

Chuuk Reef Health and Resilience Assessment Citizen Science Team Observations (17 July to 03 August 2016)

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20th December 2016



Acknowledgements

Financial support for the planning, implementation, and reporting for this Chuuk Reef Health and Resilience Assessment was provided by Alan and Ellyn Seelenfreund, Edward Warner, Byron Bishop, and Peter Landecker. Byron and Erica Bishop, Dr Edward Warner, and Peter Landecker all volunteered their time to provide valuable field observations and provided key support to secure the deposit for the vessel used as the platform for this assessment.



Summary

This report presents an illustrated compilation and analysis of the notes and photographs of the citizen scientists participating in the Chuuk reef health and resilience assessment led by The Nature Conservancy. This report complements that of the Micronesia reef monitoring teams.

The citizen science data and site descriptions are presented together with descriptions of the resistance and recovery indicators measured, records of pathology and predation, other stress indicators including levels of infestation by burrowing organisms and those of both anthropogenic (anchor damage, blast fishing) and natural causes (slumping and storm surge). Stress resistance and recovery scores are calculated and an overall potential resilience rank is attributed to each site. Furthermore, we found reef health and resilience to be weakened on reefs closer to larger islands and settlements: here reefs are more accessible and thus more heavily used and impacted by waste water and solid waste pollution, erosion and sedimentation. Based on these and our general observations, conservation actions are proposed for each site that are intended to enhance the resilience of the reefs at the location and to contribute to a State-wide network of resilient coral reef conservation areas. We acknowledge that these proposed actions are made without a deep knowledge of the cultural context at each site or any consultation with the reef owners and thus are limited in their relevance. However, they can provide a focus for discussions to develop local and State-wide strategies aimed at restoring and maintaining the integrity of the Chuuk reefs and their valuable services to Chuuk State's people. And in this respect, they will prove helpful.

The University of Guam team is undertaking a deeper analysis of the citizen science data to determine which of our measures correlate most strongly with the Micronesia reef monitoring team's reef health index, as well as which contribute most to our overall resilience scores. This information will be used to reduce the list of citizen science reef health and resilience indicators for such future assessments. The results of this analysis will be reported on separately.

Overall, the reefs of Chuuk have suffered extreme levels of destructive fishing, including both use of explosives and anchoring on corals, likely previous heat stress and related mortality linked to bleaching, crown of thorns starfish (*Acanthaster planci*) predation, as well as storm surge damage. The high levels of coral rubble suggest a combination of these three forms of damage. However, many of the coral communities exhibited strong resilience, including resistance to bleaching and storm surge or vigorous recovery from all forms of stress, or both, and we were regularly surprised by pockets of vibrant coral communities. From this we conclude that there is the strong prospect for recovery of many coral communities and related fisheries on the reefs of Chuuk and neighboring Kuop if sufficient and effective conservation management is implemented and sustained to curtail current damaging activities on and adjacent to coral reefs.

Finally, we conclude that the citizen science effort was indeed successful and generated complementary data to that of the Micronesia reef monitoring team by providing a perspective of both the influence of past events on coral reef health and resilience and the prospects for their recovery and long-term survival. We also learnt some lessons about how to implement such endeavors more effectively that are listed in Appendix 1.

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INTRODUCTION

As a contribution to the reef monitoring activities under the Micronesia Challenge, The Nature Conservancy committed to assist enable the Micronesia reef monitoring team visit the outer reefs of Chuuk and neighboring atolls. This was an opportunity to undertake a bold new citizen science venture that would achieve two objectives: (1) secure funding to support the endeavor, and (2) constitute a team of citizen scientists to focus on implementation and refinement of rapid resilience assessments methods for coral communities and provide complementary data to that collected by the Micronesia reef monitoring team.

The following report is a compilation of the citizen scientists' observations organized into four Parts lavishly illustrated with photographs:

1. Objectives and methods
2. Resilience indicators, rationale, methods, and applications
3. Observed coral pathology, predation and damage
4. Summary observations of each reef site, including specific interpretation of potential resilience and conservation options



PART 1: OBJECTIVES AND METHODS

Objectives

1. Record and provide broad overview observations of reef health and resilience to complement the benthic transect and quadrat data collected by the Micronesia reef monitoring teams
2. Provide an illustrated report of the reef communities and their various stresses and responses
3. Generate an assessment of the potential resilience at different reef sites and their conservation options in combination with the Micronesia reef monitoring teams' data.

Methods



Byron and Erica Bishop recording data at 10 m

The citizen science team was divided into two with each assigned to a different boat so that each site covered by the monitoring teams was also assessed for reef health and resilience. The reef health and resilience citizen science teams were each led by a Conservancy scientist and dive master (Zachary Caldwell or Rod Salm). The citizen science team followed a timed swim regimen of 20 minutes at 8-12 m and 20 minutes at 3-5 m.

Three sites were sampled daily and the team members generally alternated between recording general observations on reef structure and conditions or specific reef health indicators. Both teams recorded the standard information onto their underwater data sheets prior to each dive to facilitate tracking the data and ensure these were entered correctly (see Appendix 2).

General comments on reef structure, such as presence and characteristics of spurs and grooves, and overall impression of condition, including coral damage from various causes (nets, fishing lines, storms, previous bleaching events, blast fishing craters) were recorded in the notes section.

Data sheet information was entered daily into personal computers and uploaded 3-4 days onto a master computer.

In addition to the above direct resistance and recovery measures, reef resilience to stress is affected by the compounding influence of a range of natural events and anthropogenic activities that weaken the health of the coral communities, thereby increasing vulnerability to all stresses and susceptibility to disease, and lowering resilience. An effort was made to distinguish between crown-of-thorns starfish, previous heat stress and bleaching, storm surge, and anthropogenic stressors. But because of the differences in timing of these across the atolls over at least five years, it was problematic to differentiate conclusively among these.

Photographs of each site were used to supplement and clarify the written observations.

Descriptions and illustrations of the resistance and recovery indicators, including an introduction to the concept of resilience in the context of coral reefs, follow in Part 2: Resilience Indicators.

Data Analysis

The observations of each citizen scientist for each dive site were combined into a single Excel work sheet, grouped into those considered indicators of either stress resistance or recovery, and the values averaged to smooth discrepancies among observers. A potential resilience score was calculated for each site by summing the stress resistance and recovery values and a predation level score:

Potential coral community stress resistance indicators with attributed scores

Depth	depth at which observations made: 10 m for 8-12 m; 4 m for 3-5 m	
Slope	average angle of slope 4 m each side at each depth: 1 = >80°; 2 = 45-80°; 3 = 20-45°; 4 = 10-20° (scores: 1 = 3; 2 & 3 = 2, 4 = 1)	Potential resistance indicator
Rugosity	1 = flat to 30 cm high protuberances; 2 = 30 cm to 1 m high protuberances; 3 = >1 m rock/coral bommies, overhangs, caves	Potential resistance indicator
Mixing	1 = weak current/surge; 2 = moderate surge/current; 3 = strong swirling current/surge & local upwelling	Potential resistance indicator
Hard coral cover	estimated average cover (%) live hard coral on hard substrate at each depth over duration of dive (scores: <15%=1; 16-35%=2; >35%=3)	Potential resistance indicator
Coral Color/ bleaching	record %: 1 = near-white, bleached white, or blotchy color (max stress); 2 = paling/brightening (moderate stress); 3 = good/deep color (min stress) healthy	Potential resistance indicator
Table max	record estimated max diameter of live table coral: 1 = <2 m; 2 = 2-3 m; 3 = >3 m	Potential resistance indicator
Table size range	Record range of table coral colony sizes: 1 = no intermediate size colonies; 2 = few intermediate size colonies (size classes skewed toward large or very small); 3 = broad range of intermediate sizes from large to very small	Potential resistance indicator
Massive max	record estimated max diameter of live massive coral: 1 = <2 m; 2 = 2-3 m; 3 = >3 m	Potential resistance indicator
Disease	enter hatch mark for each kind: BB = black band; AWS = <i>Acropora</i> white syndrome; T = tissue loss; FB = focal bleaching; D = discoloration) (scores: <3=3; 3-10=2; >10=1)	Potential stress, health, & resistance indicator
Notes	additional observations or explanations of above & observation of damage from storms or other causes	

Potential coral community stress recovery indicators with attributed scores

Depth	depth at which observations made: 10m for 8-12m; 4m for 2-5m	
Turf algae cover	estimated average cover (%) of turf algae (T) or macroalgae (M) on hard substrate at each depth over duration of dive (scores: >40%=1; 10-40%=2; <10%=3)	Potential recovery indicator
Macroalgae cover	estimated average cover (%) of macroalgae (M) on hard substrate at each depth over duration of dive (scores: >40%=1; 10-40%=2; <10%=3)	Potential recovery indicator
Other cover	crustose coralline algae (CCA) (scores: (<5%=1; 5-20%=2; >20%=3)	Potential recovery indicator
Lesion repair	enter hatch mark & growth form for each coral colony with 1 or more lesions being repaired (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Regrowth	enter hatch mark & growth form for each coral with active regrowth over dead portion (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Reorientation	enter hatch mark & growth form for each dislodged or overturned coral with reoriented growth (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Coral Recruits	abundance per 1 sq. m dead coral or rock surface: 0 = none seen; 1= 0-2 recruits; 2 = 3-10 recruits & 1-5 spp; 3= >10 recruits & >5 spp	Potential recovery indicator
Growth margin	Growth margin is length of pale area at tips of branching (B) corals or outer perimeter of table (T) & foliose (F) coral: 1 = <2 cm; 2 = 2-3 cm; 3 = >3 cm	Potential recovery indicator
Predation	enter hatch mark for each sighting: crown-of-thorns starfish (COT), <i>Drupella</i> (D), fish (F), other/undetermined (O), burrower infestation (B) (scores: <3=3; 3-10=2; >10=1)	Stress & potential recovery indicator
Notes	additional observations or explanations of above & observation of damage from storms or other causes	

Resilience scores for each resistance and recovery indicator at each site are included in Appendix 3.

Survey sites are indicated in the following figure by push pins labelled with the Micronesia monitoring database numbers and local names. Each pin is colored according to the potential resilience score for that site (green = high potential, yellow = moderate potential, and red = low potential).

The resilience scores for each site color-coded for high (green), moderate (yellow) and low (red) values are listed in the following table:

Resilience scores for all reef sites in Chuuk assessed during July-August 2016

2016 REA SITE	Local name	Current Online Database Code	Reef type	Resilience Score	Normalised Scores
C-208	Pones	CHK-24	Outer	48.50	1.000
C-212	Ochanei-1	CHK-27	Outer	48.00	0.990
C-44	Ferit	CHK-32	Patch_back	47.75	0.985
C-40	Fonuenipin	CHK-29	Outer	47.25	0.974
C-207	Kuop_Neoch	KUOP-8	Outer	47.25	0.974
C-213	Ochanei-2	CHK-28	Outer	46.75	0.964
C-5	Faneno	CHK-35	Patch_back	46.50	0.959
C-205	Kuop_Ochamoch	KUOP-6	Outer	45.75	0.943
C-57	Onnang	CHK-57	Outer	45.00	0.928
C-61	Onno	CHK-37	Outer	44.50	0.918
C-59	Pisemu	CHK-36	Patch_back	44.50	0.918
C-38	Wonno	CHK-53	Patch_back	44.25	0.912
C-307	Sapuk	CHK-14	Inner	44.25	0.912
C-46	Pisemew	CHK-56	Channel	44.00	0.907
C-206	Kuop_Feneppi Pass	KUOP-7	Channel	43.75	0.902
C-7	Anaw-2	CHK-38	Patch_back	43.75	0.902
C-45	Fanochopenges	CHK-55	Outer	43.38	0.894
Uman	Manukun	CHK-16	Inside	43.00	0.887
C-58	Fourup	CHK-19	Patch_back	42.75	0.881
C-309	Mochanap	CHK-49	Channel	42.75	0.881
C-10	Anaw	CHK-12	Patch_back	42.50	0.876
C-41	Pukuon	CHK-30	Outer	42.00	0.866
C-12	Anaw-3	CHK-43	Outer	41.50	0.856
C-47	Terenap/Pisitini	CHK-61	Patch_back	41.25	0.851
C-201	Meseong	CHK-23	Outer	40.75	0.840
C-11	Sapung Anang	CHK-20	Channel	40.75	0.840
C-35	Moch	CHK-13	Channel	40.50	0.835
C-8	Fanananei-2	CHK-60	Patch_back	40.25	0.830
C-305	Peas	KUOP-13	Outer	40.25	0.830
C-1	Fanangat	CHK-17	Inside	39.50	0.814
C-4		CHK-54	Patch_back	39.25	0.809
C-14	Fourupw	CHK-10	Patch_back	39.25	0.809
Pisinini Inner	Pisinini Inner	N/A	Inner	39.00	0.804
C-3	Fanos	CHK-8	Patch_back	39.00	0.804
C-60	Fonuamo	CHK-58	Patch_back	39.00	0.804
C-49	Pisinini	CHK-34	Outer	39.00	0.804
C-9	Fanananei	CHK-39	Patch_back	39.00	0.804
C-209	Fanochoetiw	CHK-25	Outer	38.75	0.799
C-300	Meseong-2	CHK-47	Outer	38.75	0.799
C-55	Neoch-3	KUOP-15	Outer	38.50	0.794
C-211	Chuesen	CHK-26	Patch_back	38.50	0.794
C-302	Penson	KUOP-11	Patch_back	38.25	0.789

C-303	Penson-2	KUOP-12	Channel	38.25	0.789
C-311	Och	CHK-18	Patch_back	38.00	0.784
C-37	Sanat	CHK-3	Patch_back	37.50	0.773
C-62	Maimai	CHK-59	Patch_back	37.25	0.768
C-39	Wininen	CHK-11	Patch_back	37.25	0.768
C-16	Winipiru	CHK-44	Patch_back	37.25	0.768
C-33	Sopweru	CHK-51	Channel	37.25	0.768
C-15	Fanufon	CHK-22	Patch_back	37.00	0.763
C-308	Fanochetiw-2	CHK-48	Patch_back	37.00	0.763
C-210	Epichun	CHK-15	Patch_back	36.50	0.753
C-52	Kuop_Epismusur	KUOP-9	Outer	36.50	0.753
C-6	Parem	CHK-1	Patch_back	36.50	0.753
C-310	Sapan Anang-2	CHK-50	Patch_back	36.17	0.746
C-77	Oranu	CHK-5	Channel	35.75	0.737
C-301	Nomoneas	KUOP-10	Channel	35.75	0.737
C-42	Ochonon	CHK-31	Patch_back	35.50	0.732
C-50	Piss-Paneu	CHK-7	Patch-back/Channel	35.50	0.732
Kuop Acrop Garden	N/A	N/A	Inner	35.00	0.722
C-13	Pianu	CHK-21	Outer	35.00	0.722
C-53		KUOP-1	Patch_back	35.00	0.722
Onei MPA	Saputiu	CHK-40	Inside	35.00	0.722
C-202	Kuop_Peson	KUOP-3	Outer	33.50	0.691
C-306	Neoch-2	KUOP-14	Patch_back	33.50	0.691
C-36	Aroch	CHK-4	Patch_back	33.25	0.686
Parem	Parem	CHK-6	Inside	33.00	0.680
C-302 ext	Penson ext	N/A	Patch_back	33.00	0.680
C-34	Ochoeor	CHK-52	Outer	32.75	0.675
Onei-3	Mutonpuna	CHK-42	Patch_back	30.50	0.629
C-48	Pisitit	CHK-33	Outer	30.50	0.629
C-18	Fananu	CHK-46	Patch_back	30.50	0.629
C-75	Nematon	CHK-9	Inner	30.00	0.619
C-304				30.00	0.619
C-17	Mew Nematoll	CHK-45	Inner	29.75	0.613
C-204	Kuop_Penson	KUOP-5	Outer	29.25	0.603
C-203	Kuop	KUOP-4	Channel	28.50	0.588
C-312	Truk Stop	CHK-2	Inner	28.33	0.584
Onei Ref	Sapota	CHK-41	Inside	26.00	0.536
Max				48.50	1.000
Min				26.00	0.536
Range				22.50	0.464
High resilience					>0.845
Mod resilience					0.692-0.845
Low resilience					0.536-0.691

High resilience = $\text{Max} - \text{Range}/3$; Moderate resilience = $<\text{High} \ \>\text{Low}$; Low resilience = $\text{Min} + \text{Range}/3$

Dive locations Chuuk and Kuop (green = high potential resilience; yellow = moderate potential resilience; red = low potential resilience)



PART 2. RESILIENCE INDICATORS

Resilience in the context of coral reefs

Ecosystem resilience refers to the ability of an ecosystem to maintain key functions and processes in the face of stresses or pressures, either by resisting or adapting to change (Holling 1973; Nyström and Folke 2001). Resilient systems are characterized as adaptable, flexible, and able to deal with change and uncertainty (Hughes *et al.* 2005)

There are several iterations of these definitions of resilience and the thinking on this continues to evolve. It is the elements of resilience that these definitions try to capture that are important, especially those that can be readily recognized in the field by conservation scientists and managers. Coordinated international efforts continue to refine the resilience indicators down from the original list of 71 (Obura and Grimsditch 2009) to a more manageable and focused subset of these (Maynard *et al.* 2010, McClanahan *et al.* 2012).

The two interrelated elements used to derive resilience indicators are the ability of a coral community both to resist stress and to recover quickly from it. The degree to which a community is able to resist a stress event will shape the nature of its recovery and its consequent need to reorganize. Communities with greater ability to resist stress will be less likely to experience phase shifts and the need for internal reorganization. They will recover their natural state faster and so too their ability to maintain essential processes that sustain reef health and support the production of the goods and services of value to human societies. The reproduction and larval output of such stress resistant communities are critical to enhance recovery of more susceptible reefs to which they are connected.

Although it is relatively easy to identify indicators of resistance and recovery underwater, true resistance may be confused with avoidance if the apparently resistant communities were not in fact exposed to a heat stress event. For example, areas that have suffered infrequent or mild bleaching may have avoided heat stress altogether due to ameliorating conditions (e.g., reliable mixing of the water column that draws cooler deeper waters to the surface and keeps surface water temperatures within corals' thresholds of tolerance). This is an important concept to consider when relating somewhat coarse resolution, sea surface temperature data from satellite imagery (4 km resolution) to local within reef responses by coral communities influenced by such small scale factors as shading, screening, and mixing. This has consequences for determining conservation options (see decision tree in Salm and McLeod 2007).

There is a third important element of resilience that we need to try to measure and which will be more challenging to recognize. This is the ability of a coral community to absorb stress, reorganize with a different species composition, and yet maintain its essential processes, productivity, and values for people. Clear indicators for how to achieve this have yet to be developed.

Measuring resilience underwater

Risking oversimplifying the selection of resilience indicators, the following are the ones that we used during Chuuk reef health and resilience assessments. The values ascribed to each are included in the datasheet templates at the beginning of the Methods section above.

1. *Key local scale indicators of coral reef **resistance** recorded during 2016 Chuuk reef assessment:*
 - *steep slope* indicates proximity to deeper, cooler water and the prospect of these mixing with heated shallower water and reducing heat stress on corals there
 - *rugosity (topographic complexity)* because this provides a measure of the within community differences in water movement and shading, which are factors that can mitigate heat and light stress
 - *mixing* through the water column because this can cool heated surface water significantly and effectively remove or prevent heat stress from the affected coral reef communities: the degree of mixing is measured by determining the presence of tidal or other currents that cause irregularity in temperature across the reef and down the reef front
 - *high hard coral cover* indicates that consistent conditions exist to maintain the health and growth of corals year after year, enabling them to occupy all available space
 - *good coral color* indicates no or low and tolerable levels of stress and robust, healthy corals
 - *broad size range* of table corals indicates that corals have survived previous stress events regularly to reproduce, settle damaged areas, and recover; and significantly, that conditions favour recovery
 - *large, old susceptible branching and table Acropora corals* because they are a measure of the past consistency and reliability of conditions or phenotypic plasticity that favour stress tolerance and long-term coral growth and survival
 - *large, old resistant massive corals* because they have greater prospects of surviving coral bleaching and tropical storms and so providing structure and functionality to the reef and coral community
 - *low incidence of coral disease* indicates good water quality, low and tolerable levels of stress, abundant food and consequently stored energy (fat) resources to sustain coral metabolism during times of stress
2. *Key local scale indicators of coral reef **recovery** from stress recorded during 2016 Chuuk reef assessment:*
 - *turf algae cover* indicates substrate suitability for larval settlement and recovery from local damage and large scale stress events
 - *macroalgae cover* is widely accepted as an indicator of poor recovery of coral communities: macroalgae interfere with coral recruitment and growth and can abrade and cause lesions on living corals
 - *other cover* can indicate competition for space and stress to the coral community; however, only *crustose coralline algae* cover was used in the analysis as this contributes strongly to recovery by consolidating loose rubble and providing a suitable surface for coral recruitment
 - *strong recruitment* indicates conditions that favour effective settlement of coral larvae and their survival to develop into colonies
 - *lesion repair* indicates sufficient energy reserves and vigor in the coral colony to cope with normal levels of predation and occasional damage from rubble tossed by large swells and storm surges

- *remnant regrowth and damage repair* indicate vigour in the live portions of the colony that is an expression of coral health and resilience
- *reorientation in the plane of growth* when corals are overturned or dislodged – it is likely that only healthy, well-nourished corals with high energy reserves can survive such shocks
- *wide growth margins* of branching, table, foliose corals indicate that the coral is thriving, healthy, has good growth and recovery potential, and is relatively stress-free

Description of Resilience Indicators

Resistance indicators

Steep slopes expose deeper corals to cooler water and reduced heat stress and also place shallow corals affected by heated surface waters closer to the deeper cooler water. This increases the prospects of these shallow corals having heat stress reduced by upwards mixing of the water column. Eddies caused by ocean currents may cause this mixing by drawing up deeper waters to the surface and distributing these along the reef crest.



