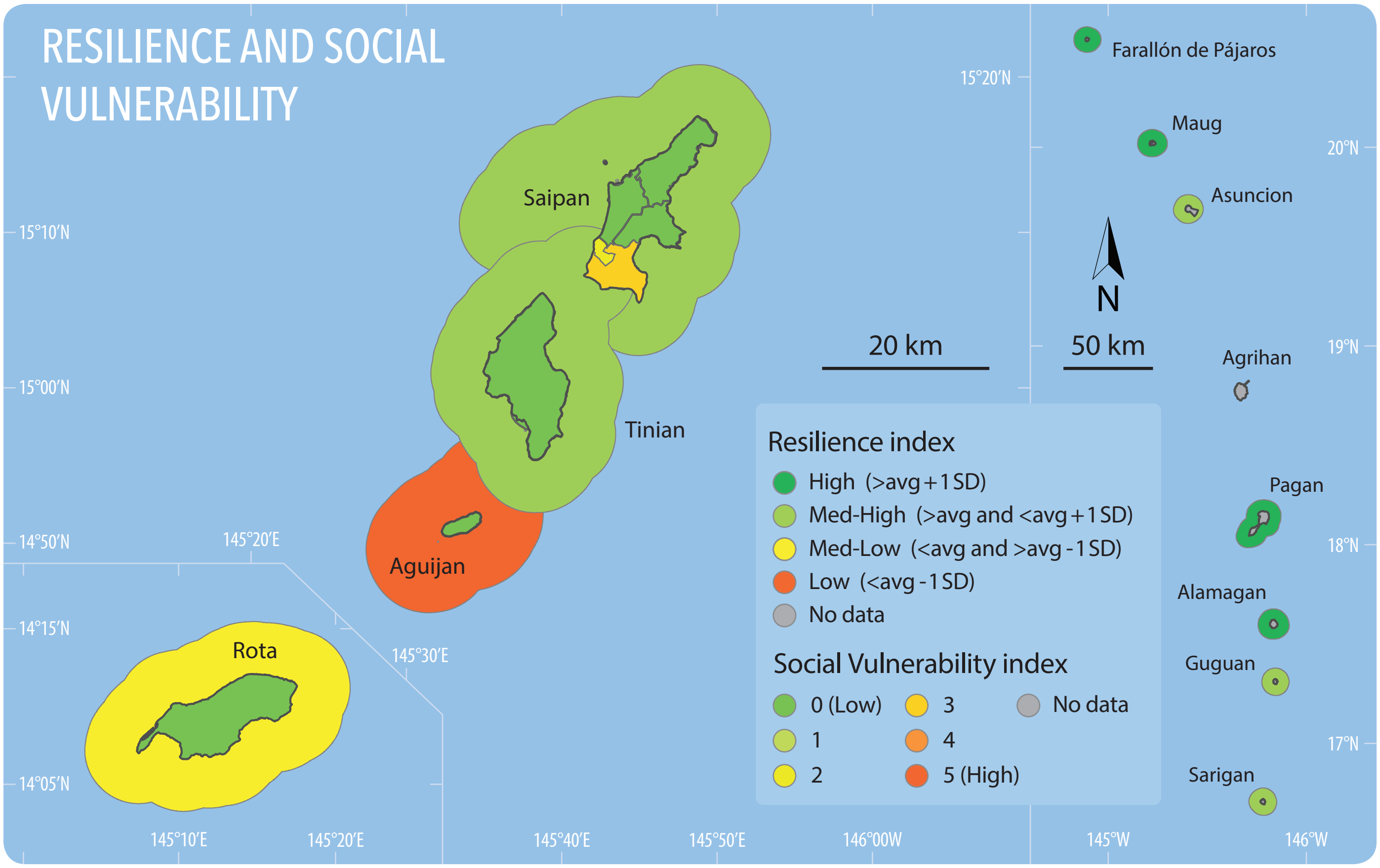
Warming is most pressing global threat to reefs. The coral bleaching event of 2014–2016 was the third global coral bleaching event recorded, leading to extensive coral death across the globe. Reefs in the CNMI suffered severe bleaching in both 2013 and 2014, with another more minor event in 2016. The 2013 event appears to have had led to significant mortalities of corals around CNMI, and the back-to-back events in 2013–2014 were unprecedented.