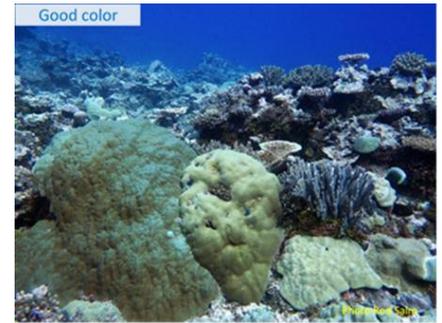
Rugosity is a measure of the topographic complexity in the structure of a coral reef. Relative rugosity determines within-habitat differences in water movement and shading, factors that can mitigate heat and light stress and contribute stress resilience to the coral community. It is determined by visual assessment of vertical height of coral colonies and the presence, absence, and relative occurrence of overhangs, caves, shaded walls, narrow steep sided gullies, and canopy corals (large colonies that overtop others). Where such features are regular components of the reef structure, the site would score high for greater rugosity.



High coral cover suggests that consistent conditions exist to maintain the health and growth of corals year after year, enabling them to occupy all available space. However, coral cover is not an independent variable. Such weedy species as *Seriatopora*, *Pocillopora*, *Stylophora*, and certain *Acropora*, may be indicators of highly disturbed environments. High coral cover should be linked with biodiversity, growth form diversity, or size class. (Ochane-i-1, site C-213).

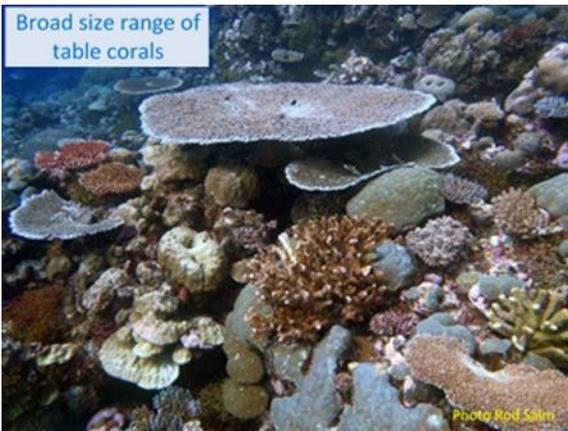


Good coral color: deep colors usually indicate healthy and stress-free coral colonies. Stress will cause corals to lose color leading to brightening, paling, and bleaching. Massive coral bleaching occurs when heat stress is taken to extreme levels and will lead to death of the corals if the heat stress levels are maintained for too long or if



temperatures reach dangerously high levels.

A *broad size range* of table corals, including ones old enough to have survived the 1998 mass bleaching event,



is a particularly important indicator of resilience. The large old table corals indicate a long history of surviving or avoiding stress and the intermediate sizes and small young ones indicate maintained health of the system, including regular reproduction and regular strong larval settlement and growth. The broad size range also tells us that corals are reproducing regularly and settling out successfully in damaged areas, from which we can deduce that water and substrate conditions favour coral health, settlement and growth. Thus size range is an indicator of both resistance and recovery.

The presence of magnificent old corals indicates decades to centuries of local oceanographic and environmental conditions favourable to stress reduction and long-term coral growth and survival. It may also indicate a high level of phenotypic plasticity that enables corals to withstand variability in environmental conditions, especially tolerance of widely ranging seawater temperatures. Such corals are important for both the structural complexity they contribute and the large quantity of larvae they produce.

Large, old susceptible branching and table Acropora corals are generally susceptible to stress of all kinds, including heat stress, tropical storms, tsunamis, siltation, and breakage from a range of destructive practices.



Onno (site 61)

These enormous, decades old table *Acropora* may have survived the 1998 mass bleaching event and clearly have lived through more recent ones. They have good color, active growth margins, and no signs of disease or lesions. This could be interpreted as an indicator of minimal exposure to stress events or the ability to tolerate moderate levels of stress. These colonies are probably good indicators that a number of factors conspire to reduce stress levels on the entire coral community.

Such enormous corals have huge reproductive potential and contribute significant quantities of larvae to the system and so play an important role in aiding the recovery of damaged coral communities.

Large, old, resistant massive corals are generally resistant to heat stress as well as other forms of perturbation, such as siltation. Large old colonies of *Diploastrea*, *Pavona clavus*, or *Porites*, such as this approximately 350-400-year-old one on the reef site Ochane-2 (C-213) indicate that conditions on this reef have favored coral growth for centuries. The good color and lack of lesions, tumors and other signs of disease or damage on this colony are also good indicators of reef health. Large (2-4 m), old *Porites* colonies are widespread throughout Chuuk, but are not common. Many sustain a high percentage, even total, mortality that appears linked to blast fishing. These dead portions often open up the colonies to invasion by borers and bioerosion that cause the colonies to break apart.



Ochane-2 (site C-213)

Recovery indicators



Onei Ref Sapota

Truk Stop (site C-312)

Low *macroalgae cover* is a good indicator of conditions that favour coral recruitment and of recovery potential. High macroalgae cover is a strong indicator of disturbance and a shift to conditions that are unfavourable for coral recruitment and growth. Dense macroalgae can also abrade and interfere with growth and survival of adult corals. Overfishing of herbivores and/or high nutrient input from terrestrial runoff contribute to the rapid growth of macroalgae following coral mortality resulting from a disturbance event, such as storm damage, flooding and sedimentation, or coral bleaching.

Suitable substrate comprising clean rock surfaces or areas of *crustose coralline algae* (CCA) are essential for larval settlement and coral recruitment. Dead coral surfaces that become heavily blanketed by *turf algae cover* and *macroalgae cover* thwart coral recruitment. The availability of suitable substrate is dependent on such other variables as water quality and the extent of pollution from terrestrial runoff, as well as the presence of adequate herbivore biomass. CCA also cement coral fragments (right) and consolidate loose substrates that are inimical to coral recruitment.



Kuop_Neoch (site C-207)

Strong coral recruitment



Strong recruitment, measured by the number of small, young corals, is an indicator that the substrate and water quality are good, local conditions support the growth of corals, and there is effective connectivity with healthy resistant communities to provide the larvae needed to repopulate damaged areas. Recruitment is a variable linked to several others, including connectivity, substrate condition, water quality, and herbivore diversity and biomass

Kuop_Neoch (site C-207)

Lesion repair and remnant regrowth and damage repair tell us that conditions favor healthy coral growth locally: localized stress levels are generally low, the corals are well nourished and so have good lipid deposits to help them invest in changing their direction of growth, repair damage, and keep back competition from other species, like sponges, that could kill and overgrow them. Regrowth and damage repair can be recognized by the presence of a pale actively growing margin to the live coral that is raised above the surface of dead coral. This tells us that the surviving or overgrowing corals are healthy, have good energy reserves (fat deposits), and are relatively stress free.

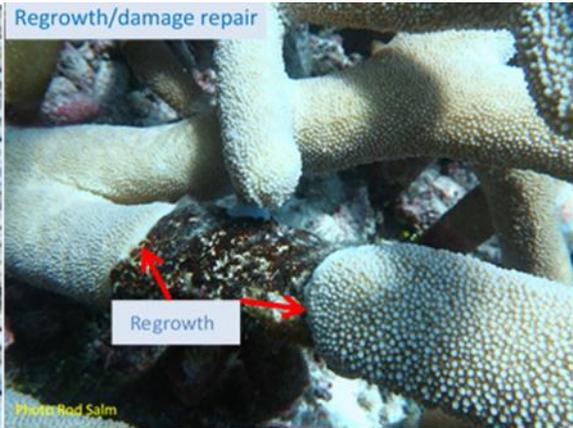
Lesion repair and



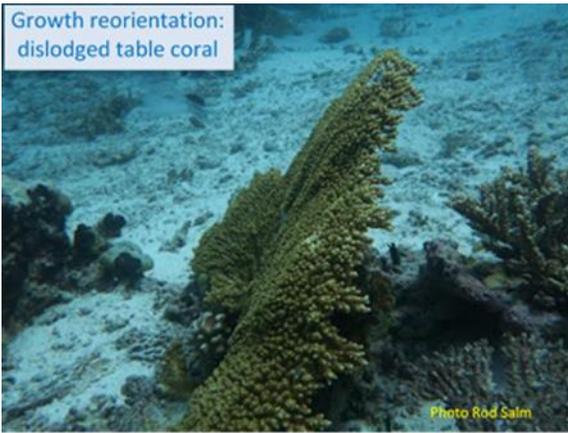
Regrowth/damage repair



Regrowth/damage repair



Growth reorientation:
dislodged table coral



Reorientation in the plane of growth when corals are overturned or displaced tells us that the coral is healthy, well nourished, and has high energy reserves to survive such shock. This table coral (left) was likely shaken loose from its pedestal, toppled on its side, and yet lived to change its plane of growth putting out new horizontal plates. It is not uncommon for corals in typhoon or severe storm prone areas such as Chuuk to be torn off their bases and toppled.

Heavy storm surge can also turn dislodged corals completely upside down, including large massive corals such as *Porites lobata*. Healthy table *Acropora* that have been overturned will reverse their growth growing up from the underside as illustrated right.

Growth reorientation:
overturned table coral



Growth reorientation:
overturned vase coral



If healthy and containing sufficient

energy reserves, overturned vase corals (*Turbinaria* left) will curl up and overgrow the underside of the colony.

Wide growth margins of branching, table, foliose corals are measureable and easily recognizable. They indicate that the coral is thriving, healthy, has good growth and recovery potential, and is relatively stress-free.

Wide growth margin



Resilience as a reorganizing principle

The ability of coral communities to absorb shocks and reorganize even with substantially different species structure and yet continue to maintain their essential functions, including benefits to people, has been the least addressed aspect of resilience. Understanding the process of reorganization to a new coral community structure that is able to maintain original goods and services will take long term research. Indicators that provide a window on what the reef structure once was are important but seldom identified: it's the Palmyra Atoll story. Following extensive impact on some reefs of Palmyra Atoll during WWII, their original structure is barely visible under the cover of quite different, present day benthic communities. Seventy years later, the new reef community in these altered locations is very different in structure yet maintains value to support abundant fish stocks, coastal protection, and dive tourism values and has recovered an apex predator dominated system that must be close to the original (Ruttenberg et al. 2011). All too often, we are distracted by the present coral cover and fish life to recognize what once was and how things have changed. Change is inevitable: since the beginning of time, species have evolved and the structure and composition of ecosystems have changed. Consequently, we should be content with change, even if accelerated, so long as we maintain the essential processes that determine reef health and the abundance of goods and services that are so valuable to people. Some key indicators of reorganization may include:

Indicating former reef structure:

- large, dead massive corals and/or large dead bases of table corals completely overgrown by veneer of new coral growth, sponges, or calcareous algae
- flat pieces of old table coral or fragments of branching corals cemented into the reef framework and overgrown by living corals, sponges, or calcareous algae

Indicating present reef value

- abundance of large fishes, especially apex predators and valuable food species
- coral rubble cemented in place by crustose calcareous algae, especially where this forms ramparts protecting island beaches from direct wave action

Implications of resilience for management of the Chuuk coral reefs

Information emerging from the reef health and resilience assessment should be factored into the any Chuuk MPA network design, MPA zoning, and management plans. A science assessment contributes guidance to this. However, the cultural and political context of the location and understanding and support by both government and affected communities are the ultimate deciders of what conservation actions are appropriate and likely to be adopted and implemented. We have been encouraged to include some thoughts on management derived from science alone to form a focus for discussion and debate within Chuuk. These are introduced below in general terms and more specifically in the table following this section and in greater detail in the site descriptions in Part 4 of the report.

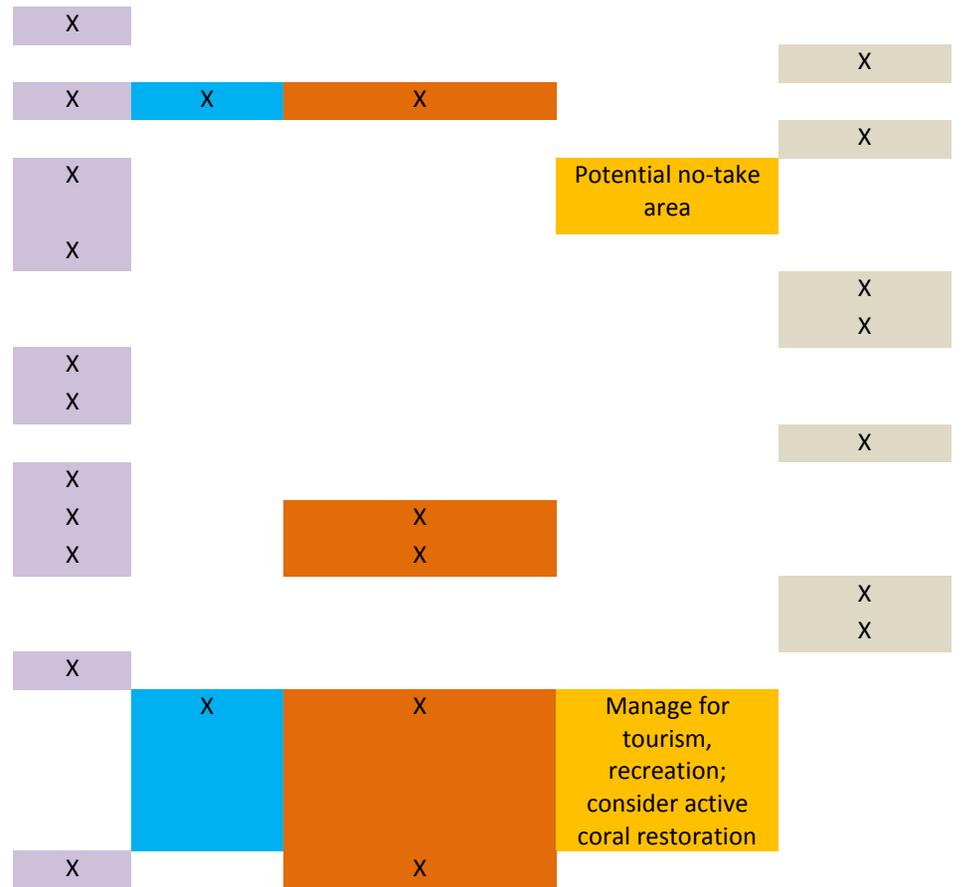
1. Areas of *high resilience* (i.e., areas that score highly for stress resistance and/or recovery) are priorities for inclusion in such strictly protected areas as no take zones and core zones: consider revision of the zoning plan to designate such areas as no-take areas or core zones to provide a balanced distribution of these throughout Chuuk.
2. Areas of *high resilience* may also be protected in tourism zones, but only if tourism development and activities are carefully planned and managed to avoid overcrowding, direct impact on coral communities (such as from holding or standing and anchoring on corals), pollution from such land-based sources as waste water discharge, erosion and resulting sedimentation, and solid waste disposal.
3. Managing *moderate to high resilience* areas effectively is a priority to eliminate all anthropogenic impacts to the coral reef community, including breakage of coral colonies and selective, destructive, or overfishing, and thereby to enhance resistance, recovery, overall reef health and values for fisheries, tourism and coastal protection:
 - Enhance the stress *resistance* potential of the coral reef community by eliminating all forms of anthropogenic stress, including blast and other forms of destructive fishing and damaging anchoring practices consistent with the sustainability principles and to enhance prospects of these reefs surviving climate change.
 - Maintain the *recovery* potential of the coral reef community by managing fisheries to avoid overfishing, especially of herbivore species, and damaging fishing practices, such as blast fishing and direct anchoring, that break apart coral creating beds of loose rubble that are unsuitable for coral recruitment and reduce three dimensional structure that provide habitats for a range of juvenile and adult fish species.
 - Monitor the area carefully, especially during heat stress events, to determine the susceptibility of the coral community to bleaching and related mortality and the prognosis for long-term survival of climate change and warming seas.
4. *Degraded* areas that have strong indicators of either resistance or recovery should be singled out for intense management to enhance the recovery and monitored to document this process. This will likely help to re-establish a vibrant coral community on the reefs at the location and restore their value for fisheries, tourism, coastal protection, and repopulation of damaged reefs through larval transport and recruitment.

2016 REA SITE	Local name	Control destructive/dynamite fishing	Manage over fishing (especially of herbivores)	Monitor & remove crown of thorns starfishes	Prevent anchor damage	Establish as no-take area	Manage land-based pollution (erosion, waste water, solid waste)	Other management actions	No specific management actions
C-208	Pones				X	X			
C-212	Ochanei-1				X	X			
C-44	Ferit				X	X			
C-40	Fonuenipin				X	X			
C-207	Kuop_Neoch				X	X			
C-213	Ochanei-2				X	X			
C-5	Faneno				X	X			
C-205	Kuop_Ochamoch				X	X			
C-57	Onnang				X	X			
C-61	Onno				X	X			
C-59	Pisemu				X	X			
C-38	Wonno				X	X			
C-307	Sapuk				X	X			
C-46	Pisemew				X	X			
C-206	Kuop_Feneppi Pass				X	X			
C-7	Anaw-2	X	X		X				
C-45	Fanochopenges				X	X			
C-58	Fourup				X	X			
C-309	Mochanap				X	X			
C-10	Anaw				X	X			
C-41	Pukuon				X	X			
Uman	Manukun				X	X			
C-12	Anaw-3	X	X		X				
C-47	Terenap/Pisitit				X	X			
C-201	Meseong	X	X		X				
C-11	Sapung Anang	X	X		X				
C-35	Moch	X	X		X	X			
C-8	Fanananei-2	X	X		X				
C-305	Peas				X	X			
C-1	Fanangat	X							

C-4		X	X		X		
C-14	Fourupw	X	X		X		
Pisinini Inner	Pisinini Inner	X	X		X		
C-3	Fanos	X	X		X		
C-60	Fonuamo						X
C-49	Pisinini	X	X		X		
C-9	Fanananei	X	X		X		
C-209	Fanochoeti	X	X		X		
C-300	Meseong-2	X	X		X	X	
C-55	Neoch-3						X
C-211	Chuesen	X	X		X		
C-302	Penon				X	X	
C-303	Penon-2			X	X	X	
C-311	Och	X					
C-37	Sanat	X	X		X		
C-62	Maimai						X
C-39	Wininen	X	X		X		
C-16	Winipiru	X	X		X		
C-33	Sopweru	X	X		X		
C-15	Fanufon	X	X		X		
C-308	Fanochetiw-2	X	X		X		
C-210	Epichun	X	X		X		
C-52	Kuop_Episumur				X	X	
C-6	Parem	X	X		X		
C-310	Sapan Anang-2	X	X		X		
C-77	Oranu	X	X		X		
C-301	Nomoneas						X
C-42	Ochonon	X	X		X		
C-50	Piss-Paneu	X	X		X		
Kuop Acropora Garden	Kuop Acropora Garden				X	X	

confirm if fish spawning aggregation; if yes, establish as no-take MPA

C-13	Pianu	X	X
C-53			
Onei MPA	Saputiu	X	X
C-202	Kuop_Peson		
C-306	Neoch-2	X	X
C-36	Aroch	X	X
Parem	Parem		
C-302 ext	Penson ext		
C-34	Ochoeor	X	X
Onei-3	Mutonpuna	X	X
C-48	Pisitn		
C-18	Fananu	X	X
C-75	Nematon	X	X
C-17	Mew Nematoll	X	X
C-204	Kuop_Penson		
C-304			
C-203	Kuop	X	X
C-312	Truk Stop		
Onei Ref	Sapota	X	X



PART 3. CORAL PATHOLOGY, PREDATION AND DAMAGE

Pathology

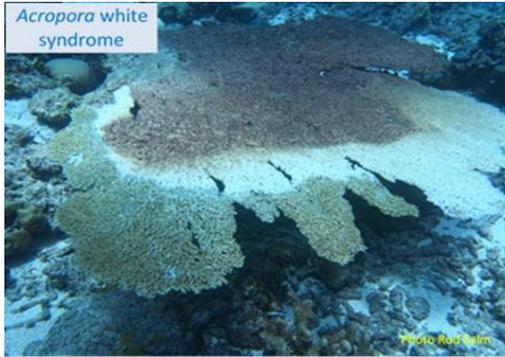
In the context of this report, we are extending pathology beyond diseases linked directly to pathogens to include in this category all forms of naturally occurring or stress induced indicators of compromised coral health. Such indicators may include dead and sloughing coral tissue, gradual die back and inability to repair lesions, discoloration, or overgrowth by other organisms. In so doing, the assumption is made that heavy loads of borers in live corals is enabled due to weakening of the coral skeleton, recruitment of these onto exposed coral skeleton in lesions, and abundant particulate food supplies on which these filter-feeding organisms are able to thrive.

Corals on the reefs of Chuuk showed evidence of multiple stresses, some ongoing and others from times past. It is clear that certain coral communities have suffered extensive previous mortality and it is difficult to consign the cause to one or another stressor with conviction. It appears that the crown of thorns starfish outbreak of five years ago caused extensive loss of table and branching corals and damaged massive coral colonies. The typhoon of 2015 has also caused damage by breaking apart and toppling larger coral colonies and reducing branching corals to rubble fields. Heated water stress has evidently also killed corals in years past and appears to be the principle cause of stress to corals during the time of this reef assessment, explaining the high incidence of discoloration, tissue loss, and paling of corals at many of the locations surveyed.

Disease

White syndromes are common and easily recognized on table *Acropora* colonies, but also occur on other corals. Typically, a white syndrome can be recognized by sloughing coral tissue at the margin between the living and the white, newly dead portion of the colony. Some white syndromes are aggressive and spread quickly over a coral colony. These have a broad white portion bordered by living tissue on one side and a wide margin of yellowing coral skeleton on the other. The dead coral skeleton yellows as it becomes colonized by filamentous algae. Progressing further from the white band, the coral skeleton becomes brown and more densely covered by turf algae. *Acropora* white syndrome occurs widely on the reefs in Chuuk and was found in greatest abundance on the channel reef at Penson-2 (site C-303; online database code: KUOP-12 – photo right).





Pones (site C-208)



Sapan Anang-2 (site C-310)

Black Band Disease has a clearly defined black band of necrotic tissue, which can differ greatly in width, separating the live tissue from the white coral skeleton. Black band disease was uncommon on the reefs of Chuuk during the period of this assessment. Photo on right from Anaw (site: C-10; online database code CHK-12).



Growth anomalies are tumor like growths of the coral skeleton that may be cancerous. These can occur singly but often occur in clusters occasionally moving rapidly away from a parent growth across the coral colony. Growth anomalies are commonly encountered on corals on the reefs of Chuuk.



Penson-2 (site C-303)



Pukuon (site C-41)



Piss-Paneu (site C-50)



Pisititn (site C-48)



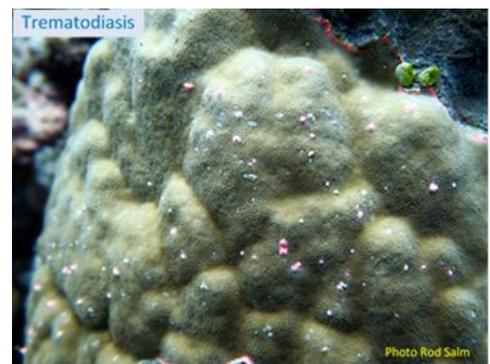
Pukuon (site C-41)



Piss-Paneu (site C-50)

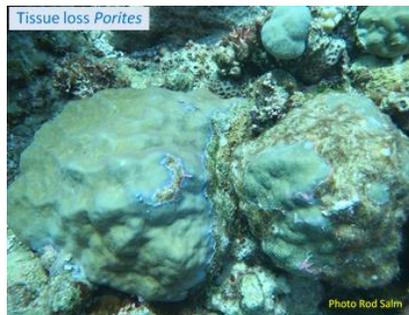


Trematodiasis results when trematodes form cysts in coral tissues that are clustered on one colony. The coral tissues surrounding the cysts will swell becoming visible as white, or more usually pink, raised spots. Heavy *Trematodiasis* will reduce growth and reproduction of the host coral thereby reducing the resilience of the colony.



Heavy *Trematodiasis* will reduce growth and reproduction of the host coral thereby reducing the resilience of the colony.

Tissue Loss is characterized by unexplained loss of coral tissue and exposure of white underlying skeleton. Tissue loss cannot be readily attributed to predation or heat related bleaching, but it seems likely that the corals are responding in some places, such as around Onei, to pollution and sedimentation and in others to low levels of heat stress. Tissue loss is clearly related to poor health of coral colonies and as such functions as an indicator of compromised resilience.



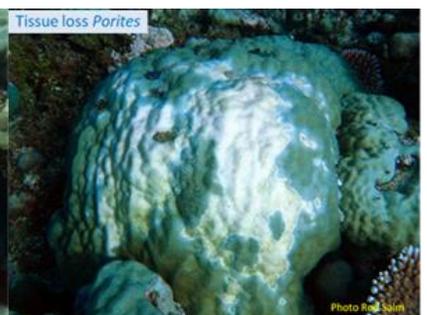
Sapung Anang (site C-11)



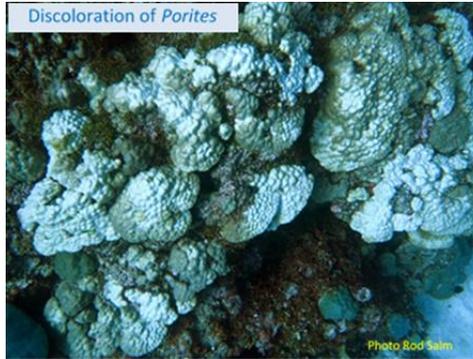
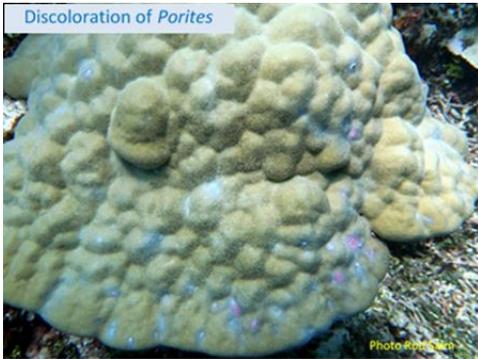
Ochanei (site C-212)



Moch (site C-35)



Kuop_Neoch (site C-207)

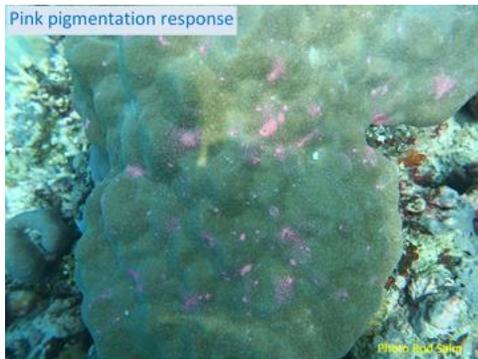


Meseong (site C-300) top left; Ochanei (site C-212) top right; Fourupw (site C-14) bottom left; Anaw-3 (site C-12) bottom right

former usually preceding the latter

Discoloration of coral colonies was common in Chuuk during the period of this assessment. Low levels of heat stress contributed to this by causing uneven paling of coral colonies. Blotchy discoloration of massive corals was likely caused by heat stress also, but sedimentation, mucus production, and shore based sources of pollution certainly contributed.

Discoloration and tissue loss are often associated, with the

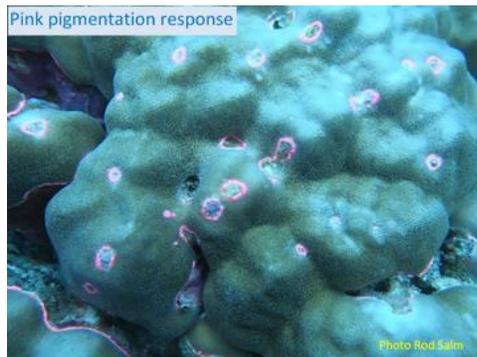


Terenap/Pisitini (site C-47)

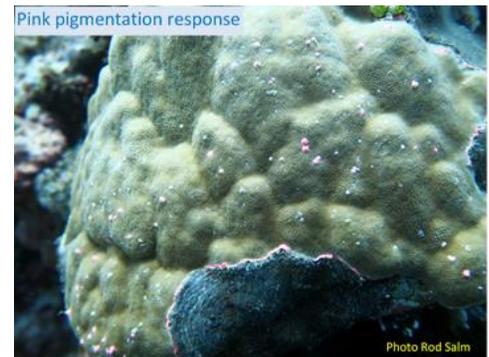
Porites pink pigmentation response around lesions caused by fish bites, trematodes, borers, abrasion, or other causes indicates inflammation of coral tissue usually associated with healing.



Onei Ref_Sapota



Kuop_Ochamoch (site C-205)



Moch (site C-35)

Predation

Starfishes

The crown of thorns starfish *Acanthaster planci* is a notorious coral predator. Evidence of previous outbreaks and ongoing infestations abound on the reefs of Chuuk. Crown of thorns starfishes were recognized by direct observations or by their feeding scars, both old and new.



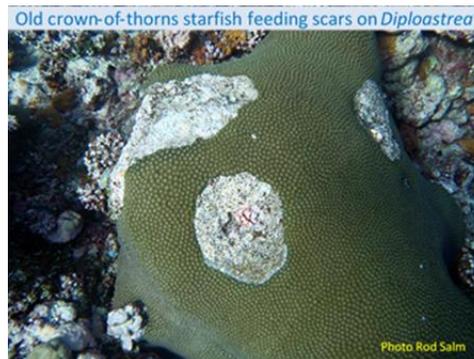
Crown of thorns starfish feeding on branching *Acropora* coral at Ochonon (site C-42)



Crown of thorns starfish feeding on table *Acropora* coral at Sapan-Anang-2 (site C-310)



Recent crown of thorns feeding scars on bushy *Acropora* at Pisinini (site C-49)



Old crown of thorns feeding scars on *Diploastrea* colony at Fanananei-2 (site C-8)



Meseong-2 (site C-300)

Molluscs

The coral predator snail *Drupella* is seen clearly in these two photographs. *Drupella* frequently appears purple to red in color due to coralline algae covering the shell and is most often seen feeding on branching corals. *Drupella* can form outbreaks of many hundreds on one coral colony and completely kill off large old table *Acropora* corals or open lesions allowing algae, borers, or diseases to enter the wound and spread across the colony.



Drupella snail feeding on bushy *Acropora* at Sapung Anang (site C-11). *Drupella* is commonly seen feeding on *Acropora* and *Pocillopora* that provide *Drupella* refuge among their branches.



Drupella snail feeding on massive *Porites* colony at Oranu (site C-77); it is uncommon to see *Drupella* on massive corals such as *Porites*.

Coralliophila is another predatory snail that feeds on coral. It occurs throughout the coral reefs in Chuuk where it is typically seen feeding on *Porites*, but also may infest colonies of *Turbinaria*. By day, *Coralliophila* are frequently seen tucked into grooves in *Porites* colonies and may contribute to deepening these grooves and to the bioerosion of



their host colonies. Diseases, algae and borers may gain access to the colony when their health is compromised by such stress events as storms or hot water and bleaching.

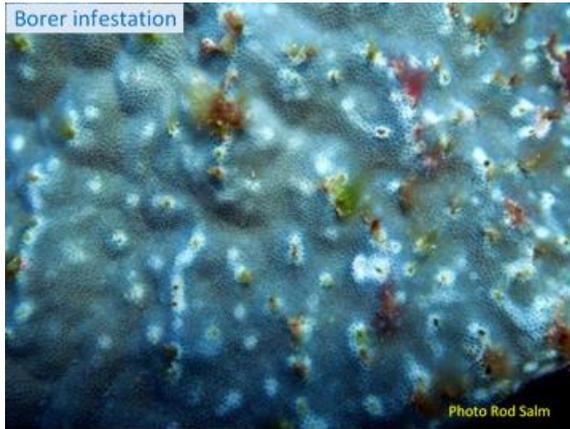
Fishes

A variety of fishes feed on corals: some browse on surface tissues and leave healthy corals without any long term effect. Others will scrape of tissues and skeleton together which can leave lasting scars that become infected by pathogens or algae when the health of the corals is compromised and they are unable to repair the lesions. The excavator parrotfishes will take large bites out of coral skeletons leaving deep scrapes and broken branches that can lead to serious impact on coral colonies especially during periods of stress when corals lack the energy reserves to repair damaged areas.

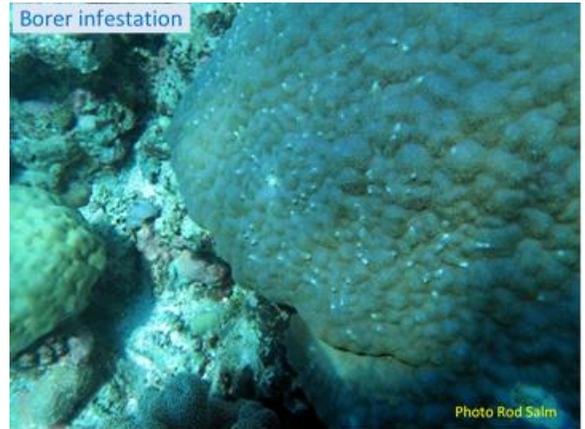


Superficial fish feeding scars on *Porites* that should heal well (top). Deep excavator parrotfish bite out of *Porites* (lower left) that may lead to a permanent lesion in the colony if colonized by algae before the coral is able to repair the damage. Tips of an *Acropora* coral's branches bitten off by a fish (lower right) is likely to lead to death of the coral colony

Borer Infestation



Mochanap (site C-309)



Maimai (site C-62)

A variety of worms and barnacles are the common borers in the corals at Chuuk. In low numbers these live in harmony with the corals and have little impact. However, under certain circumstances, perhaps due to nutrient loads or compromised vigor of the coral colonies, the borers can infest coral colonies in large numbers and weaken them as in the ones illustrated here.



Moch (site C-35)



Sapung Anang (site C-11)

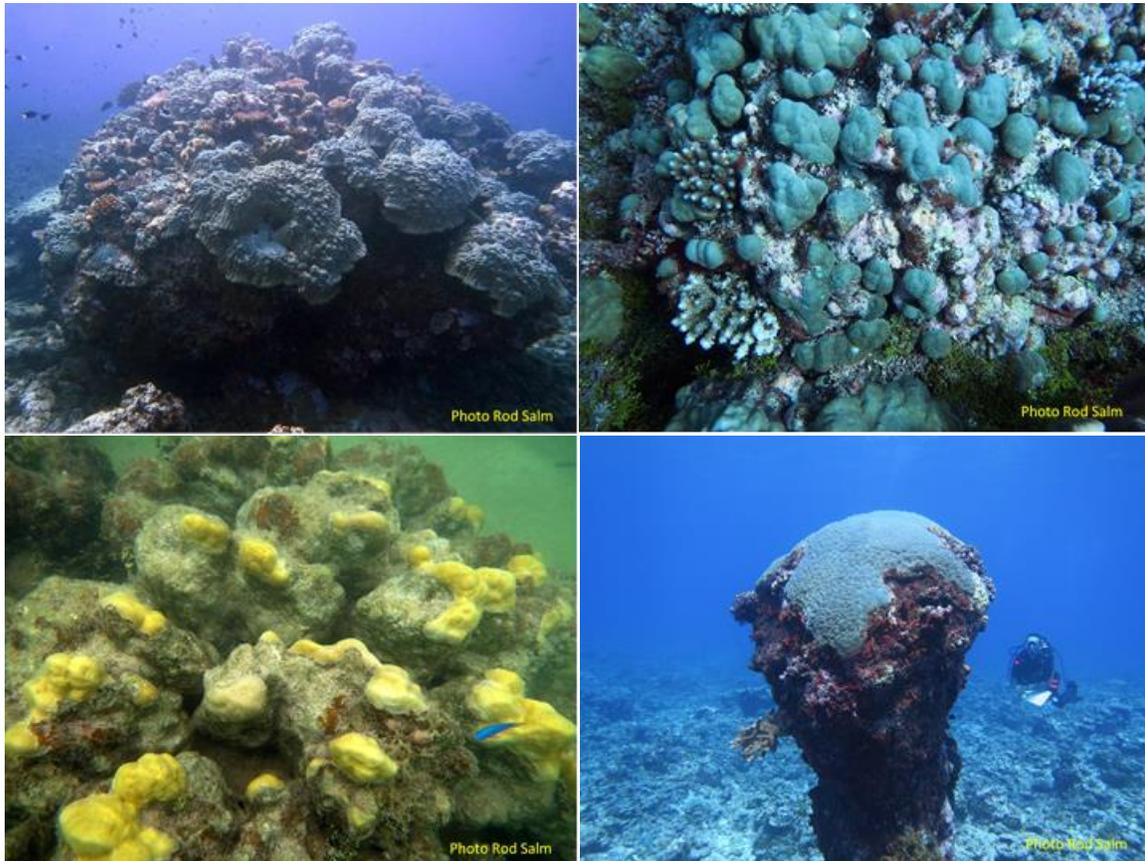


Kuop_Neoch (site C-207)



Sapan Anang-2 (site C-310)

Burrowing sea urchins, such as *Echinostrephis* and *Echinometra*) bore deeply into corals and cause colonies to break apart. *Echinostrephis* was encountered boring into both massive corals and the underlying reef rock at several sites in Chuuk.



Various stages of bioerosion that leads to the cleavage of coral colonies into blocks of variable size. Massive corals on pedestals reaching from 20 cm to four meters above the reef attest to major bioerosion of the Chuuk reefs: Ochane-2 (site C-213) top left, Kuop_Neoch (site C-207) top right, Onei Ref_Sapota bottom left, Ochoeor (site: C-34) bottom right.

Undetermined and/or multiple sources of pathology and predation



Undetermined causes of paling and tissue loss at Mochanap (site C-309)



Undetermined causes of discoloration and lesions: Pisitin (site C-48) right; Kuop_Ochamoch (site C-205) left & center

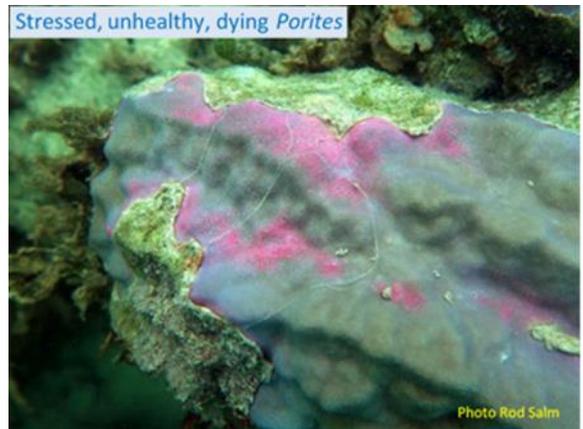


Undetermined cause of tissue loss and disease at Kuop_Ochamoch (site C-205)

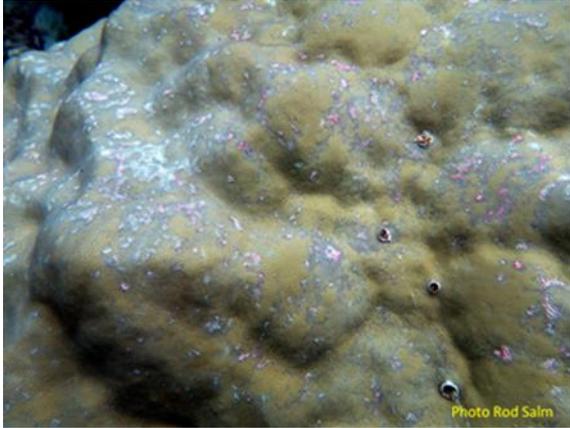


Large dead surface on this *Porites* colony is likely the blast surface caused by dynamite fishing (Pisinini, site C-49)

Corals on all reefs at Chuuk showed signs of stress: the levels of disease, discoloration, and tissue loss are of concern. However, of greater concern is the cause of these symptoms.



Onei Ref_Sapota



Porites with multiple small lesions and discoloration, including pink pigmentation response, at Meseong_2 (site C-300)

Recently dead corals can be attributed to ongoing crown of thorns starfish predation and disease, and broken corals to anchors, dynamite fishing, or the 2015 typhoon. The extent of older dead *Acropora* and *Pocillopora* corals is likely linked to either previous crown of thorns predation or bleaching, but it is difficult to be sure. Land-based sources of pollution and El Niño related heat stress over the past three years could explain the poor health of so many Chuuk corals.

It is often nearly impossible to determine the cause of death or damage when these are old. Even for less severely or recently affected corals it can be difficult to diagnose the reason for the decline in health of a colony, especially when there appear to multiple causes.

colony, especially when there appear to multiple causes.

Overgrowth and Competitive Exclusion



Competitive overgrowth by sponge & algae

The encrusting sponge *Chalinula nematifera* is an aggressive competitor that overgrows and kills corals. It has settled on a *Porites* coral suffering from multiple stresses, but the coral is fighting back in places and pushing back the sponge. The prospect of the coral surviving is bleak due to the dual onslaught of sponge and macroalgae overgrowth and poor water quality here at the Onei Ref_Sapota site.