Models of future temperatures suggest that this unprecedented annual bleaching could become the new normal in as little as 20 years. This grave situation raises a critical question:

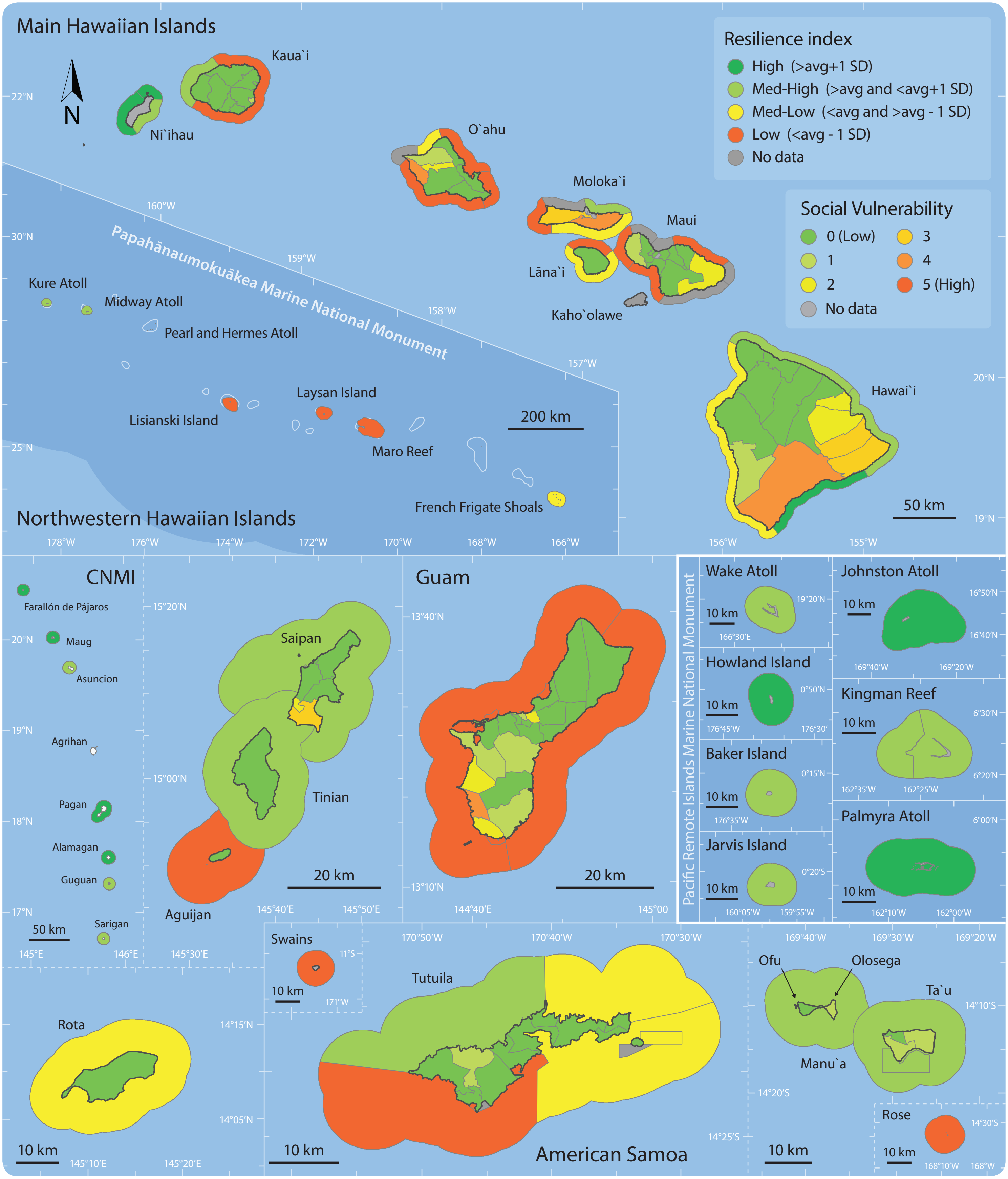
How can citizens and reef managers respond locally to counter global threats to reefs?

To manage reefs effectively, we need to know which areas are least vulnerable to climate change. Planning local responses to globally rising temperatures requires we understand: (1) ***Exposure*** — when will a given reef face potentially catastrophic warming? (2) ***Resilience*** — how likely is a given reef to resist or recover from high temperature events? (3) ***Social Vulnerability*** — how difficult will it be for the communities that depend on reefs to reduce their reliance on reef resources?

We present the best available data to answer these questions in a coherent way across the CNMI and all other US Affiliated Pacific Islands.



The composite of the coral reef Resilience index (sectors in the water) and Social Vulnerability index (sectors on land) for islands of the CNMI. See associated text for details.



These nested maps highlight each U.S.-Affiliated Pacific Island, showing the aggregate Resilience index along the coast and the Social Vulnerability index with sectors on land. We see that many remote areas show relatively high resilience, including many of the islands across the Pacific Remote Island Marine National Monument, but remoteness itself is not a guarantee of resilience, as islands in Papahānaumokuākea Marine National Monument range from medium-high to low resilience. Many areas around population centers in O'ahu, Maui, S. Tutuila, and Guam show low resilience. Social Vulnerability indices show low vulnerability in Hawai'i and Guam, but higher vulnerability in Tinian, Saipan, and American Samoa.

Coral Reef Resilience

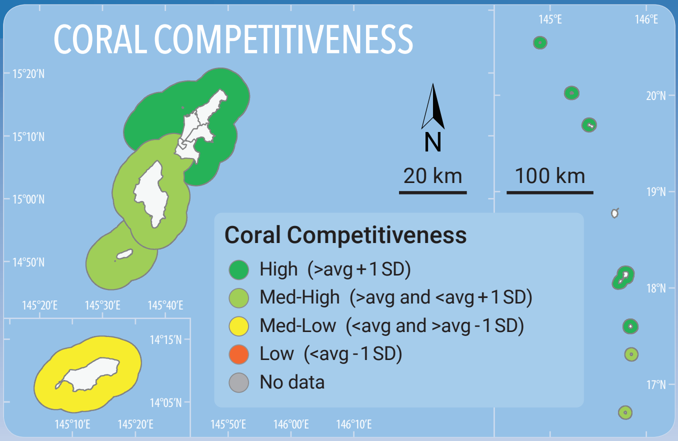
RECOVERY

Coral competitiveness

Coral Reef Resilience is a function of both how likely a system is to ***Resist*** stress before showing negative impacts, and how likely a system is to rapidly ***Recover*** from impacts once they occur.

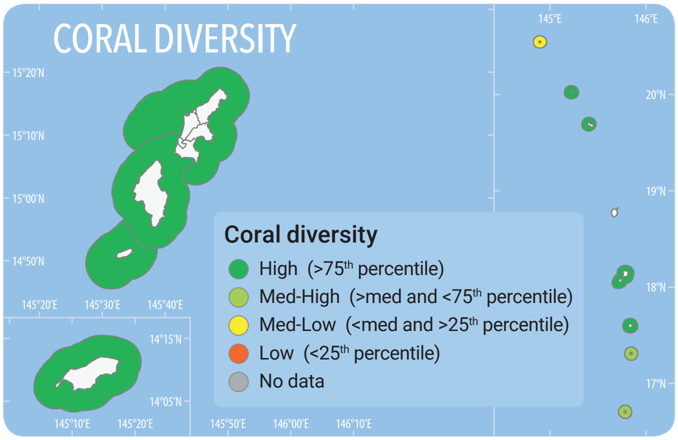
The eight reported resilience factors will each have different impacts on resistance and recovery. To highlight these distinctions, we break the eight factors into three groups:

- ***Coral Competitiveness*** primarily describes a reef's ***Recovery***,
- ***Other Stressors*** affect both ***Resistance*** and ***Recovery***, and
- ***Bleaching Resistance*** primarily describes a reef's ***Resistance***.

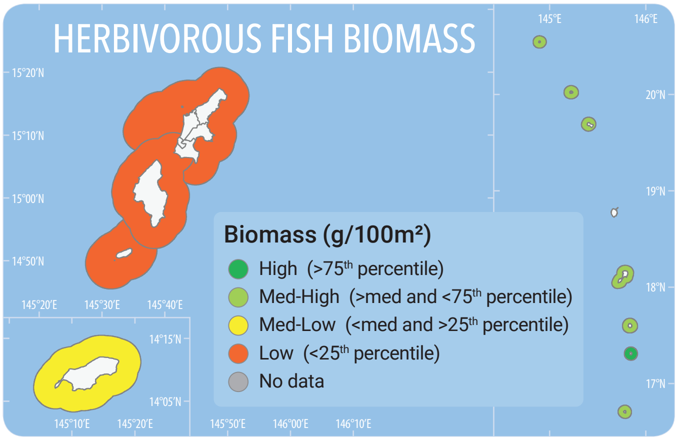


This aggregate index primarily describes a region's capacity for corals to compete for benthic space, and includes **Coral Diversity**, **Herbivorous Fish Biomass**, **Macroalgal Cover**, and **Juvenile Coral Density**.