Other aggressive competitors that can overgrow and kill established coral colonies and which are present



Competitive overgrowth of *Porites* by *Heliopora*

Aroch (site C-36)



Competitive overgrowth of *Porites cylindrica* by *P. rus*

Sapuk (site C-307)



Competitive overgrowth of massive *Porites* by *Millepora*

Fanochetiw-2 (site C-308)

and active in Chuuk include *Millepora*, *Porites rus* and a variety of macroalgae of which *Halimeda* is the most widespread across different reef environments.

Anthropogenic Damage

The reefs of Chuuk are heavily used for livelihoods and recreational fishing in Chuuk, and to a lesser degree for tourism. And in addition to food production, these reefs also play an important role in coastal protection and provision of sheltered waters for boats to anchor. Collapse of the reef structure will remove the benefits of the reef for all of these services and will prevent the corals from growing upwards to keep up with sea level rise. There are four widespread and conspicuous impacts that people have on the reefs of Chuuk:

1. Many Chuukese use a traditional and very destructive anchoring practice that deploys a large hook or weight onto the reef to drag the bottom until it catches. While dragging, the hook anchor breaks apart branching and more fragile corals and dislodges others that are insufficiently securely attached to the substrate to withstand the weight of a drifting boat. Evidence of anchor damage on Chuuk reefs is widespread and an unnecessary additional source of damage to the structure of the reefs.
2. Another widespread and greater threat to the health and integrity of corals on Chuuk's reefs is dynamite fishing. This breaks apart even large massive corals and creates beds of loose rubble on which coral recruitment is difficult and in places with high wave action may never happen.



Kuop_Feneppi Pass (site C-206)



Fanananei-2 (site C-8)



Sapuk (site C-307)



Sapuk (site C-307)

3. On inhabited islands, especially adjacent to settlements, pollution caused by runoff, including sediments, waste water discharge and seepage, and solid waste disposal has contributed to coral disease and death, reduced the resilience of the community, and turned certain reefs to banks of dead coral covered by dense macroalgae.

4. Parrotfishes are heavily overfished on many reefs which disrupts their role in grazing down macroalgae and controlling the height and density of algal turfs. The various types of parrotfishes and surgeonfishes collectively control algal density and cover to enable successful coral settlement and recruitment. When overfished their contribution to reef health and resilience is diminished and the reef can transition from coral to algal dominated community.

Fish data were collected by members of the Micronesia reef monitoring team only. Algal cover, on the other hand, varies greatly among the reef sites and is tied to both fishing pressure on herbivores and nutrient input from land.



Fanananei-2 (site C-8)

Although not widespread, graffiti on table corals, apparently used to demarcate fishing or access rights, was seen at not less than three sites. This can cause lesions in the corals that get invaded by pathogens, sponges or algae, resulting in extensive damage to the coral and mortality.

Natural Causes of Coral Damage and Mortality

Slumping

Vigorous coral growth on some reefs in Chuuk can cause coral to grow out from shelves to the point where they break under their own weight, especially during storms or if weakened by borers, such as is shown happening with *Porites cylindrica* in these pictures. Pix will be added

Storm surge

The reefs and islands of Chuuk are occasionally affected by tropical storms. In 2015, Chuuk suffered a powerful typhoon that likely explains the many dislodged and overturned table *Acropora* and massive *Porites*. The seaward reefs have a well-developed spur and groove structure. The scoured nature of the grooves illustrates the extent of storm surge damage.



References

- Beeden, R., Willis, B. L., Raymundo, L. J., Page, C. A., & Weil, E. (2008). Underwater cards for assessing coral health on Indo-Pacific reefs. *Coral Reef Targeted Research and Capacity Building for Management Program. Currie Communications, Melbourne, 22.*
- Maynard, J. A., P. A. Marshall, J. E. Johnson, and S. Harman. 2010. Building resilience into practical conservation: identifying local management responses to global climate change in the southern Great Barrier Reef. *Coral Reefs* 29(2): 381-391.
- McClanahan, T.R., S.D. Donner, J.A. Maynard, M.A. MacNeil, N.A.J. Graham, *et al.* 2012. Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE* 7(8): e42884. doi:10.1371/journal.pone.0042884.
- Obura, D.O. and Grimsdith, G. 2009. *Resilience Assessment of coral reefs – Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress.* IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pp.
- Salm, R.V. and E. McLeod. 2007. Building resilience into coral reef management. Pp. 205-221 in Keller, B.D., and F.C. Wilmot, eds. 2007. *Connectivity: science, people and policy in the Florida Keys National Marine Sanctuary.* Colloquium proceedings, 19-21 August 2004, Key West, FL. Marine Sanctuaries Conservation Series NMSP-07-xx. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, MD. 272 pp.

PART 4. CHUUK REEF ASSESSMENT SITE DESCRIPTIONS

The following section includes a description of each site covered by the citizen science team that was derived from notes entered on the field data sheets and an interpretation of the data. The resilience scores reflect the values for each site calculated from the cumulative resistance and recovery components of resilience and the predation and disease values. The management suggestions include actions that are aimed at reinforcing the health and resilience of the coral reef community at each site. Generally, these include effective management of overfishing and destructive fishing practices, particularly dynamite fishing and anchoring on corals. While these are good practices on all reefs, some sites have no specific management recommendations. This is to avoid diluting management effort over too many sites and keeping it focused on those that make a potential contribution to (1) connecting larval dispersal over a broader area, (2) protection of coastlines, particularly those close to villages, or (3) maintaining fisheries. Some low resilience sites may be identified for management attention if they potentially could contribute to any of these three functions.

Site name: Fanangat; C-1 (7/16/2016)

Latitude: 7.54245°N; Longitude: 151.81007°E

Reef type: Inside; Transect heading: SE

Current Online Database Code: CHK-17

General Description:

Reef slopes very gradually from a 2.5-4 m rampart that forms the reef crest. The fore reef is covered by extensive rubble that is consolidated by crustose coralline algae, which constitutes on average 30% of the hard substrate cover, and has patchy outcrops of *P. cylindrica* and moderate levels of branching *Acropora* recruits; table *Acropora* is missing entirely. The resistant massive corals reach more than 3 m in diameter. Dead (white) *Halimeda* flakes are compacted under the rubble and scattered lightly across the surface in patches, but live macroalgal cover is low. Although turf algal cover averages 41% on the rubble, it forms a very fine closely grazed down cover.

At 10 m the diversity of coral recruits on consolidated rubble increases, but remains at moderate levels. There is patchy branching *Acropora* and *Porites cylindrica* and a cover of very fine, heavily grazed algal turf on dead massive *Porites* and table *Acropora* colonies. Table *Acropora* colonies are all smaller than 2 m and massive species reach more than 3 m diameter.

Potential resilience:

The coral community demonstrates moderate levels of stress resistance and recovery and has suffered extensive mortality of branching and table corals due perhaps to crown-of-thorns starfish and typhoon damage and almost certainly previous undocumented heating-bleaching mortality. Recovery is underway but table *Acropora* species are slow to repopulate the shallower portions of this reef. Large massive corals (>3 m) have survived, preserving the reef framework. Rugosity decreases with depth. Resistant coral species are faring better than the susceptible species and there is the danger that these may disappear unless the reef is carefully managed. Resistance and recovery indicators are low to moderate. Overall **the potential resilience is moderate.**

Conservation action:

It is important to control destructive fishing practices and give the coral community the chance to build its health and resilience.

Site name: Fanos; C-3 (7/16/2016)

Latitude: 7.53707°N; Longitude: 151.76695°E
Reef type: Patch_back; Transect heading: N/A
Current Online Database Code: CHK-8

General Description:

The reef slopes gradually from the crest and has moderate rugosity. Hard coral cover is low and variable on a substrate of sand with staghorn coral rubble; live hard coral cover averages 18% across all depths, being higher (30%) at 10 m than at 4 m (6%). Diploastrea formed the largest colonies. But branching *Acropora* is recovering strongly on the shallower rubble fields and there are numerous small colonies with active blue growth margins. Algal cover is high: turf algae 35% and macroalgae 30%.

It is possible that disease and other distress indicators were undercounted due to difficulty recognizing these on the first dives of the assessment.

Potential resilience:

Both the resistance and recovery indicators are moderate yielding a **moderate potential resilience**.

Conservation action:

The site's resilience could be enhanced by managing the herbivore fisheries, anchor damage, and destructive fishing practices.

Site name: N/A; C-4 (7/17/2016)

Latitude: 7.61779°N; Longitude: 151.82033°E
Reef type: Patch_back; Transect heading: N/A
Current Online Database Code: CHK-54

General Description:

The reef slopes gradually from the crest steepening with increasing depth. Cover of live hard corals is low, averaging 16%. Exposed rock and rubble surfaces are covered by crustose coralline algae (36%), turf (29%) and macro algae (16%).

Potential resilience:

Recovery indicators score higher than those for resistance, and this coral reef community has a **moderate overall potential resilience**.

Conservation action:

The prospects for maintaining and even enhancing the health and resilience of this coral reef community and increasing its survival outlook are strong if effective measures are applied to

manage overfishing and destructive fishing practices. It is important to manage fisheries carefully to avoid overfishing of herbivore species and to prevent destructive fishing practices, particularly dynamite fishing and anchoring on corals.

Site name: Faneno; C-5 (7/17/2016)

Latitude: 7.5847°N; Longitude: 151.85286°E

Reef type: Patch_back; Transect heading: S

Current Online Database Code: CHK-35



General Description:

Reef slopes gradually from crest. Reef slope has high rugosity, high live hard coral cover (45%), moderate turf cover (23%), low macroalgae cover (3%) and high crustose coralline algae cover (30%) that is consolidating the branching *Acropora* rubble. Dense *Halimeda* grows between the branching *Acropora* colonies. Massive *Porites* and *Diploastrea* reach sizes exceeding 3 m diameter and, like the table *Acropora*, have good size range indicating regular recruitment. The large patches of branching *Acropora* rubble and toppled massive *Porites* suggest previous storm damage and possibly dynamite fishing. Live branching *Acropora* patches are paling. Despite the paling, broken branching *Acropora* is rapidly regrowing and appears robust and healthy.

Potential resilience:

Both resistance and recovery score highly and indicate a coral community with overall **high potential resilience**.

Conservation action:

The area needs to be managed to maintain or enhance the resistance and recovery potential and prevent dynamite fishing and damaging anchoring on corals. In addition, the area should be considered for establishment as a no-take zone to protect it as a natural refuge to support recovery of neighboring coral communities to which it is connected. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Parem; C-6 (7/17/2016)

Latitude: 7.57095°N; Longitude: 151.88739°E
Reef type: Patch_back; Transect heading: N/A
Current Online Database Code: CHK-1

General Description:

This low to moderate rugosity reef slopes gradually from the crest. Live hard coral cover is low (13%), turf (26%) and macro algae (22%) cover is moderately high and crustose coralline algal cover is high (39%). Resistant massive corals attain large sizes, but coral color shows high levels of early paling and recruitment is low to moderate indicating a coral community responding relatively weakly to stress.

Potential resilience:

The resistance indicators are moderately weak and corroborate this observation. Recovery indicators also score relatively low indicating some challenges with recovery. Overall **the potential resilience of this reef is moderate.**

Conservation action:

The area requires management to enhance the health and condition of the coral community and its contribution to the resilience of the larger Chuuk coral reef system through effective control of overfishing, anchoring, and destructive fishing methods.

Site name: Anaw-2; C-7 (7/19/2016)

Latitude: 7.52947°N; Longitude: 151.6286°E
Reef type: Patch_back; Transect heading: NE
Current Online Database Code: CHK-38

General Description:

Reef slopes moderately steeply down the fore reef. Rugosity is moderate and live hard coral cover is high (43%). Cover by turf algae (25%), macroalgae (20%) including *Halimeda* and filamentous algae, and crustose coralline algae (13%) all moderate. The substrate cover is patchy with areas of *Porites rus*, loose and crustose coralline algae consolidated rubble. Recruitment is low. Parrotfishes are abundant. One large overturned *Porites* had no recruits established on the dead portion of the colony. Another large *Porites* exceeded 3 m across its largest dimension.

Potential resilience:

The resistance and recovery scores are moderately high and overall **potential resilience is high** also.

Conservation action:

Managing to reduce fishing pressure and eliminate destructive fishing practices and anchoring will make a significant contribution to strengthening the potential resilience of this coral reef community.

Site name: Fanananei-2; C-8 (7/20/2016)

Latitude: 7.45755°N; Longitude: 151.56348°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-60



General Description:

The reef slope is gradual and rugosity is high. Substrate is covered primarily by crustose coralline algae (CCA) (64%), with live hard coral cover and turf algae both low at 9% each and macroalgae 4%. Recruitment is moderate to high. Despite generally good coral color, some early paling has begun (*Pocillopora*). Old dead table and branching *Acropora* are abundant with one dead overturned *Acropora* table reaching 3 m across. Spurs have abundant dead coral heavily covered by CCA and scattered live coral. CCA is especially thick on spurs. Even though corals are dead their structure is not lost to the reef because of the heavy CCA blanketing the dead corals and rubble. Old crown of thorns starfish feeding scars are evident on *Porites* and *Diploastrea* and one *Diploastrea* affected by white syndrome was recorded. Overall disease levels are low, but predation is high.

Potential resilience:

The stress resistance indicators score high, recovery indicators score low, and the overall **potential resilience of this coral community is moderate.**

Conservation action:

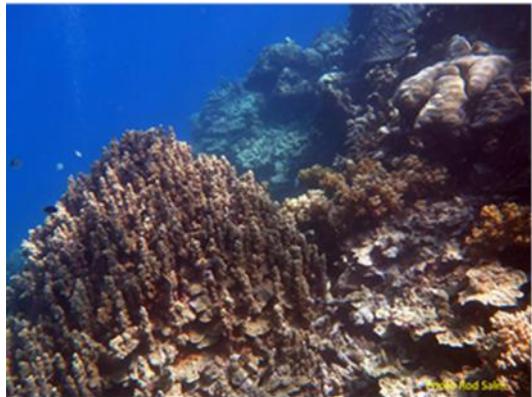
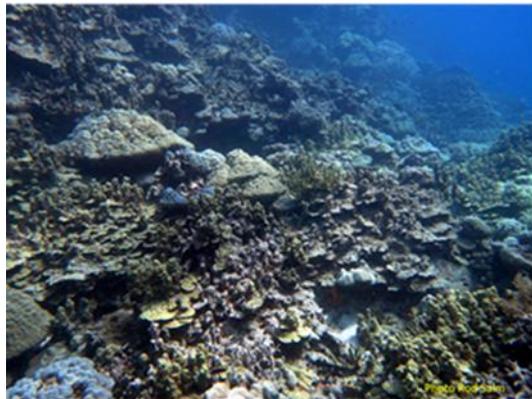
It is important to manage this area for recovery and to enhance its potential resilience building on the strong resistance indicators and strengthening the recovery potential. This will require management of the herbivore fisheries and prevention of destructive practices such as dynamite fishing and anchoring directly on the corals.

Site name: Fanananei; C-9 (7/22/2016)

Latitude: 7.44854°N; Longitude: 151.56259°E

Reef type: Patch_back; Transect heading: NE

Current Online Database Code: CHK-39



General Description:

The reef falls sheer down a wall to 4 m from where the slope is moderately steep and rugose. Live hard coral cover across all depths is high, varies little, and averages 63% over the available hard substrate; turf algae cover is 20%, macroalgae cover is low (4%), and crustose coralline algae cover (CCA) averages 13%. There are patches of alcyonarians, but these are not common. At 4 m CCA is very thick and well established; *Stylophora* and *Acropora* bleached near white in one area and most corals are pale to near white and anemones are also very pale to near white; one massive *Porites* covered by mucus. There are few and small (<50 mm) table *Acropora* corals and interestingly no old dead colonies. There are large numbers of small reef fishes, many butterflyfish species and schools of parrotfishes and surgeon fishes. The reef at 10 m is strongly consolidated by CCA with *Porites lobata*, *P. rus* and *P. cylindrica* dominant. There is some siltation in pockets in massive corals. The sandy substrate surrounding the reef had well developed thickets of healthy branching *Acropora* (good color, active growth margins, no disease). One 50 cm *Tridacna squamosa* was recorded. Coral recruitment is high but growth margins of branching, table and foliose corals are narrow and growth rates appear low. Levels of coral disease are moderate and predation is high.

Potential resilience:

Stress resistance indicators are moderately high, but recovery indicators are low, and overall **potential resilience for this coral community is moderate.**

Conservation action:

It is important to manage this reef to enhance resilience through strengthening the resistance and recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Anaw; C-10 (7/17/2016)

Latitude: 7.56471°N; Longitude: 151.68158°E

Reef type: Patch_back; Transect heading: NW

Current Online Database Code: CHK-12



General Description:

Moderately steep, rugose slope from crest down fore reef with loose rubble covered in crustose coralline algae (CCA) and fine turf and 10% cover *Halimeda*. Large *Porites* (<4 m) are found on the upper slope along with alcyonarians, table *Acropora* (small, averaging less than 20 cm), CCA. Several COT scars in this zone; and some *Porites* stressed (tissue loss and discoloration). Plating *P. rus* and massive *Porites* dominate down rubble-sand slope, with *Halimeda* and sand on live coral and patches of alcyonarians and table *Acropora* and *Millepora*. CCA cover increases to 30% at 10 m. Coral color is good at all depths and the table corals exhibit active but narrow growth margins. Small parrotfishes are abundant across the depth range covered.

Potential resilience:

The coral community exhibits moderate levels of stress resistance and recovery with recruitment stronger in the shallower reaches of the reef than deeper. Rugosity is moderate and increases to high deeper. Overall, **the potential resilience is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a western inner patch reef of Chuuk atoll and is placed in a major channel where it can facilitate spatial ecological connectivity among the inner and outer reefs of the atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. This would benefit fisheries by spill-over and larval

replenishment for the communities fishing nearby reefs. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Sapung Anang; C-11 (7/19/2016)

Latitude: 7.61229°N; Longitude: 151.68527°E

Reef type: Channel; Transect heading: NE

Current Online Database Code: CHK-20



General Description:

Weak current; calm; high visibility. The reef structure comprises deep, well-developed spur and groove formations from the shallows to >10 m. Coral cover increases from 27% at 4 m to 70% at 10 m. At 4 m there is abundant old dead coral covered by algal turf or crustose coralline algae. 30% of the substrate is dead coral, especially table *Acropora*; there is almost no live branching coral. This was once a beautiful table coral garden that now is dead but recovering: recruits are high in numbers but low in diversity on spurs. One *Porites* reached at least 7 m along its greatest length. *Goniastrea* white syndrome seen on one colony; 7 crown of thorns starfish feeding scars were recorded; there were schools of small-medium parrotfish.

Potential resilience:

Massive *Porites* is dominant at 10 m and corals have good color; recruitment is strong; coral cover is high and corals are healthier at this depth (lower levels of disease and predator, wider growth margins, and deeper color). Overall, the **potential resilience is moderate and approaching high.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery of branching and table corals that have suffered high mortality. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Anaw-3; C-12 (7/19/2016 & 8/2/2016)

Latitude: 7.5579°N; Longitude: 151.64987°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: CHK-43



General Description:

The shallows are a table coral graveyard: bushy, table and branching *Acropora*, *Pocillopora* are all dead and covered by algal turf or crustose coralline algae (CCA). The reef structure is spurs and grooves, rugosity is high; CCA is dense and averages 60% on spurs, which also have dead corals and low cover (17%) of small live corals. Rolled rocks in the grooves are covered with algal turf. *Porites* has numerous old crown of thorns starfish (COT) scars that may explain the extensive death of acroporid corals. Recruitment is low with only a few patches reaching level 2. Coral color is good across the depth range covered (2-12 m). At 10 m depth, live hard coral cover increases to an average of 37% and the community is dominated by massive *Porites* and *Diploastrea*, with *P. rus* and scattered small coral colonies on a substrate covered with abundant *Halimeda*, turf algae (15%) and CCA (50%). Although only one live table *Acropora* was seen, there are many old dead colonies along with abundant old dead branching corals: three old COT scars were recorded on *Porites*, which may explain the death of these corals. Neither table *Acropora* nor massive *Porites* reach large sizes. Massive *Porites* colonies are all deeply pitted and eroded. *Pocillopora* colonies are brightening to purple and pink; *Porites* colonies sustain numerous lesions and two colonies were observed with pink pigmentation spots. Recruitment is higher than in shallower zones of the reef with many patches reaching level 3. Lesion repair was observed, especially on massive corals as these were more abundant, and regrowth over dead portions of the coral colonies was seen on massive and branching corals. A moderate amount of disease, especially discoloration of *Porites* colonies, and of predation was recorded.