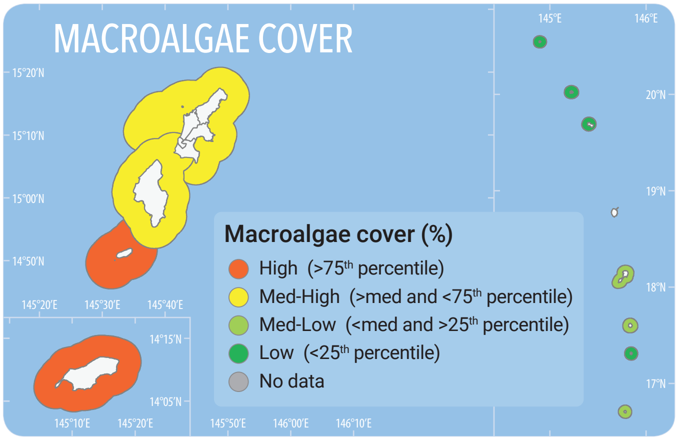
A primary driver in maintaining resilient corals reefs is whether coral populations can maintain a competitive edge over other benthic species like turf algae and macroalgae. High **Coral Diversity** supports this competiveness through a range of different growth forms and life histories. High **Herbivorous Fish Biomass** supports high grazing rates on corals' primary competitors, turf algae and macroalgae. Low **Macroalgae Cover** indicates that corals are maintaining this competive edge. High **Juvenile Coral Density** also suggests that corals are managing to successfully recruit to the area, ensuring a continual supply of new corals to the population.



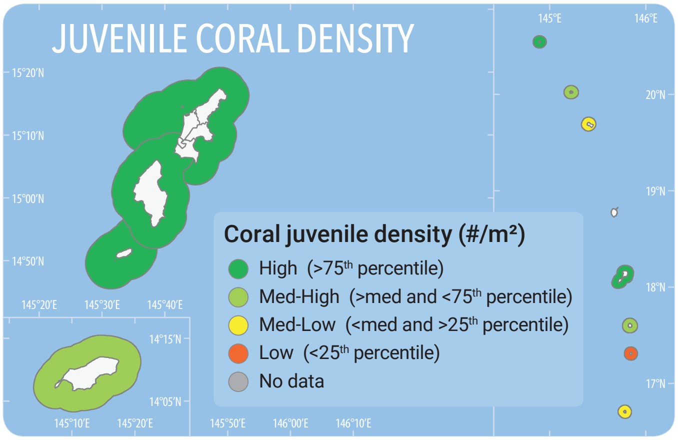
Diversity of hard corals, expressed as the effective number of coral genera (exponential of the Shannon entropy index).



Observed biomass of herbivorous fishes, grams per 100 meters square.



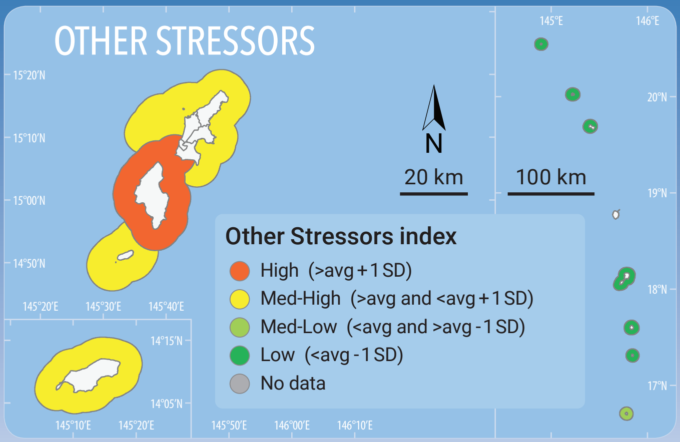
Observed percent cover of macroalgae.



Observed number of corals under 5 cm per square meter.

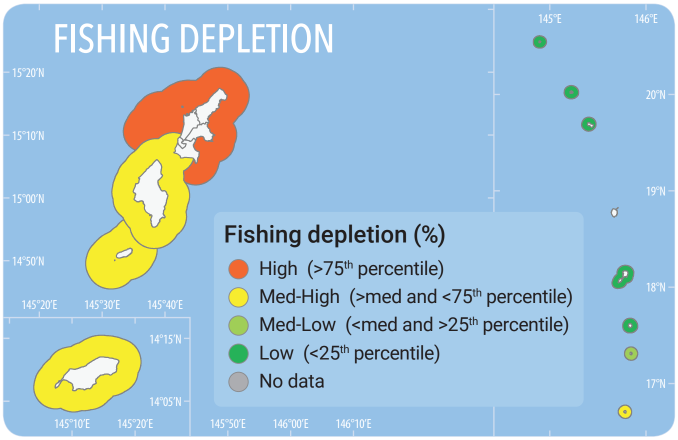
RESISTANCE

Other stressors

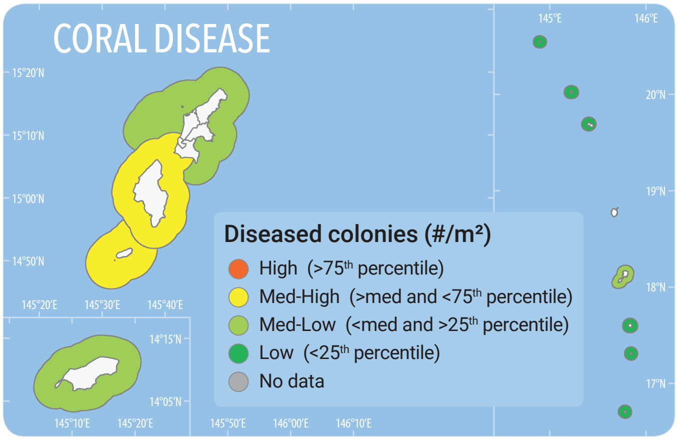


This aggregate measure of **Fishing Depletion** and **Coral Disease** highlights areas where resilience is likely negatively impacted by overfishing or by coral disease outbreaks.

In addition to coral's competitive dominance, both recovery and resistance can be affected by other forms of stress. In particular, **Fishing Depletion** and outbreaks of **Coral Disease** can negatively affect a reef's resilience.

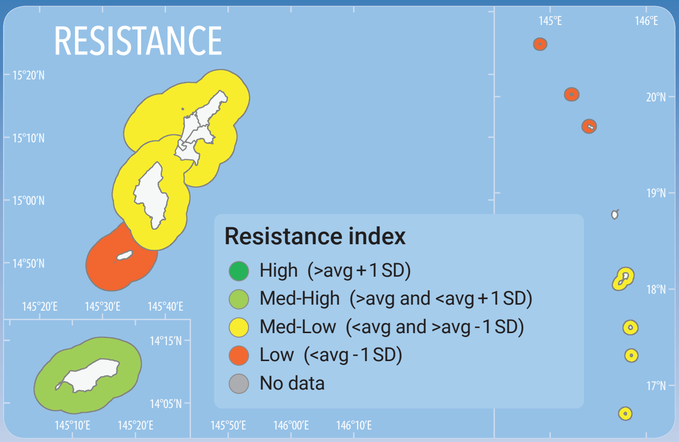


Percentage depletion of reef fishes due to fishing mortality, calculated from differences between observed biomass and biomass expected in the absence of fishing pressure (Williams et al. 2015).



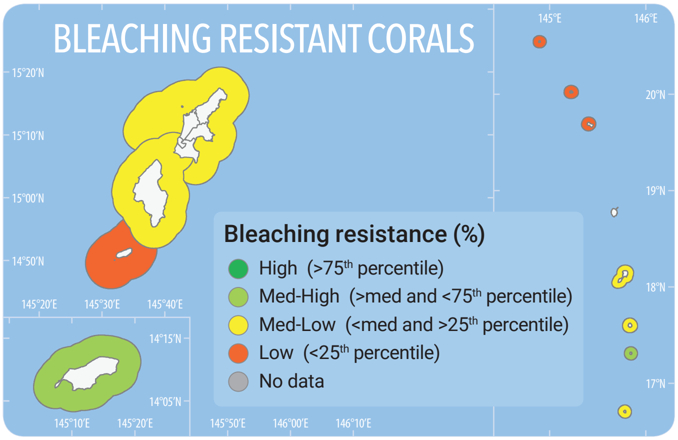
Observed number of diseased colonies per square meter.