Potential resilience:

Despite the extensive dead coral, the recovery and overall **potential resilience of this coral community is high.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery of branching and table corals that have suffered high mortality. This will require management of the herbivore

fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Pianu; C-13 (7/20/2016)

Latitude: 7.31349°N; Longitude: 151.43742°E

Reef type: Outer; Transect heading: S

Current Online Database Code: CHK-21

General Description:

Relatively steep slope from reef crest with moderate rugosity. Abundant *Millepora* in large patches around 4 m across; *Diploastrea* colonies exhibiting regrowth over dead patches at this depth with good crustose coralline algae (CCA) cover on the substrate, but low coral recruitment. There is evidence of several actively feeding crown of thorns starfishes (COTs) from scars on the live corals. Turf algae cover decreases with depth to 20% at 10 m; macroalgae constant at 10% cover across the depths and CCA constant at 25%. Live coral cover increases from 15% at 4 m to 25% at 10 m. There has been a big die-off of Acroporid corals and table corals were entirely absent at both depths. The dead coral and rock substrate is covered by turf and CCA with relatively low levels of coral recruitment comprising mostly massive *Porites* and encrusting corals. There is evidence of many COTs and live massive *Porites* have COT scars, near circular bleached areas, and many small lesions. A school of humphead parrotfishes seen.

Potential resilience:

Potential resilience is moderate, but approaching low, especially as indicators of recovery potential are weak. There may be a transition from a diverse community of mixed susceptible and resistant species to a community dominated by such resistant corals as *Diploastrea* and *Porites*.

Conservation action:

Although it may appear too late to avoid a transition to a different coral community structure, it is important to manage this reef to enhance its resilience, especially the recovery of branching and table corals that have suffered high mortality. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Fourupw; C-14 (7/20/2016)

Latitude: 7.29689°N; Longitude: 151.5641°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-10



General Description:

At 4 m the reef slope is moderate and increases slightly with depth. Rugosity is high. Cover of hard substrate varied little across both deep and shallow areas surveyed and averaged about 50% for live hard coral, 12% for turf algae and 20% for crustose coralline algae. Coral color was generally good. There were no table *Acropora* corals seen at shallower depths and very few deeper. At 10 m the coral community is dominated by branching and massive *Porites* species and *P. rus*; *Seriatopora* is bleached and many species exhibit early paling. Crown of thorns starfishes are active and 16 feeding scars were recorded.

Potential resilience:

Coral recruitment is high but other recovery indicators are low. Disease and predation levels are moderate. The overall **potential resilience of this coral community is moderate.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Fanufon; C-15 (7/20/2016)

Latitude: 7.39416°N; Longitude: 151.46045°E

Reef type: Patch_back; Transect heading: N

Current Online Database Code: CHK-22

General Description:

Across full depth range 4-10 m: Moderately steep slope with high rugosity and some mixing of the water column. Hard coral cover is consistent and moderately high at 40%. Macroalgal cover is also moderately high at 20% and turf and crustose coralline algae consistent at 20% from 4-10 m.

Tunicates are abundant. Table *Acropora* absent. Rubble is moderately well cemented by crustose coralline algae, but recruitment is low. Massive *Porites* dominates with some colonies exceeding 3 m.

Potential resilience:

Indicators suggest low recovery potential and low-moderate resistance. There appears to be a shift to the more resistant massive species, but this needs to be confirmed over time. Overall **potential resilience of this coral community is moderate.**

Conservation action:

This coral reef community needs to be managed to enhance its resilience, especially as it appears to be low and suggests that the long term survival of this reef may be in jeopardy. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Winipiru; C-16 (7/22/2016)

Latitude: 7.29716°N; Longitude: 151.52336°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-44

General Description:

Moderately steep reef slope with high rugosity. Live hard coral cover of available hard substrate is moderate at 37%, and turf algae cover is 19%, macroalgae cover is 14%, and crustose coralline algae cover is 19%. No table *Acropora* corals were encountered at either 4 m or 10 m; *Diploastrea* forms the largest massive colonies at shallower depths. Corals are exhibiting some early paling especially at shallower depths.

Potential resilience:

Stress resistance indicators are moderately high and recovery indicators score low. Levels of disease and predation are moderate and overall **potential resilience for this coral community is moderate.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Mew Nematoll; C-17 (7/21/2016)

Latitude: 7.36271°N; Longitude: 151.5948°E

Reef type: Inner; Transect heading: N/A

Current Online Database Code: CHK-45

General Description:

Steep, rugose slope. Live hard coral cover of available hard substrate is low (13%), macroalgae (primarily *Halimeda*) is high (54%), cover by turf algae is 12%, and crustose coralline algae is (18%). The hard corals are paling; no table *Acropora* corals were encountered; one gigantic *Porites* colony at 10 m depth (size not determined); and *Porites rus* is the dominant coral species. Disease and predation levels are moderate.

Potential resilience:

Resistance and recovery scores are low and overall **potential resilience for this coral community is low.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and issues related to runoff and pollution. It is important to try and strengthen its resilience, including both the resistance and recovery potentials. This will require management of land-based sources of pollution including erosion and sedimentation, waste water and solid waste disposal into the nearshore waters, and the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Fananu; C-18 (7/22/2016)

Latitude: 7.39042°N; Longitude: 151.55464°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-46

General Description:

The reef has a gradual slope and low rugosity. Live hard coral cover averaged across all depths is low (11%) and turf algae cover is high (44%); average macroalgae and crustose coralline algae cover overall depths are 21% and 22% respectively. Cyanobacteria patches are conspicuous. Some paling of corals is occurring, but coral color is generally good. No table *Acropora* corals were seen. Levels of coral disease and predation are moderate, but there are signs of active dynamite fishing everywhere across all depths.

Potential resilience:

Stress resistance indicators for corals score moderate and are low for coral recovery. Overall **potential resilience for this coral community is low.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and ease of access. It is important to strengthen its resilience, particularly to enhance the recovery potential.

This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing which is rampant and anchoring directly on corals.

Site name: Saputiu; Onei MPA (7/21/2016)

Latitude: 7.3864°N; Longitude: 151.59125°E

Reef type: Inside; Transect heading: NW

Current Online Database Code: CHK-40



General Description:

Calm, turbid area (visibility 10 m max): heavily silt stressed community; silt deposits on *Porites*, causing heavy mucus production, filling pockets in coral colonies and causing lesions. Macroalgal cover high, primarily *Halimeda*: bank of dense *Halimeda* on old dead *P. cylindrica*. *P. cylindrica* formed an extensive bank fringing the shallows. Now the upper slope has *Halimeda* sand with large *Porites* boulders (2-3 m); corallimorphs covering patches of dead *Porites cylindrica*; *Halimeda* rubbing *Porites* and causing irritation and tissue loss; silted upper horizontal surfaces of *Porites* and many colonies covered by silt with heavy mucus; one ~10 m *Goniopora columna* colony. Very variable cover with coral rubble patches interspersed between live hard coral outcrops, sandy areas, and soft coral and sponge patches. Soft substrate comprises *Halimeda* sand, loose coral rubble, and fine silt. Coral disease level is moderate and predation low.

Potential resilience:

Coral stress resistance indicators score moderate to high, but recovery indicators are low. Overall **potential resilience of this coral community is moderate, but approaching low.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and issues related to runoff and pollution. It is important to try and strengthen its resilience, especially the resistance and recovery potentials. This will require management of land-based sources of pollution including erosion and

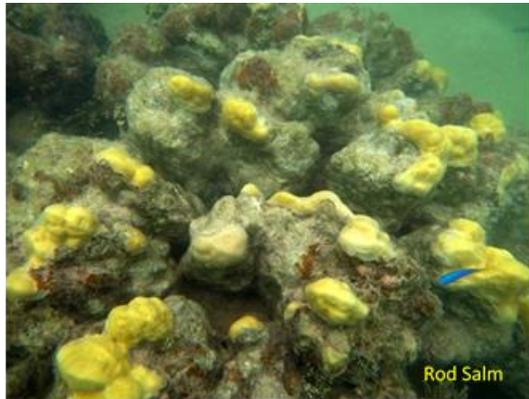
sedimentation, waste water and solid waste disposal into the nearshore waters, the herbivore fisheries, and all forms of destructive fishery practices and anchoring directly on corals.

Site name: Sapota; Onei Ref (7/21/2016)

Latitude: 7.38425°N; Longitude: 151.58893°E

Reef type: Inside; Transect heading: NW

Current Online Database Code: CHK-41



General Description:

Shallow bay site with no 10 m transect possible. Turbid, 4 m vis; silty sand with large *Porites* colonies, many covered with silty mucus, mottled and discolored, infested with borers. But *P. cylindrica* grows up to 3 m across and doesn't trap silt consequently is clean and has good color. Hard coral cover is low at on average 14 % of the hard substrate. Macroalgae cover is high at 43% and turf algae covers 26% of the hard substrate. Corals are pale in color. No table *Acropora* corals were encountered. A red-brown plankton bloom covered a large area up to 1.5 m above the silty substrate. Massive *Porites* covered by encrusting blue sponge has small live pieces that are fighting back and overgrowing the sponge. Also, *Porites* pink pigmentation response around lesions indicates inflammation of coral tissue usually associated with healing. Soft substrate comprises mud, silt and *Halimeda* sand; there are large clumps of *Halimeda*.

Potential resilience:

Both resistance and recovery indicators for corals are low and the overall **potential resilience of this coral community is low.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and issues related to runoff and pollution. It is important to try and strengthen its resilience, especially the resistance and recovery potentials. This will require management of land-based sources of pollution including erosion and sedimentation, waste water and solid waste disposal

into the nearshore waters, the herbivore fisheries, and all forms of destructive fishery practices and anchoring directly on corals.

Site name: Mutonpuna; Onei-3 (7/22/2016)

Latitude: 7.40238°N; Longitude: 151.59689°E

Reef type: Patch_back; Transect heading: counter-clockwise

Current Online Database Code: CHK-42

General Description:

Reef slope is gradual and has low rugosity. Live coral cover is low at 4% on average. *Acropora* is noticeably stressed exhibiting the brightening and paling early stages of the bleaching process. Anemones are white. Reef structure is broken old dead branching coral rubble densely covered by *Halimeda*, averaging 56%, with flat filamentous algae and cyanobacteria. Appears completely dead and irredeemable. One closer inspection there are numerous small coral recruits on the exposed crustose coralline algae covered pieces of rubble. It is a reef fighting to recover and already has some small patches where the algae are sparser and coral have established to form small colonies, particularly *Porites rus* and acroporids.

Potential resilience:

The resistance and recovery scores are low. It is clear that the area has suffered a massive coral mortality event. The presence and abundance of coral recruits and large massive coral providing some framework are positive indicators that with careful threat abatement the coral community may indeed recover. However overall **potential resilience is low**.

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and ease of access. It is important to strengthen its resilience, particularly to enhance the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing which is rampant and anchoring directly on corals.

Site name: Sopweru, C-33 (7/17/2016)

Latitude: 7.64946°N; Longitude: 151.88742°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: CHK-51

General Description:

The reef has high rugosity and slopes gradually in the shallows (2-6 m) becoming steeper with depth. 4m: some *Porites* with lumpy looking growths; patches of healthy soft coral also. Coral color generally good but paling has begun. Massive corals reach large size (>3 m). Coral recruitment is low and growth margins are narrow.

Potential resilience:

Coral recovery indicators are weak, but stress resistance indicators are strong and overall **potential resilience of this coral community is moderate**.

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Ochoeor; C-34 (7/30/2016)

Latitude: 7.47907°N; Longitude: 151.99144°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: CHK-52



General Description:

The reef slopes gradually from the shallows to deeper than 12 m and has moderate rugosity. Live coral cover on suitable hard substrate averaged 12% across all depths, being very slightly higher at 10 m than shallower depths. Turf algal cover was high and averaged 45% but decreased deeper from as high as 55% in shallower zones. Macroalgae cover was fairly constant and averaged 3%. Crustose coralline algae (CCA) increased markedly with depth and averaged 33%. The spur and groove formations are covered by CCA and coral colonies are small and robust. The burrowing urchin *Echinostrephis* is common at shallower depths and in some eroding deeper corals. The grooves have bare rock with turf algae. Areas of thick CCA cover are contrasted with areas of no CCA and high turf algae cover; table corals are very small (<40 cm); an estimated 80% of the *Pocillopora* colonies were dead fully or partly dead. At 10 m the shelf has very old dead corals covered by turf and CCA. Dead corals include massive *Porites*, table, bushy and robust branching *Acropora* that are deeply eroded. *Porites* pink pigmentation response was recorded on one live massive colony. This reef appears to be in decline: the robust *Acropora* species (*A. robusta* and *A. abrotanoides*) are gone and are not being replaced; recruitment is limited to few species, corals are paling, and the massive *Porites* are full of lesions and deeply pitted/eroded. It is a high energy area and all colonies are small although many and larger table *Acropora* colonies could be seen at depths below the limit of our deeper transect. Seven of the burrowers were in the *Pocillopora*. A curiosity is a 4 m tall narrow column with

a massive *Porites* on top.

Potential resilience:

Stress resistance and recovery indicators score low and the overall **potential resilience of this coral community is low.**

Conservation action:

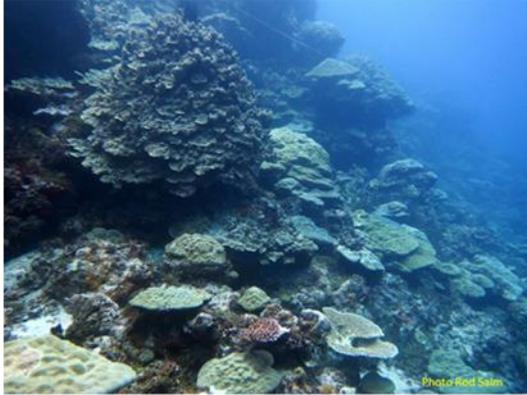
This coral reef community needs to be managed to enhance its resilience, especially as this appears to be low and the coral community in decline, which suggests that the long term survival of this reef may be in jeopardy. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Moch; C-35 (7/30/2016)

Latitude: 7.52526°N; Longitude: 151.9671°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: CHK-13



General Description:

The reef slope has a moderately steep gradient and high rugosity. Hard coral cover and turf algal cover remain more or less consistent across the depths covered, averaging 34% and 26%, respectively. Macroalgae cover is relatively high and averages 19% while crustose coralline algae (CCA) cover increases with depth and averages 15%. At 4 m the reef framework and several large *Porites* are deeply pitted and eroded by borers, including the sea urchin *Echinostrephis*. Coral rubble above 5-6 m is heavily cemented by crustose coralline algae (CCA). The upper reef slope is dominated by massive *Porites* and *P. rus* with scattered *Pocillopora* (only about 40% still alive), faviids, encrusting *Montipora*, *Symphyllia*, *Hydnophora*; sponges, corals, and algae. Most corals grow low or are encrusting. Only one table *Acropora* was seen. Several colonies of *Porites rus* have many *Coralliophila* burrowed in, but no browsing scars. At 10 m the channel edge of the reef is dominated by castellated massive *Porites* and *P. rus*. Pink pigmentation response seen on two adjacent *Porites* colonies. All *Seriatopora* colonies are white but coral color is generally good. Most colonies are massive and mainly *Porites*, but *Diploastrea* formed the largest colonies. Coral recruitment is moderate. Coral disease levels are moderate, but predation, including bioerosion, is high.

Potential resilience:

Resistance indicators are strong but recovery weak. The overall **potential resilience of this coral community is moderate and approaching high.**

Conservation action:

It is important to manage this reef to enhance its potential resilience from moderate to high. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals. Given its position in the reef system of Chuuk and its potentially high resilience, this reef should be considered for establishment as a protected area as its larval output would likely be an important source of seed for less resilient reefs to which it is connected by currents.

Site name: Aroch; C-36 (7/23/2016)

Latitude: .24136°N; Longitude: 151.89838°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-4



General Description:

The reef has low rugosity, is subject to surge, and slopes from a shelf at 3 m down to sand at 12 m that is densely covered by algae including mats of fine filamentous alga covered by a film of cyanobacteria. The reef substrate comprises broken, compacted, long dead, branching coral firmly cemented by crustose coralline algae (CCA) and devoid of any three-dimensional structure with the exception of a few scattered coral boulders. Dead table *Acropora* and broken up branching corals provide evidence of a former luxuriant coral community. Live hard coral cover is very low increasing from 2.5% at 4 m to 10% at 10 m. Turf algae and macroalgae cover also increase with depth from 15% to 65.5% and 0% to 15%, respectively; and CCA cover decreases with depth from 82% to 8.5%. There is some active coral recruitment but recovery is likely to be slow. Soft coral is patchy. Live table corals appear to be absent. Towards 10 m small live coral colonies and small coral recruits are scattered down the rubble slope with several patches of branching corals and many large, toppled, old dead table *Acropora*. Paling and bleaching is conspicuous and dominates the coral colonies. This is the first stressed area exhibiting such extensive paling we have seen.

Potential resilience:

Stress resistance and recovery indicators and overall **potential resilience for this coral community are all low.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and ease of access. It is important to strengthen its resilience, particularly to

enhance the recovery potential and repopulation with branching and table corals. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing which is rampant and anchoring directly on corals.

Site name: Sanat; C-37 (7/29/2016)

2016 REA site: C-; Current Online Database Code: CHK-3

Latitude: 7.23986°N; Longitude: 152.01132°E

Reef type: Patch_back; Transect heading: N/A



General Description:

Gradual to moderate reef slope with high rugosity and highly variable live coral cover (<5-60%) across all depths. Live hard coral cover averaged 25%, turf algae cover averages 47.5%, macroalgae average 7% cover, and average crustose coralline algae cover is 17.5%. Fine sediment covers coral and rubble. Much of the *Porites* is damaged and unhealthy in appearance; no foliose corals were seen; some massive corals have big tube worm infestations surrounded by mucus causing lesions in the coral colonies. *Millepora* and *Porites* spp dominate at 10 m with the former constituting the majority of coral cover when this is low and the latter, with other massive species, the main constituents of communities with higher cover. There are large areas of loose coral rubble at this depth. Coral recruitment is low (many individuals in some patches but only 1-2 species). Several crown of thorns starfish were seen but no fresh feeding scars noted. Foliose corals appear to be absent.

Potential resilience:

Resistance indicators are moderate, recovery indicators are low, and overall **potential resilience is moderate**.

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Wonno; C-38 (7/28/2016)

Latitude: 7.33172°N; Longitude: 151.95198°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-53

General Description:

The reef slopes gradually and supports a moderately rugose coral community with large numbers of small scarids across all depths. Broken and tumbled coral bear witness to massive storm surge damage and/or blast fishing damage from the shallows to 10 m. Rubble fields were cemented by crustose coralline algae (CCA). Live hard coral cover averages 31% of available hard substrate, turf algae 34%, macroalgae 9%, and CCA 22%. *Porites rus* dominates at 4 and 10 m, but *Porites cylindrica* constitutes a greater percentage of the coral community at 10 m.



Potential resilience:

Both *Porites* species appeared healthy (good color, free of lesions, actively reorienting the plane of growth when toppled or overturned). *Acropora* species were exhibiting some paling. Recruitment is moderate, but both the resistance and recovery indicators are strong and overall **potential resilience is high**.

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is strategically placed within the southern Chuuk lagoon to function as an important stepping stone for connectivity among the lagoon reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of the State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Wininen; C-39 (7/29/2016)

Latitude: 7.17499°N; Longitude: 151.95059°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-11

General Description:

The reef slopes moderately and has high rugosity. The substrate comprises less than 5% sand at 4 m but this increases to 50% at and below 10 m. At 4 m the corals are stressed: many colonies are covered by mucus and all *Porites* colonies have some degree of discoloration. *Halimeda* dominates across the depths covering 50% of the hard substrate. At both depths, live hard coral cover gradually increased along the transect (range 10-20%) and cover for both hard coral and turf algae averages 19% and 12.5% for crustose coralline algae. Table *Acropora* reaches a maximum size of only 50 cm and foliose corals appear to be absent. At 10 m there are many >1 m dead table corals (both standing and toppled), and 3 dead tables that are over 3 m in size; heavy cover of mucus on corals also occurs at this depth. Coral color is good across all depths, with a small amount of early paling, and coral recruitment is low to moderate.



Potential resilience:

Stress resistance indicators are moderate, recovery indicators are low, and overall **potential resilience is considered moderate.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the recovery potential. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Fonuenipin; C-40 (7/23/2016)

Latitude: 7.15493°N; Longitude: 151.93033°E

Reef type: Outer; Transect heading: E

Current Online Database Code: CHK-29

General Description:

The reef slopes gradually and has a spur and groove structure with moderate rugosity. Live hard coral and crustose coralline algae (CCA) cover decrease with depth, averaging 29.5% and 32.5%, respectively, macroalgae cover remains relatively constant at 13% on average, and turf algae cover increases markedly with depth from 11-35% and averages 23%. Coral color is good at all depths, although some branching *Acropora* exhibits early paling at 10 m, and corals are growing actively with both branching and table *Acropora* colonies having wide growth margins. Table corals attain large sizes at 10 m and have a good range in colony size. Coral recruitment at 4 m is stronger on spurs with many recruits but few species. 1 on flanks, great CCA but poor recruitment. Disease and predation levels are low.

Potential resilience:

Both stress resistance and recovery indicators are strong and the overall **potential resilience is high**.

Conservation action:

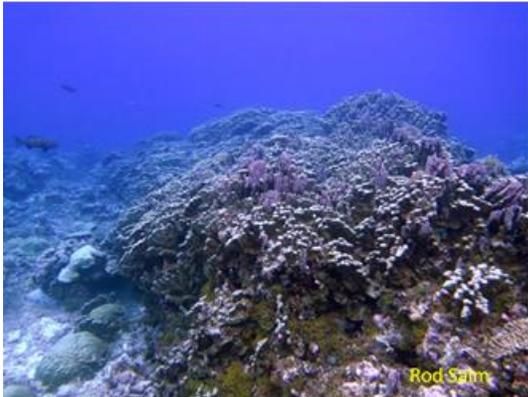
It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of the southern Chuuk barrier reef and strategically placed to function as an important larval source for the southern inner and outer reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of the State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Pukuon; C-41 (7/29/2016)

Latitude: 7.28754°N; Longitude: 152.0247°E

Reef type: Outer; Transect heading: S

Current Online Database Code: CHK-30



General Description:

The reef has a gradual slope and low to moderate rugosity, but some patches with notable exceptions: one such example was a most unusual, huge *Isopora* colony measuring 15-20 m long and 7-8 m wide. Cover of available hard substrate by live hard coral and crustose coralline algae drop with increasing depth and average 21% and 38%, respectively. Turf algae and macroalgae cover both increase with depth, averaging 27.5% and 5.5%, respectively. Coral color is good at both depths, despite some very early paling of a few corals, and recruitment is strong. The substrate is covered by rock and rubble at 10 m with scattered corals at this depth; coral cover higher below 14 m and above 7 m. Between 7 m and 14 m there are old dead turf and crustose coralline algae covered table *Acropora*. About 50% of massive *Porites* colonies have extensive lesions and dead patches Table *Acropora* reaches 2 m diameter.

Potential resilience:

Stress resistance and recovery indicators are strong and the overall **potential resilience for this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of the southern Chuuk barrier reef and strategically placed to function as an important larval source for the southern inner and outer reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of the State-wide

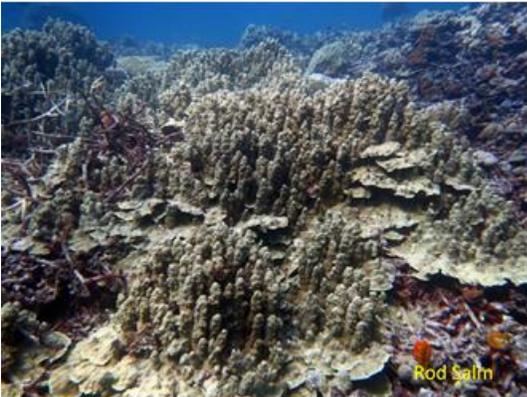
Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Ochonon; C-42 (7/28/2016)

Latitude: 7.27527°N; Longitude: 151.95175°E

Reef type: Patch_back; Transect heading: N

Current Online Database Code: CHK-31



General Description:

The reef has a gradual slope and has low to moderate rugosity. At 4 m there is extensive branching coral rubble cemented in place by crustose coralline algae and other means and is covered principally by close-cropped turf algae. The likely cause of this extensive rubble is a combination of dynamite fishing, crown of thorns starfishes (COTs), and the typhoon of 2015. Fungiids, *Platygyra*, and *Leptoria* corals all have good (= normal, deep) color. *Porites rus* is growing back strongly and overgrowing the rubble. *Acropora*, *Montipora*, *Pocillopora*, *Porites* spp and some faviids are bright or pale; 100% of the anemones are white; dead table *Acropora* is obvious with one huge dead colony lying broken on the substrate. The dead massive corals and some living ones were deeply eroded. Even at 10 m there is evidence of serious dynamite fishing damage and a huge expanse of branching coral rubble. There are large patches of cyanobacteria and *P. rus*, *P. cylindrica*, and branching *Acropora*. *Porites* colonies are darker down their sides and pale on upper horizontal surfaces. 100% of the branching *Acropora* are paling, but not yet bleaching. A reliable average of all COTs seen by various divers would be between 12 and 15, with as many as 124 COT scars, including in large patches of branching *Acropora*.

Potential resilience:

Coral recruitment is low to moderate, stress resistance indicators are weak but recovery indicators are strong and the overall **potential resilience of this coral community is moderate.**

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and ease of access. It is important to rebuild its resilience, particularly to enhance the recovery potential from the heavy crown of thorns starfish outbreak and repopulation with branching and table corals. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing which is rampant and anchoring directly on corals.

Site name: Ferit; C-44 (7/30/2016)

Latitude: 7.41397°N; Longitude: 151.93324°E

Reef type: Patch_back; Transect heading: NW

Current Online Database Code: CHK-32

General Description:

This reef has a gradual slope, moderate rugosity, and relatively high average cover of live hard corals at both depths (50%) and turf algae (38%); cover by macroalgae averages 5% and crustose coralline algae 16%. There is abundant broken branching and foliose coral at 10 m but little recruitment at either depth. Coral color is good at both depths and coral regrowth is rapid over dead patches at 10 m.

Potential resilience:

Both stress resistance and recovery indicators are strong and the overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is strategically placed within the central Chuuk lagoon to function as an important stepping stone for connectivity among the lagoon reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Fano chopenges; C-45 (7/18/2016)

Latitude: 7.67528°N; Longitude: 151.84938°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: CHK-55

General Description:

The reef slopes gradually and has high rugosity. Live hard coral cover on available hard substrate increases with depth and averages 29%; cover of turf algae remains fairly constant across depths and averages 36%; macroalgae cover is low averaging 4%; and crustose coralline algae cover decreases with depth and averages 29%. There are few table *Acropora* corals at both depths, but they have a range in size classes and some attain large size. Branching corals have active broad growth margins and most corals have good color, but some early stage paling is evident. At both 4 m and 10 m the exposed hard substrate has a dusting of sand most likely stirred up by high surge area.

Potential resilience:

Stress resistance indicators are strong, but recovery indicators moderately weak, and the overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of the northern Chuuk barrier reef and strategically placed to function as an important larval source for the northern inner and outer reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Pisemew; C-46 (7/18/2016)

Latitude: : 7.6836°N; Longitude: 151.79491°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: CHK-56

General Description:

The reef slopes gradually and has moderate rugosity. Hard coral and crustose coralline algae cover of available substrate remain relatively constant across the depths averaging 38.5% and 33%, respectively; turf algae cover drops markedly from 29% at 4 m to 11% at 10 m (average 20%); macroalgae cover averages 3.5%. Table *Acropora* corals are poorly represented at 4 m.

Potential resilience:

Stress resistance and recovery indicators are strong; and overall **potential resilience of this coral community is high.**

Conservation action:

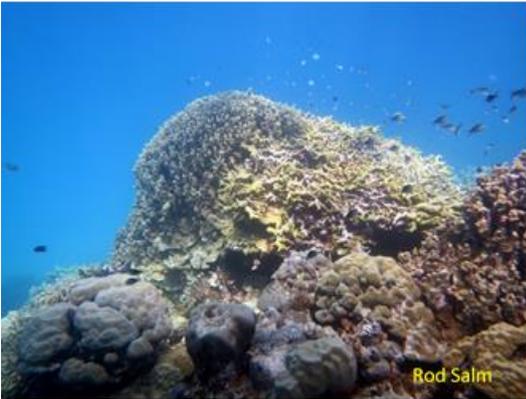
It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of the northern Chuuk barrier reef and strategically placed in an outer channel to function as an important larval source for the northern inner and outer reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Terenap/Pisitini; C-47 (7/17/2016)

Latitude: 7.633733°N; Longitude: 151.90302°E

Reef type: Patch_back; Transect heading: Clockwise

Current Online Database Code: CHK-61



General Description:

This reef has a moderately steep slope and high rugosity. Macroalgae cover differs little across depths from the average of 1%; live hard coral, turf and crustose coralline algae (CCA) cover varies markedly across depths: live hard coral cover averages 45%, but is highest (60%) at 4 m; turf algae cover increases from 18% at 4 m to 60% at 10 m and averages 38%; CCA cover averages 12.5%, decreasing from 20% at 4m to 5% at 10 m. At 4 m branching and castellated *Millepora* colonies form an impressive coralscape and dominate the upper reef slope along with massive *Porites*. There are small patches of a bright orange encrusting alga. Coral recruitment is very strong. At 10 m *Porites rus*, *P. cylindrica* and other massive corals dominate; there is a broad size range of massive *Porites* indicating regular reproduction and recruitment; the rock substrate is grazed bare and coral recruitment on these surfaces is strong; CCA has cemented branching and other coral rubble; *P. rus* is actively overgrowing the substrate and other live corals. Massive *Porites* colonies are tumbled down the slope and into gullies that may be the result of typhoon and/or dynamite fishing damage; table *Acropora* recruitment is strong and there are many colonies; *Porites* pink pigmentation response was observed on two colonies. *Halimeda* is abundant and much is near dead, greyish, dying. Corals are paling (35%) and growth margins are narrow. Burrowing clams are common in massive coral colonies.

Potential resilience:

Both the stress resistance and recovery indicators are moderately strong and the **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a northern Chuuk inner barrier patch reef and likely strategically placed to function as an important larval source for the northern inner reefs and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing

anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Pisitin; C-48 (7/18/2016)

2016 REA site: C-; Current Online Database Code: CHK-33

Latitude: .62643°N; Longitude: 151.91727°E

Reef type: Outer; Transect heading: S



General Description:

This reef has a spur and groove structure that slopes gradually and has low to medium rugosity and strong surge. The spurs are heavily covered by crustose coralline algae (CCA), even overgrowing coral recruits. Live hard coral cover is low across all depths (average 10%) and turf algae cover is high (average 72.5%), reaching 95% in places. Macroalgae are apparently absent and CCA cover is 25% at 4 m and decreases to 7% at 10 m. Coral recruitment is very strong, but there is low diversity of species. In contrast to the spurs, there is no coral recruitment in grooves, which are scoured. Fine turf algae occur in patches on top of spurs and carpet the sides and grooves, though some grooves are scoured clean to the rock substrate. There are many old dead corals on spurs including large broken dead *Isopora*. Several large (>1 m) massive coral boulders have been rolled up the grooves by the waves and surge. At 10 m the reef is scoured, as at 4 m, and is clearly a scoured, high energy, low gradient and low relief (rugosity) shelf environment. Corals are small and robust with occasional higher massive species (mainly *Porites*). Rock surfaces are turf covered. There are many dead corals, especially acroporids and gullies with unconsolidated branching coral rubble.

Potential resilience:

Coral recruitment is generally low. Some early paling of corals (15.5%) is occurring. Stress resistance and recovery indicators are both weak and the overall **potential resilience of this coral community is low.**

Conservation action:

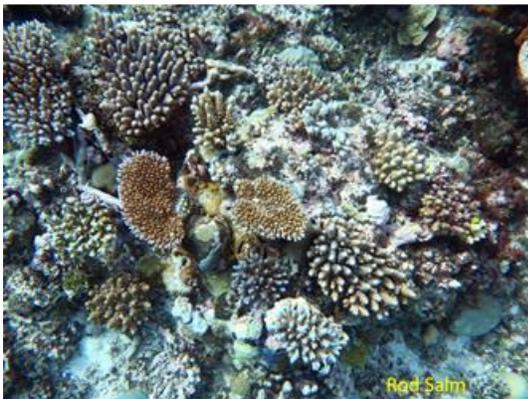
It is unclear whether management intervention can help this high-energy, wave scoured, low resilience area to recover. Over time the site would benefit from release from dynamite fishing, but directed, site-focused management effort would be better invested elsewhere.

Site name: Pisinini; C-49 (7/18/2016)

Latitude: 7.65072°N; Longitude: 151.67984°E

Reef type: Outer; Transect heading: N

Current Online Database Code: CHK-34



General Description:

This reef has a low gradient slope and medium to high rugosity. Live coral cover of available hard substrate is good, averaging 42.5% over both depths, but reaching as high as 50% at 4 m; turf algae cover averages 10%, macroalgae are apparently absent, and crustose coralline algae cover remains consistent across the depths at 47% on average. There are a great number of dead table and branching *Acropora* (30% of the latter are dead) and of crown of thorns (COT) and *Drupella* feeding scars, but coral color and recruitment are strong and recovery prospects appear to be good. At 10 m the proportions of live and dead corals are approximately equal and fresh COT scars are numerous (28 counted), but COTs are difficult to see because they are tucked under coral: only 15 COTs actually seen. *Drupella* seen but abundance not recorded. There are many small table *Acropora* (<40 cm) indicating good recruitment and recovery potential, but 5-7% are white and recently eaten by COTs. Schooling small parrotfishes are abundant. Levels of coral disease are moderate and coral predation is high.

Potential resilience:

Stress resistance indicators are strong, but recovery is weak. The overall **potential resilience of this coral community is moderate.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the currently weak recovery potential. This would benefit fisheries for the resident community of Pis Island, but will require management of

the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

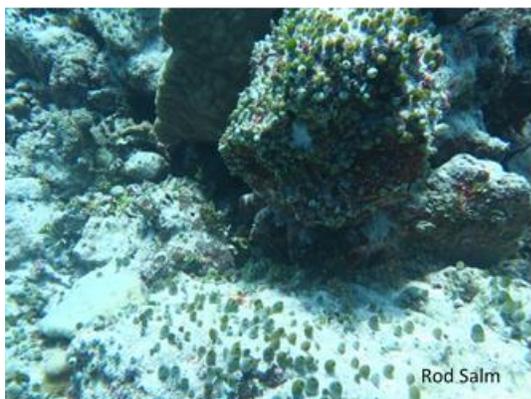
Site name: Pis-Paneu; C-50

(7/18/2016)

Latitude: 7.67662°N; Longitude: 151.7766°E

Reef type: Patch-back/Channel; Transect heading: E

Current Online Database Code: CHK-7



General Description:

The reef slopes steeply and has high rugosity. It appears to have been blasted from the shallows to 10 m depth by the typhoon of 2015 and likely dynamite fishing: much coral rubble, many toppled or overturned coral blocks and massive colonies, some dead or dying, including blocks measuring as large as 3x3 m. Low places in the reef structure are covered by fine carbonate silt or clay. A layer of fine carbonate silt and turf algae covers the large rubble blocks at 4 m. There are also patches of dense filamentous algae and cyanobacteria and schools of small parrotfishes. Only 50% of the substrate is currently consolidated and suitable for coral settlement and growth. Average cover of suitable hard substrate by live hard corals is 32.5%, turf algae is 22.5%, macroalgae is 1.5% and crustose coralline algae is 33.5%. In addition to physical damage, several massive coral colonies are partially or completely covered by silty mucus.

Potential resilience:

Coral recruitment is low and evidently compromised by the unstable and silty substrate; and 32.5% of the corals are pale in color. Stress resistance indicators are moderate, but recovery indicators score very low in all likelihood as a result of the disturbance caused by the 2015 typhoon and destabilization of the substrate by dynamite fishing. Overall **potential resilience of this coral community is moderate.**

Conservation action:

It is important to manage this reef to enhance its resilience, especially the currently weak recovery

potential. This would benefit fisheries for the adjacent community on Pis Island, but will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals, which could be enforced by the Pis island community.

Site name: Kuop_Episumur; C-52 (7/25/2016)

Latitude: 7.11661°N; Longitude: 151.838°E

Reef type: Outer; Transect heading: NE

Current Online Database Code: KUOP-9

General Description:

The reef has a moderate slope and medium rugosity. Mixing is intense and team members struggled to collect sufficient data. Nonetheless they feel confident that they did indeed get a good understanding of the coral community. They probably weren't able to cover sufficient reef to be comparable to other transects. It was an interesting spot and that type of current is probably fairly typical for the location. Coral cover is low (13%), turf (36%) and crustose coralline algae (43%) cover are moderately high and dominate, and macroalgae cover is 3%. Coral color is good. No table corals were recorded. Recruits are mostly massive *Porites* and are few branching species. Corals appear to have been killed off by a big bleaching event or crown of thorns starfish outbreak. Such promontories with strong currents tend to support fish spawning aggregations, but this was not explicitly noted.

Potential resilience:

Stress resistance indicators are moderate and elevated by the strong mixing. Recovery indicators are weak and the overall **potential resilience of this coral community is moderate** despite the difficulty of data collection in the strong current.

Conservation action:

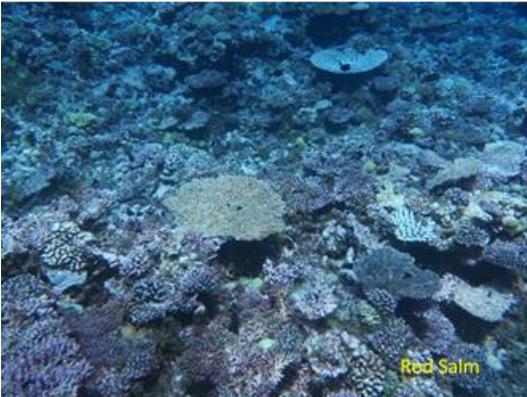
It is strongly recommended that this site be investigated as a potential fish spawning aggregation site. If confirmed it should be established as a no-take marine protected area to safeguard the stocks of spawning fishes. This will require full protection of the fishes and corals, total prohibition of fishing activities, anchoring on the corals, and (or strict control) of visitation by tourist divers during the spawning season(s).

Site name: N/A; C-53 (7/26/2016)

Latitude: 6.99285°N; Longitude: 151.95102°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: KUOP-1



General Description:

The reef has a gradual slope, high rugosity, and well-developed spurs and deep grooves covered by crustose coralline algae (CCA). At 4 m the grooves are littered with rounded coral boulders rolled about by surge; turf here and deeper is grazed down to near-clean rock. Average cover of suitable substrate by live corals is low (10.5%) and roughly equivalent to that by turf and macroalgae (11% and 14%, respectively). CCA cover is high at 61% on average and reaches 70% at shallower depths. Coral color is generally good, but about 10% of the corals and all anemones exhibit early stages of paling. Recruitment is moderately strong holding promise for the recovery of this highly stressed coral community. 80% of coral at both 4 m and 10 m is dead, partly dead, or dying: branching, bushy and table *Acropora* and *Pocillopora* are especially badly affected, but *Porites* and other corals also sustain major lesions and dead patches. Live table *Acropora* appears to be absent entirely at 4 m, but does occur deeper, and there are few large corals which may indicate regular turnover of the corals in this community. At both depths, dead coral is thickly covered by CCA. One crown of thorns starfish (COT) was recorded from 4 m and nine recent feeding scars; COTs are more active and abundant at 10 m, with 18 recorded and 23 recent feeding scars. While COTs account for some of the present coral mortality, the majority of dead coral is thickly covered by CCA indicating old mortality that is possibly from the 2010 COT outbreak, a bleaching event, or a combination of the two.

Potential resilience:

Stress resistance indicators are strong but recovery indicators are weak, despite the moderately strong recruitment. The overall **potential resilience of this coral community is moderate, but approaching low.**

Conservation action:

No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Neoch-3; C-55 (7/28/2016)

Latitude: 7.0512°N; Longitude: 151.98239 °E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: KUOP-15



General Description:

Reef has a gradual slope and low to moderate rugosity and strong surge in the shallows, but still evident at 10 m. There is evidence of high energy at times as almost all coral colonies are small (most <30 cm) and compact. It is difficult to know with certainty whether colonies are small because of environment factors, such as surge stress, or because these are new recruits in a community recovering from a prior stress event such as coral bleaching, typhoon, or crown of thorns outbreak, all of which have affected these reefs within the past five years. Cover by live hard corals averages 27% of suitable substrate, being slightly higher at 4 m (33%) than 10 m. Turf algae cover averages 11% and is consistent at both depths. Macroalgae cover is higher at 10 m (18.5%) than shallower (4%) and averages 11%. Crustose coralline algae dominate the cover of hard substrate at 44% on average. Coral color is generally good but approximately 10% of the corals exhibit early paling at both depths. Coral recruitment is strong in numbers and variety and corals have wide active growth margins. Up to 70% of *Pocillopora* colonies, which make up 20-25% of small coral colonies, are infested with “black borers” at both depths.

Potential resilience:

Stress resistance indicators are strong and recovery indicators are weak to moderate. The overall **potential resilience of this coral community is moderate.**

Conservation action:

No directed, site-specific management intervention indicated for this site; management effort would be

better invested elsewhere.

Site name: Onnang; C-57 (7/22/2016)

Latitude: 7.22074°N; Longitude: 151.63257°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: CHK-57

General Description:

The reef has a gradual slope and moderate to high rugosity and strong surge in the shallows and deep gullies and overhangs at 10 m. Cover by live hard corals averages 13% of suitable substrate; turf algae cover averages 41%; macroalgae cover averages 8%; and crustose coralline algae is 33% on average. Coral color is generally good but 10% of the corals exhibit early paling at both depths. Coral recruitment is strong in numbers and variety and corals have wide active growth margins. Coral disease levels are low and predation is moderate with molluscs contributing strongly to this.