Bleaching resistance

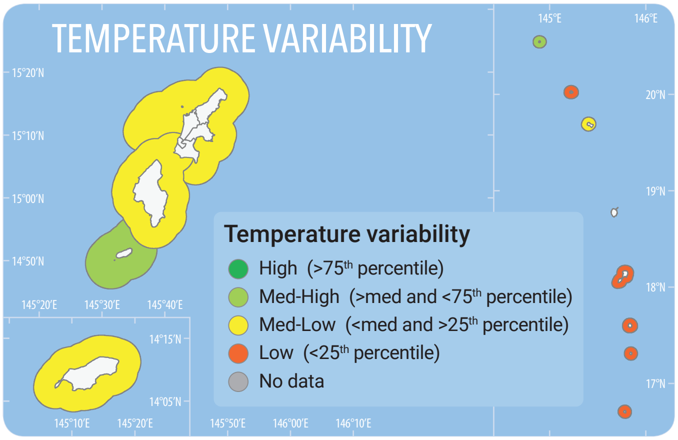


This aggregate measure of **Bleaching Resistant Corals** and **Thermal Variability** highlights areas likely to better ***resist*** high water temperatures.

Factors that support recovery can be distinct from those that promote resistance to the stress in the first place. Both the proportion of **Bleaching Resistant Corals** and a reef's history of high **Temperature Variablity** have been shown to help a reef resist high temperature bleaching.



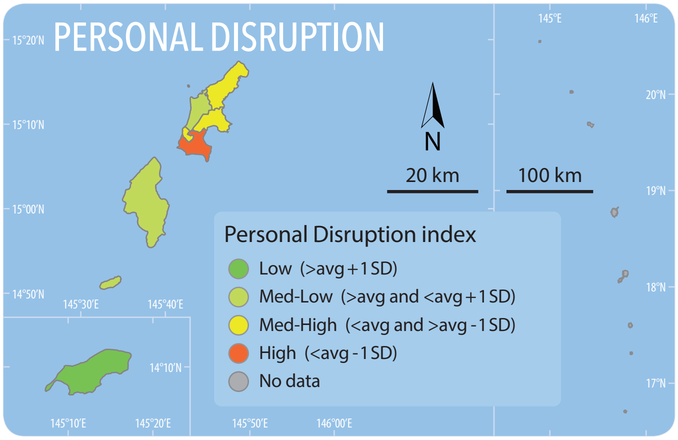
Proportion of bleaching resistant coral species in an area, calculated from observed proportional abundance by species and observed patterns of bleaching by species.



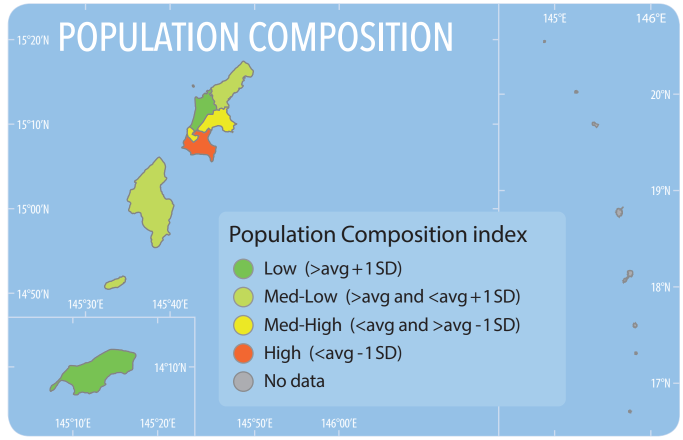
History of high temperature variability in an area, calculated from the climatological summer temperature range divided by the annual temperature range (Heron et al. 2016).