Potential resilience:

Stress resistance and recovery indicators are strong and overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a southern Chuuk outer barrier reef environment, adjacent to a channel and thus strategically placed to function as an important larval source for the southern inner reefs and outer reef habitats. It should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Fourup; C-58 (7/23/2016)

Latitude: 7.29086°N; Longitude: 151.70177°E

Reef type: Patch_back; Transect heading: E

Current Online Database Code: CHK-19

General Description:

The reef has a gradual slope and moderate rugosity. Cover by live hard corals averages 32% of suitable substrate; turf algae cover averages 11%; macroalgae cover averages 17.5%; and crustose coralline algae is 12.5% on average. *Acropora* diversity is high. Coral color is generally good but 11% of the corals (notably branching *Acropora*) exhibit early paling and approximately 4% are in early stages of bleaching at both depths. Both table *Acropora* and massive *Porites* attain large sizes, with the former exhibiting a broad size range. Coral recruitment is strong in numbers and variety and corals have moderately wide active growth margins. Coral disease and predation levels are moderate. Crown of thorns starfish feeding scars were encountered but only one seen.

Potential resilience:

Stress resistance and recovery indicators are strong and overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is strategically placed within the southern Chuuk lagoon to function as an important stepping stone for connectivity among the lagoon reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Pisemu; C-59 (7/23/2016)

Latitude: 7.28794°N; Longitude: 151.78618°E

Reef type: Patch_back; Transect heading: W

Current Online Database Code: CHK-36

General Description:

The reef has a gradual slope and moderate to high rugosity. Cover of suitable substrate by live hard corals ranges from 35.5% at 4 m to 16% at 10 m and averages 25.5%; turf algae cover decreases markedly from 28% at 4 m to 5% at 10 m averages 16.5%; macroalgae and crustose coralline algae cover varies little between depths, averaging 6% and 16.5%, respectively. Coral color is generally good but about 12% of the corals exhibit early paling to early stages of bleaching at both depths. Coral recruitment is weak to moderate, mostly massive *Porites* recruits, and corals have moderately wide active growth margins. Coral disease levels are low and predation moderate. There are many reef sharks and small-medium size parrotfishes.

Potential resilience:

Stress resistance and recovery indicators are strong and overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a southern Chuuk lagoon habitat and is strategically placed to function as an important stepping stone for connectivity among the southern lagoon reefs of Chuuk and thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Fonuamo; C-60 (7/23/2016)

Latitude: 7.27086°N; Longitude: °151.65877E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-58



General Description:

The reef has a gradual slope and moderate to high rugosity. Cover of suitable substrate by live hard corals and turf algae cover are fairly consistent across the depths and average 24% and 23%, respectively; macroalgae cover increases markedly from 9.5% at 4 m to 29.5% at 10 m and averages 19.5%; crustose coralline algae (CCA) cover decreases from 41.5% at 4 m to 21% at 10 m, averaging 31%. Corals (notably *Stylophora* and *Acropora*) are exhibiting early paling with 35% succumbing at 4 m and 20% at 10 m. Approximately 40% of table and branching *Acropora* colonies are dead and covered by turf algae and CCA. Coral recruitment is strong in numbers and variety and corals have wide active growth margins. Nearly every branching *Acropora* colony has regrowth down from the tip over the dead portions. Coral disease levels are moderate and predation is high with the molluscs *Drupella* and *Coralliophila* contributing strongly to this. Crown of thorns starfishes also contribute and, although one was seen, there were many recent feeding scars. There are schools of small scarids and wrasses.

Potential resilience:

Stress resistance indicators are moderate and recovery indicators are strong. The overall **potential resilience of this coral community is moderate.**

Conservation action:

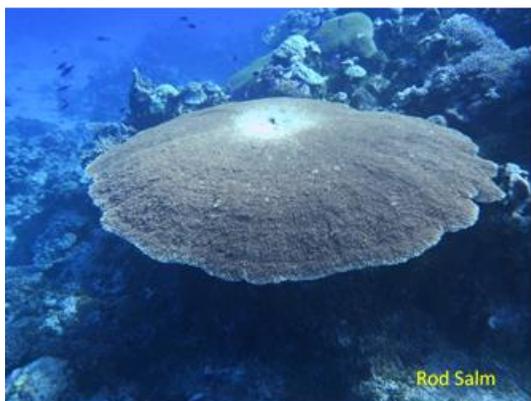
No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Onno; C-61 (7/22/2016)

Latitude: 7.2235°N; Longitude: 151.71132°E

Reef type: Outer; Transect heading: E

Current Online Database Code: CHK-37



General Description:

This reef has a moderately steep slope, moderate to high rugosity, and moderate mixing. Sand/rubble chutes cover an estimated at 20% of the substrate. The reef structure comprises large coral outcrops in a series of hummocks 10-12 m high separated by gullies strewn with rounded dead coral boulders. This appears to be a high energy area with surge moving and rounding off these boulders. The water is very clear (50 m visibility), with surge and weak to moderate current. Average cover of suitable substrate by live hard corals is 40% reaching to 55% at 4 m, turf algae is 16%, macroalgae is 14%, and crustose coralline algae (CCA) is 17.5% and very thick in places. This community can only be described as *Acropora* mayhem for the abundance and variety of species and size classes of this genus, including table *Acropora* larger than 2 m and *A. robusta* in the shallows (< 5 m) strongly developed with good deep color. Generally, however, 25% of the corals are in the early stages of paling. Both table *Acropora* and massive coral colonies attain large sizes, recruitment is strong in numbers and variety, and growth margins on table and branching *Acropora* corals indicate active growth. At 10 m *Halimeda* is abundant with close cropped fine turf algae, CCA, and high hard coral diversity. Here, 70% of *Acropora* species are paling to bright, but shaded walls and steep slopes have corals with good color. This is a beautiful reef with a huge variety of corals, especially acroporids, but despite their healthy appearance, *Acropora* white syndrome disease is more prevalent than at other sites. In patches 35% of table and branching *Acropora* are dead (old) and covered by dense turf or

CCA.

Potential resilience:

Stress resistance indicators are very strong and recovery indicators relatively weak. The overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a southern outer barrier reef and strategically placed adjacent to channels where

it can function as a source of larvae among the inner and outer reefs of Chuuk atoll. It should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Maimai; C-62 (7/23/2016)

Latitude: 7.22717°N; Longitude: 151.79243°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-59



General Description:

Gradual reef slope with moderate rugosity. 4 m: 2 crown of thorns starfish feeding scars; massive *Porites*, *Millepora* and large *Sarcophyton* clearly dominate this shallower reef assemblage. Cover by live hard corals averages 27.5% of suitable substrate; turf algae cover averages 11%; macroalgae cover averages 1%; and crustose coralline algae is 48.5% on average. At 10 m *Millepora* remains abundant and only two table *Acropora* were seen (and none at 4 m); and there is extensive broken coral, some recent and alive, loose branching coral rubble covering much of the substrate, and evidence of dynamite fishing, including clearly visible blast craters. There have been previous successive mortality events (7, 12 years ago based on upward growth of *Porites* on colonies with dead patches). Coral color is generally good but 17.5% of the corals exhibit early paling. Coral recruitment is strong in numbers and variety and corals have active, but relatively narrow (1 cm), growth margins. Coral disease levels are low and predation is high with borers contributing strongly to this. One large *Turbinaria* colony is infested with *Coralliophila*.

Potential resilience:

Stress resistance and recovery indicators are moderate and overall **potential resilience of this coral community is moderate.**

Conservation action:

No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Nematon; C-75 (7/21/2016)

Latitude: 7.36228°N; Longitude: 151.5787°E

Reef type: Inner; Transect heading: N/A

Current Online Database Code: CHK-9

General Description:

This reef has a moderately steep slope, moderate to high rugosity. Cover by live hard corals is low and averages 12% of suitable substrate; turf algae cover averages 32%; macroalgae cover is high and averages 36%; and crustose coralline algae is 10% on average. An average of 49% of the corals are paling across the depths; no table *Acropora* were seen at either depth, and recruitment is low (only one seen at 4 m and two at 10 m). At 4 m many coral colonies have a mucus covering, which can be heavy on *Porites*; and *Porites* pink pigmentation response also recorded. *Halimeda* dominates. At 10 m: there are large patches of *Padina*, mucus covers several *Porites*, and a dark purple sponge is actively overgrowing live coral.

Potential resilience:

This is clearly a distressed coral community: both stress resistance and recovery indicators score low and disease levels are moderate. The overall **potential resilience of this coral community is low.**

Conservation action:

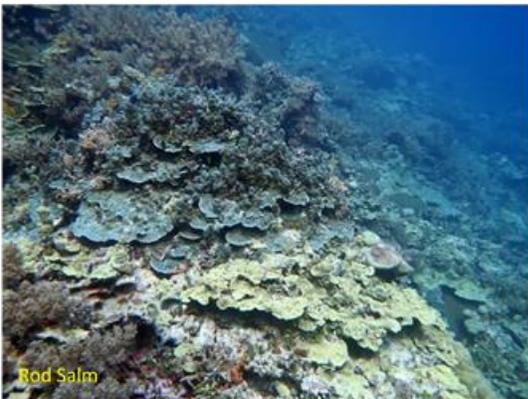
The resilience of this coral reef community is compromised by its proximity to land and issues related to runoff and pollution. It is important to try and strengthen its resilience, including both the resistance and recovery potentials. This will require management of land-based sources of pollution including erosion and sedimentation, waste water and solid waste disposal into the nearshore waters, and the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Oranu; C-77 (7/19/2016)

Latitude: 7.47627°N; Longitude: 151.59201°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: CHK-5



General Description:

This reef has a gradual slope and high rugosity. Cover by live hard corals is low and averages 24% of suitable substrate; turf algae cover averages 14%; macroalgae cover is high and averages 0%; and crustose coralline algae is 42% on average. Coral color is generally good, with an average of 11% of the corals exhibiting early paling across the depths. At 4 m there are huge old dead table and branching *Acropora* and massive species and tumbled boulder coral colonies in the gullies. There are abundant old crown of thorns starfish (COT) feeding scars and clearly very heavy predation with closely cropped, sparse algal turf on *Porites*. At 10 m rubble is cemented fast by crustose coralline algae. Soft corals form conspicuous patches. COT scars numerous with fine turf on *Diploastrea*; *Porites* has no lesion repair; *Porites* with silty mucus. Coral recruitment is low and growth margins narrow.

Potential resilience:

Coral resistance indicators suggest moderate ability to cope with stress events but recovery indicators are low. Coral disease levels are low and predation levels high with COTs leading the way. Overall **potential resilience of this coral community is moderate.**

Conservation action:

The reef is strategically placed in a channel to facilitate connectivity among inner and outer atoll reefs and is representative of such a habitat. Consequently, it is important to manage this reef to enhance its resilience, especially the currently weak recovery potential, so that it can contribute to the ecological functioning of a State-

wide MPA network. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Meseong; C-201 (7/24/2016)

Latitude: 7.14381°N; Longitude: 151.90359°E

Reef type: Outer; Transect heading: W

Current Online Database Code: CHK-23

General Description:

Reef slopes gradually to a steep drop-off and is subject to high current and surge. Live hard coral cover of suitable substrate is relatively low at 18%, turf algae cover high at 50%, macroalgae cover is 7.5%, and crustose coralline algae cover averages 20%. Coral color is generally good, but 15% of coral colonies are paling, *Pocillopora* colonies are brightening, massive *Porites* is paling and mottling, with several large old colonies mostly dead and supporting good coral recruitment; 2 bumphead parrotfish; big school of snappers; numerous crown of thorns starfish feeding scars.

Potential resilience:

Coral recruitment is relatively strong and corals are actively growing. Despite low resistance scores, the recovery indicators are strong and overall **potential resilience is moderate trending toward high**.

Conservation action:

It is important to enhance the resilience and reinforce strong recovery tendency of this coral community. The reef is representative of a southern outer barrier reef and could contribute greater benefits to the fisher community if managed effectively to reduce destructive fishing practices including in particular, overharvest of herbivore species, dynamite fishing, and anchoring directly on corals by visitors to the area, whether for fishing, tourism, recreation, or monitoring purposes.

Site name: Kuop_Peson; C-202 (7/25/2016)

Latitude: 7.06794°N; Longitude: 151.86411°E

Reef type: Outer; Transect heading: S

Current Online Database Code: KUOP-3

General Description:

Moderately steep fore reef slope with high rugosity. Live hard coral cover is low (average 4%) and cover of the substrate is dominated by crustose coralline algae (73%). Table *Acropora* is absent and coral recruitment is low. Coral cover generally good, but 15% of the colonies exhibiting early to advanced paling.

Potential resilience:

The resistance and recovery scores are low and the coral community appears to have **low potential resilience**.

Conservation action:

No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Kuop; C-203 (7/26/2016)

Latitude: 7.05581°N; Longitude: 151.8870°E

Reef type: Channel; Transect heading: NE

Current Online Database Code: KUOP-4

General Description:

This channel reef has a shallow gradient slope, with low rugosity and low live hard coral cover (8%). crustose coralline algae and macroalgae cover are high at 50% and 18% respectively. Coral recruitment is low to moderate and 31% of the coral colonies are paling at all depths covered and showing the symptoms of stress. Table *Acropora* are missing.

Potential resilience:

Both resistance and recovery scores are low, and the recovery prospects are especially poor. The coral community has **low potential resilience**.

Conservation action:

It is important to enhance the resilience and reinforce strong recovery tendency of this coral community. The reef is representative of a western Kuop channel reef and could facilitate connectivity among the inner and outer reefs of the atoll. The area should be managed effectively to reduce destructive fishing practices including in particular, overharvest of herbivore species, dynamite fishing, and anchoring directly on corals by visitors to the area, whether for fishing, tourism, recreation, or monitoring purposes.

Site name: Kuop_Penson; C-204 (7/26/2016)

Latitude: 7.02361°N; Longitude: 151.91472°E

Reef type: Outer; Transect heading: N

Current Online Database Code: KUOP-5

General Description:

The fore reef has a moderately steep slope with low rugosity and extremely low hard coral cover (5%). Macroalgae (18%) and crustose coralline algae (CCA) cover (65%) are both high. CCA forms columnar "fairy towers" along the shallower parts of the reef (~4 m), resembling those of Cappadocia in Turkey or the Hoodoos of Bryce Canyon National Park in Utah. Table *Acropora* were missing from this coral community. Half of all coral colonies are either paling or approaching early stages of bleaching. There were high numbers of crown of thorns starfish. One *Turbinaria* coral was infested with *Drupella*.

Potential resilience:

The resistance and recovery scores are low and recovery is especially so making the prospects for recovery poor. Overall **coral community potential resilience is low**.

Conservation action:

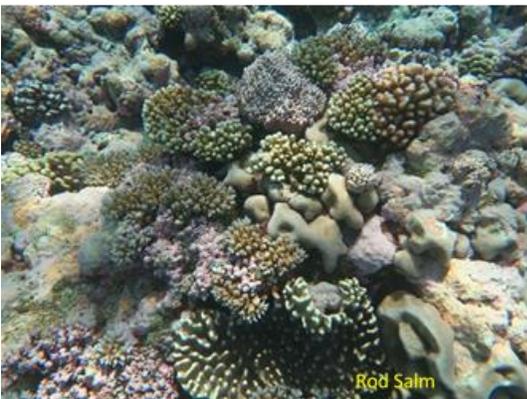
No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Kuop_Ochamoch; C-205 (7/27/2016)

Latitude: 6.98899°N; Longitude: 151.98146°E

Reef type: Outer; Transect heading: E

Current Online Database Code: KUOP-6



General Description:

Reef slopes gradually from the crest. Some surge evident. Rugosity is high and live hard coral (39%) and crustose coralline algae (CCA) cover (40%) are also both high. CCA overgrowing live *Porites*, *Heliopora* and *Millepora* colonies and forming heavy deposits. Healthy reef: vibrant coral growth, diverse coral assemblage, deep coral color, and strong coral recruitment, especially *Acropora*; larger table *Acropora* more abundant than seen at most other sites; turf algae close-cropped exposing grey rock; school of >200 parrotfishes. Disease and predation also are relatively high: *Porites* pink pigmentation response and some *Porites* with multiple lesions; *Porites* white syndrome on one colony. Patchy distribution of the soft coral *Lithophytum*.

Potential resilience:

Stress resistance and recovery indicators both are strong and overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a southern outer barrier reef of Kuop atoll and placed relatively near to a major channel where it can function as a source of larvae among the inner and outer reefs of the atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring

purposes.

Site name: Kuop_Feneppi Pass; C-206 (7/27/2016)

Latitude: 7.10661°N; Longitude: 151.87112°E

Reef type: Channel; Transect heading: S

Current Online Database Code: KUOP-7



General Description:

This is a 4-12 m deep patch reef in channel with strong tidal currents and good mixing; Rugosity high across all depths and live hard coral cover (63%) and crustose coralline algae (CCA) cover (28%) both high on average. Turf algae cover (3%) and macroalgae cover (7%) low on average. At 4 m a *Millepora-Heliopora* assemblage dominates, with scattered small *Porites*, *Pocillopora*, bushy and table *Acropora*; time for this 4 m transect was cut short because of fierce current. There is one large *Goniopora* colony (5 m diameter by 3 m high) and huge 6 m *Turbinaria* colony. CCA is overgrowing *Porites*; abundant recently broken *Millepora* (anchors); some potential typhoon damage; moderate to heavy crown of thorns (COT) damage with at least 10 COTs seen; large school of bigeye jacks.

Potential resilience:

Both the resistance and recovery indicators are strong, recruitment is high and coral colonies are all actively growing and corals have good color. However, both disease and predation levels are relatively high. The overall **potential resilience is high** but would likely improve if the area was managed to prevent damage to corals from anchoring and possible blast fishing.

Conservation action:

The coral reef community is representative of a channel reef for Kuop atoll. It is strategically placed in a wide north-facing channel where it can facilitate larval exchange between the inner and outer reefs and between Kuop and Chuuk atolls. It is important to maintain and reinforce the high resilience of this coral

community. The site should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing continued anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: N/A; Kuop Acropora Garden (7/25/2016)

Latitude: 7.107579°N; Longitude: 151.882704°E

Reef type: Inner; Transect heading: N/A

Current Online Database Code: N/A



General Description:

Incredible branching *Acropora* garden on sand where conditions are shallow and very bright. All corals are pale but evidently long-term survivors because there are no signs of previous mortality from either bleaching or crown of thorns starfish (COTs) predation; corals also exhibit strong lesion repair including at ends of broken branches which are growing over the broken portion and also strong overgrowth. This may prove to be a valuable refuge for the *Acropora* species present and source of larvae to repopulate other more susceptible communities where these species are being lost to COTs, bleaching, anchoring, or dynamite fishing.

Potential resilience:

Stress resistance indications for corals are low to moderate and recovery indicators are strong. The overall **potential resilience of this coral community is moderate.**

Conservation action:

The unique composition and structure of this coral community and its survival through crown of thorns starfish outbreaks, the 2015 typhoon and seawater heating cycles suggests that this should be included in a marine protected area that captures a larger area. It is important to enhance the potential resilience of this coral community and restrict access for fishing through establishment as a no-take MPA and prohibit anchoring on or beside the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Kuop_Neoch; C-207 (7/28/2016)

Latitude: 7.06041°N; Longitude: 151.96036°E

Reef type: Outer; Transect heading: N

Current Online Database Code: KUOP-8



General Description:

Reef slopes gradually from crest and has moderate rugosity and mixing. Live hard coral cover is high (49%). There is strong recruitment, both in number and variety, and corals are actively growing and have good color with some early paling at 4 m. At 4 m the crustose coralline algae pavement is studded with a variety of small coral colonies, principally bushy *Acropora* and *Pocillopora*, but including branching and table *Acropora*, *Porites*, faviids, and *Stylophora*. The turf is closely cropped exposing the underlying rock. The coral community appears very healthy: lacking disease and lesions, actively recruiting and growing. Despite high recruitment, corals do not attain large sizes. In fact, there is a distinct absence of large coral colonies, even among the dead colonies that would indicate an area of high periodic turnover. There is a notable absence of lesions in table *Acropora*. Foliose corals are absent.

Potential resilience:

Stress resistance and especially recovery indicators are strong and overall **potential resilience is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of an eastern outer barrier reef of Kuop atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Pones; C-208 (7/29/2016)

Latitude: 7.20632°N; Longitude: 151.9922°E

Reef type: Outer; Transect heading: S

Current Online Database Code: CHK-24



General Description:

Reef slopes gradually from crest. Rugosity is high and there is surge in the shallows and signs that this is a high energy zone with mixing of the water column at different times of the year (low, robust coral colonies in shallower than 6 m and low profile spur and groove formation). This zone is a crustose coralline alga (CCA) pavement dominated by a diverse assemblage of *Acropora* species, notably the robust *A. robusta* and *A. abrotanoides*, with smaller *A. humilis* and similar species. On average, live hard coral cover is high at 44% and turf algae (33%) and crustose coralline algae (22%) also high. Macroalgae cover is low (1% on average). Some 20% of the corals are exhibiting early stage paling/brightening, but appear healthy and actively growing and repairing lesions and overgrowing dead areas, notably on branching *Acropora*, which are good health indicators. One crown of thorns starfish (COT) feeding scar. Lesion repair on one branching *Acropora*. At 8-12 m the corals show sustain high prevalence of disease and COT predation while, at the same time, demonstrating higher frequency of such good health indicators as lesion repair, regrowth and reorientation. Live table *Acropora* reaches over 3 m across between 14 and 20 m depth. 30% of the large old table *Acropora* are dead and turf covered. However, recruitment is strong and corals are growing actively, repairing lesions, overgrowing dead portions and reorienting their plane of growth when toppled. Turf algae are closely cropped on exposed rock surfaces, less so on branching corals rubble, but dense turf not inhibiting overgrowth from the live tips branching *Acropora*. Dead coral is likely the

result of previous COT outbreaks and/or disease and seem to have died at two distinct times, one more recent where corals retain most of their structure and are covered by dense turf, and one older where colonies are eroded and often covered by turf and CCA or CCA alone.