Social Vulnerability

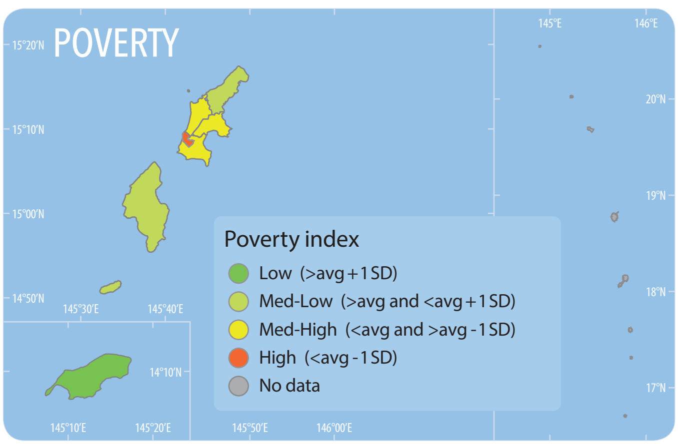
While **Exposure** and **Resilience** play important roles in a coral reef's ecological response to warming temperatures, human **Social Vulnerability** can indicate a community's ability to handle changes in their resources. We present five aspects of Social Vulnerability of the communities living near these reef resources: **Personal Disruption**, **Population Composition**, **Poverty**, **Labor Force Structure**, and **Housing Characteristics** (following Jepson and Colburn 2013; Kleiber et al. 2018). In the descriptions below, the ↑ symbol indicates that an increase in a particular variable increases vulnerability, while ↓ indicates that the increase in the variable decreases vulnerability.



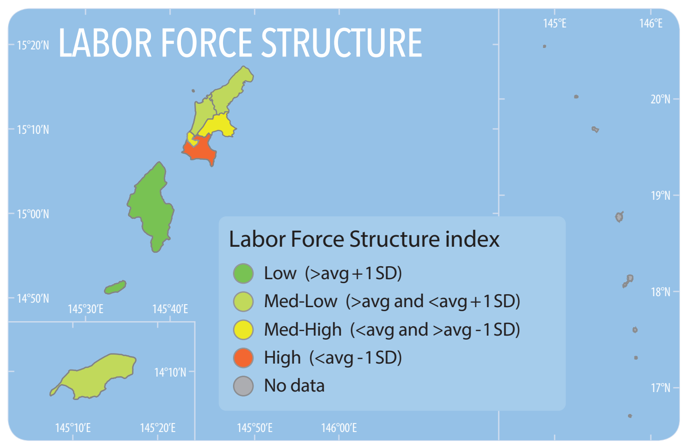
The Personal Disruption index includes variables that might indicate unstable personal circumstances, including poverty (↑), unemployment (↑), and low educational attainment (↑).



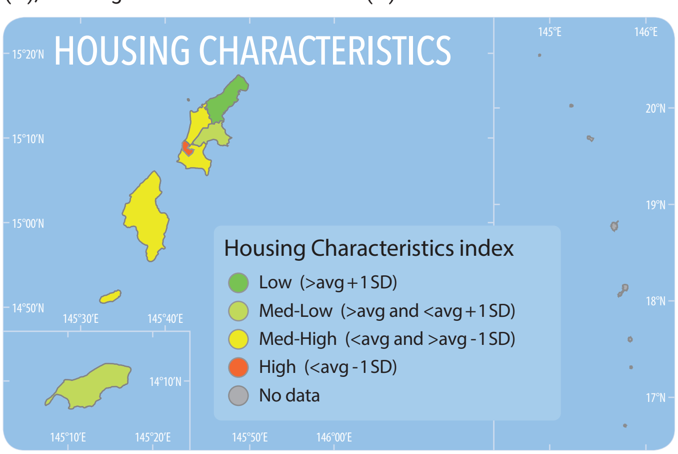
The Population Composition index describes demographic variables identified as indicators of socially vulnerable populations, including the percent of young children (↑), the percent of female-headed households (↑), and the percent of people without a Bachelor's degree (↑).



The Poverty index highlights the percentage of the total population in poverty (↑) as well as the percentage in poverty of other vulnerable groups such as children (under 18) (↑), families with children under 5 (↑), and single-female headed families (↑).



Labor Force Structure index provides an indication of the strength and stability of the labor force, including variables on the percent of females in the labor force (↓), the percent of those in the service industry (↓), as well as the percent of families with income under $10,000 (↑)



The Housing Characteristics index highlights the character of housing available within a community and measures the median rent (↓), median number of rooms in family dwellings (↓), and the percentage of houses that lack plumbing facilities (↑).

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Acknowledgements

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