Paling/brightening of corals is in the early stages.

Potential resilience:

The stress resistance and recovery indicators are both strong. Overall **the potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a southeastern outer barrier reef of Chuuk atoll and is strategically placed adjacent to a major channel where it can function as a source of larvae among the inner and outer reefs of the atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Fanochoetiwi; C-209 (7/30/2016)

Latitude: 7.57968°N; Longitude: 151.95261°E

Reef type: Outer; Transect heading: S

Current Online Database Code: CHK-25

General Description:

The reef slopes gradually from the crest over a well-developed spurs and grooves area that is subject to high wave energy; rugosity is low; coral cover is very low, averaging 5%, and turf algae cover (66%) and crustose coralline algae cover (23%) are high. There are abundant coral recruits but these are low in variety of species. There are remnants of very large old dead table *Acropora* in the 5-7 m diameter range, but none are live. At 10 m, below the spur and groove zone, there are also abundant coral recruits and again with low diversity, and predominantly small table *Acropora* and branching species. The surviving hard coral is predominantly massive *Porites* with few *Acropora* and *Isopora*. Corals are actively growing, especially around 4 m depth and 22% are exhibiting some early paling/brightening.

Potential resilience:

Stress resistance indicators are relatively weak. However, recovery indicators are moderate and promising for reef recovery. Overall, **the potential resilience of this coral community is moderate.**

Conservation action:

It is important to enhance the resilience and reinforce strong recovery tendency of this coral community. The reef is representative of a northeastern outer barrier reef and could contribute greater benefits to the fisher community if managed effectively to reduce destructive fishing practices including in particular, overharvest of herbivore species, dynamite fishing, and anchoring directly on corals by visitors to the area, whether for fishing, tourism, recreation, or monitoring purposes.

Site name: Epichun; C-210 (7/31/2016)

Latitude: 7.41656°N; Longitude: 151.90366°E

Reef type: Patch_back; Transect heading: NE

Current Online Database Code: CHK-15

General Description:

The reef slopes gradually from the crest. Rugosity is moderate. Live hard coral cover (13%) is low and turf cover (45%) is high, macroalgae cover (10%) and crustose coralline algae cover (20%) are moderate. Corals are actively growing but recruitment is low and 15% of the corals display early paling/brightening. There is evidence of disturbance to the corals from anchors and possibly blast fishing and cyclone damage. There are few live table *Acropora* and dead *Acropora* species dominate the reef scape. Rubble is partly consolidated by crustose coralline algae.

Potential resilience:

Stress resistance indicators are weak, but recovery indicators moderate. Overall **potential resilience is moderate** possibly drawn down by the anthropogenic disturbance to the reef.

Conservation action:

The resilience of this coral reef community is compromised by its proximity to land and ease of access. The indicators suggest that recovery would happen with control of anchoring and destructive fishing practices. It is important to strengthen its resilience, particularly to enhance the recovery potential and improve the fisheries production. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Chuesen; C-211 (7/31/2016)

Latitude: 7.58391°N; Longitude: 151.94188°E
Reef type: Patch_back; Transect heading: N/A
Current Online Database Code: CHK-26

General Description:

This reef has a moderate slope down from crest and has moderate rugosity. Coral cover is low (11%); macroalgae cover is very high at 70% and turf cover (13%) and crustose coralline algae cover (10%) are moderate. Massive corals reach large sizes, show moderate growth, and coral recruitment is moderate. Coral color is mostly good, but 24% of the colonies exhibit early paling. The reef is damaged evidently by the typhoon of 2016.

Potential resilience:

Both stress resistance and recovery indicators are moderate to weak. The overall **potential resilience of this coral community is moderate**.

Conservation action:

It is important to enhance the resilience and reinforce strong recovery tendency of this coral community. The reef is representative of an eastern inner patch reef and could contribute greater benefits to the fisher community if managed effectively to reduce destructive fishing practices including in particular, overharvest of herbivore species, dynamite fishing, and anchoring directly on corals by visitors to the area, whether for fishing, tourism, recreation, or monitoring purposes.

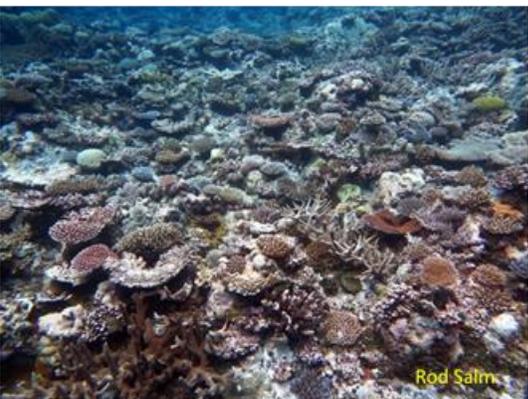
Site name: Ochanei-1; C-212

(8/1/2016 & 8/2/2016)

Latitude: 7.6758°N; Longitude: 151.7442°E

Reef type: Outer; Transect heading: W

Current Online Database Code: CHK-27



General Description:

This is a high rugosity reef with a gradual slope. Average cover of suitable substrate by live hard corals is 29.5%, turf algae is 12%, macroalgae is 14.5%, and crustose coralline algae is 27%. Coral color is good, with about 8% of the colonies beginning to pale. The reef at 4 m is vibrant: strong recruitment, wide growth margins for table, branching and foliose corals, colony sizes in excess of 2-3 m for both table *Acropora* and massive *Porites*, and a broad size range of the former; and parrotfishes are spawning at this time of year. Many medium-large size parrotfishes were observed at 10 m where the reef is undergoing rapid recovery. Two coral colonies have crown of thorns starfish feeding scars.

Potential resilience:

Stress resistance and recovery indicators are both very strong and the overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a northern outer barrier reef of Chuuk atoll and is placed relatively near to a major channel where it can function as a source of larvae among the inner and outer reefs of the atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. This would benefit fisheries by spill-over and larval replenishment for the community on Pis Island that could enforce the no-take status. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the

area, whether for tourism, recreation, or monitoring purposes.

Site name: Pisinini Inner; N/A (8/1/2016)

Latitude: 7° 39.010'N; Longitude: 151° 41.044'E

Reef type: Inner; Transect heading: N/A

Current Online Database Code: N/A



General Description:

Substrate 70% sand with scattered coral patches, very flat with moderate rugosity; extensive dead branching *Acropora* and dead table coral covered by algal turf. Average cover of suitable substrate is 16% for live hard corals, 58% for algal turf, 16% for macroalgae, and 6% for crustose coralline algae. Massive corals sustain numerous lesions and sediment is packed in pockets on massive *Porites*; 4 crown of thorns feeding scars recorded; branching *Acropora* is paling and all *Seriatopora* are completely white, but 95% of coral colonies have deep color. Coral recruitment is strong in both numbers and diversity of species; and four colonies of branching *Acropora* have growth reorientation. Disease level is moderate and predation is high, especially by borrowing organisms.

Potential resilience:

Stress resistance indicators are moderate and recovery indicators are strong, the overall **potential resilience of this coral community is moderate.**

Conservation action:

This reef should be managed together with the Pisinini site (C-49) to enhance its resilience, especially to reinforce its strong recovery potential. This would benefit fisheries for the resident community of Pis Island, but will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Ochanei-2; C-213

(8/1/2016 & 8/2/2016)

Latitude: 7.66912°N; Longitude: 151.70871°E

Reef type: Outer; Transect heading: W

Current Online Database Code: CHK-28



General Description:

This reef slopes very gradually and has low to medium rugosity. Average coral coverage of suitable substrate by live hard coral is 20.50%, by turf algae is 20.50%, by macroalgae is 10.50%, and by crustose coralline algae is 36%. At 4 m there are the remains and pedestals of very large old dead table *Acropora*. At 10 m three 2 m *Acropora* tables seen. Coral color is generally deep, but nearly 20% are paling. Generally, the table and massive coral colonies reach large sizes. The coral growth margins are moderately wide and recruitment is moderately high.



Potential resilience:

Stress resilience and recovery indicators are both strong and overall **potential resilience for this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a northern outer barrier reef of Chuuk atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. This would benefit fisheries by spill-over and larval replenishment for the community on Pis Island that could enforce the no-take status. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

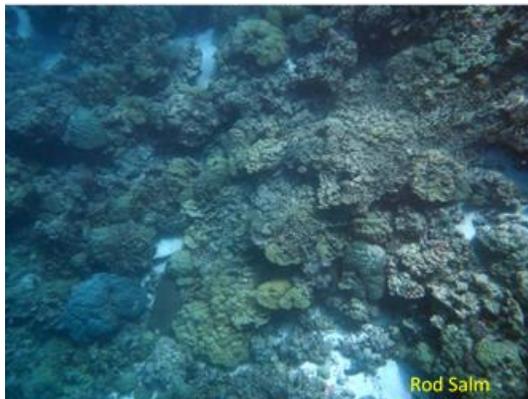


Site name: Meseong-2; C-300 (7/24/2016)

Latitude: 7.1461°N; Longitude: 151.89751°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: CHK-47



General Description:

This reef slopes gradually and has high rugosity. There is extensive bare substrate (37%) at 4 m where turf algae are grazed very short or almost completely away.

Average cover of available substrate by live hard corals is 40%, 24% for turf algae, 4% for macroalgae, and 32% for crustose coralline algae. Coral paling reaches 47.5% at 10 m and averages 36.5% across all depths: *Acropora* colonies are bright to light blue, one anemone is white.

Porites is the largest of the massive species. At 10 m, the reef is dominated by massive *Porites*: some are large and healthy but others scarred and pitted or grooved by burrowers, bald on top, discolored, or losing tissue. The largest *Porites* is 3.3 m, but the inshore side has a large dead patch, possibly from a dynamite fishing blast.

Another 2.5 m *Porites* colony is healthy, with good color and no lesions or dead areas. About 35% of the *Porites* are 50% or more dead and eroded. Some dead spots are surrounded by living ridges or knobs raised about 7 cm above the dead portion indicating a past mortality event of approximately 7 years ago (using the 1 cm per year growth rate for massive *Porites*).

From a distance the reef is structurally complex and scenic with the different sizes, shapes and colors of *Porites* creating a scenic coralscape. There are many toppled massive *Porites* colonies. There are also abundant, old, dead branching and bushy *Acropora*. Fish bites on coral are everywhere; no live table *Acropora* at this depth. Recruitment is strong in both numbers and diversity of species. Coral disease levels are moderate and predation is high, especially by fishes and burrowing organisms.

Potential resilience:

Stress resistance indicators are strong and recovery indicators moderately weak. Overall **potential resilience of this coral community is moderate.**

Conservation action:

This reef site should be managed together with Meseong (C-201). Together, the reefs are representative of a southern outer barrier reef and could contribute greater benefits to the fisher community if managed effectively to reduce destructive fishing practices including in particular, overharvest of herbivore species, dynamite fishing, and anchoring directly on corals by visitors to

the area, whether for fishing, tourism, recreation, or monitoring purposes. Consideration should be given to including these two sites into a State-wide MPA network. Such action would contribute to enhancement of spatial ecological connectivity between Chuuk and Kuop atolls.

Site name: Nomoneas; C-301 (7/25/2016)

Latitude: 7.12242°N; Longitude: 151.87758°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: KUOP-10



General Description:

Shallow consolidated intertidal reef flat that drops sheer with small caves and overhangs to 5 m and then to near sheer slope with generally low rugosity and patches where this rises to moderate, especially where *Millepora* forms larger (<2 m) colonies. Current developed during course of the dive. At 10 m the substrate is bare rock or close-cropped sparse algal turf (45%) covered with very small scattered corals. The upper wall has patches of dense sponge and *Halimeda* (4%) cover, crustose coralline algae (38%), few scattered corals (5% cover) and a variety of invertebrates, but is notable for the low diversity and cover of species. Coral color is good and recruitment is high. There are no table *Acropora* at 4 m: there is active predation of corals by the crown of thorns starfish and two were seen as well as 19 feeding scars.



Potential resilience:

Stress resistance indicators are moderate and recovery indicators weak. Overall **potential resilience of this coral community is moderate.**



Conservation action:

No directed, site-specific management intervention indicated for this site; management effort would be better invested elsewhere.

Site name: Penson; C-302 (7/25/2016)

Latitude: 7.00857°N; Longitude: 151.98393°E

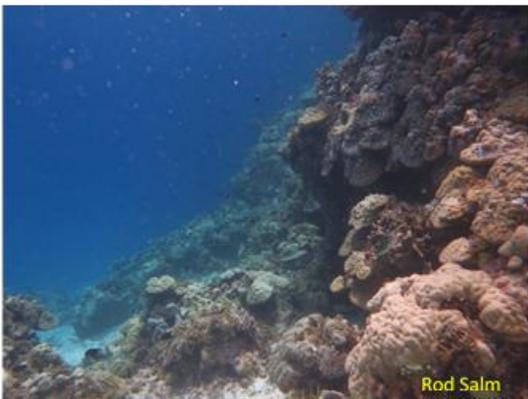
Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: KUOP-11



General Description:

Shallow reef flat to steeply sloping reef with sections of wall and moderately high rugosity ending on sand; dominated by *Porites lobata* and *P cylindrica*; dense *Padina* blankets the corals. Cover averages 29.5% for live hard corals, 4% for turf algae, is high for macroalgae at 50%, and 14% for crustose coralline algae. Coral cover varies greatly and is patchy at both depths. There are scattered small patches of sponge and soft corals. Coral color is deep, but with 30% of the coral colonies paling. Coral recruitment is moderate and corals are actively growing with table *Acropora* having the widest growth margins. *Porites* pink pigmentation response is noticeable.



Potential resilience:

Stress resistance and recovery indicators are moderate and the overall **potential resilience of this coral community is moderate.**



Conservation action:

It is important to enhance the resilience of this coral community. This coral reef community is representative of a southeastern inner channel patch reef at Kuop atoll. As such, it is well placed to facilitate larval exchange between the inner and outer reefs of the atoll. The site should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: N/A; C-302 extension (7/25/2016)

Latitude: 7° 0.549'N; Longitude: 151° 59.049'E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: N/A



General Description:

Substrate has moderate slope and comprises large bommies on sand, including one enormous *Porites* of approximately 10 m high that is 50% dead (mainly deeper portion). Average cover of suitable substrate for live hard corals is low at 10% and high for macroalgae at 86%. Coral recruitment is moderate and table *Acropora* have wide growth margins. *Seriatopora* coral colonies are all bleached white except where deeply shaded in a fissure in the reef or under an overhang. *Astreopora* and table *Acropora* also had good color where shaded; otherwise 95% of the corals are paling at 9 m.



Potential resilience:

Both stress resistance and recovery indicators are weak and the overall **potential resilience of this coral community is low.**

Conservation action:

This site should be managed together with Penson (C-302).



Site name: Penson-2; C-303 (7/26/2016)

Latitude: 7.0098°N; Longitude: 151.93234°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: KUOP-12;



General Description:

Steeply sloping reef with walls and high rugosity. Average cover of the available substrate is high for live hard corals (64%), 13% for turf algae, 3% for macroalgae and 15.5% for crustose coralline algae. Corals are noticeably paling in color, with 47.5% in early stages and 5% near bleaching across all depths. Table corals cover a broad range of sizes and massive corals reach at least 4 m in size and one of these reaches the surface. Coral recruitment is high in numbers and diversity of species at 10 m but low to moderate at 4 m. Coral disease, notably *Acropora* white syndrome (AWS), and predation, notably by crown of thorns starfish (COTs), are both high. At 10 m 70% of table *Acropora* is dead (either AWS or COTs) and covered by turf algae; 100% of the *Seriatopora* colonies are bleached; Strong current at first; gone within 5 minutes. COTs actively feeding at both depths and numerous feeding scars seen.



Potential resilience:

Stress resistance indicators are strong, but recovery indicators somewhat weak. Overall **potential resilience of this coral community is moderate.**



Conservation action:

It is important to enhance the resilience of this coral community. This coral reef community is representative of a western channel patch reef at Kuop atoll. As such, it is well placed to facilitate larval exchange between the inner and outer reefs of the atoll. The site should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on

enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes. Monitoring and removal of COTs to facilitate reef recovery should be undertaken.

Site name: N/A; C-304 (7/26/2016)

Latitude: N/A; Longitude: N/A

Reef type: Outer; Transect heading: N/A

Current Online Database Code: N/A



General Description:

Reef slopes steeply and has low rugosity. Live hard coral cover is low (5% on average), turf algae cover averages 13%, macroalgae average 20% cover, which is moderately high, and crustose coralline algae have an average cover of 51% and are clearly dominant on the rock slope and over dead bushy *Pocillopora* and *Acropora* corals with few small scattered corals to estimated 25 m where the slope transitions to a sheer wall down into the depths. Coral recruitment is moderate, disease levels are moderate, with

discoloration most prevalent, and predation is high especially from crown of thorns starfishes and burrowing organisms. 21% of the corals were paling across the depths. *Echinostrephis* seen boring into rock.

Potential resilience:

The stress resistance indicators are moderately weak and recovery indicators notably weak. The overall **potential resilience of this coral community is low.**

Conservation action:

None prescribed; management effort would be better invested elsewhere.

Site name: Peas; C-305 (7/27/2016)

Latitude: 7.01407°N; Longitude: 151.99774°E

Reef type: Outer; Transect heading: N/A

Current Online Database Code: KUOP-13



General Description:

This reef slopes gradually and has moderate rugosity. Average cover of available substrate by live hard coral is 21%, by turf algae is 3%, by macroalgae is 15%, and by crustose coralline algae is 56.5%. At 4 m no table corals seen and >50% of the coral colonies are less than <30 cm. There is noticeable brightening stressed coral (26%), but not yet advancing to bleaching. Coral recruitment is moderate (high in numbers but low in species diversity). At 10 m there are >3 m diameter table *Acropora* and massive coral colonies. Small round predation scars are noticeable,

but predation levels are moderate and spread principally among fishes, *Drupella*, and burrowing organisms. The incidence of coral diseases is low.

Potential resilience:

Stress resistance indicators are strong but recovery indicators weaker. The overall **potential resilience of this coral community is moderate.**

Conservation action:

It is important to enhance the resilience of this coral community, especially to strengthen the recovery potential. The reef is representative of a southeastern outer barrier reef of Kuop atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Neoch-2; C-306 (7/27/2016)

Latitude: 7.0451°N; Longitude: 151.94325°E
Reef type: Patch_back; Transect heading: N/A
Current Online Database Code: KUOP-14

General Description:

This reef has a low gradient slope and low to moderate rugosity. The shallows are dominated by the macroalga *Microdictyon* sp. that covers 69.5% of the substrate on average. Average cover of available substrate by live hard corals is 17.5%, turf algae is 4%, and crustose coralline algae is 8%. Coral are paling noticeably with approximately 39% in the earlier stages and 8% more advanced. There is very little coral growth at 10 m; fine sand covers much of the hard substrate, 95% of the hard coral colonies are smaller than 30 cm, and coral recruitment is low at both depths. Coral disease is moderate to relatively low and predation is low.

Potential resilience:

The stress resistance indicators are moderate, but recovery indicators weak. The overall **potential resilience of this coral community is low.**

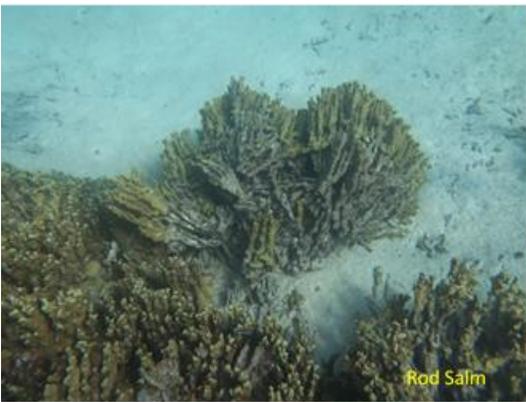
Conservation action:

It is important to include representative examples of inner patch reefs into a State-wide MPA network to ensure inclusion of the coral community type specific to this habitat. This may not be the best reef to include and it is recommended that additional inner patch reefs of Kuop atoll be surveyed as potential better examples of the habitat type. Nonetheless, destructive fishing practices should be prohibited throughout the Kuop lagoon and barrier reef system, including in particular dynamite fishing and direct anchoring on corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Sapuk; C-307 (7/31/2016)

Latitude: 7.45636°N; Longitude: 151.90401°E

Reef type: Inner; Transect heading: N/A



General Description:

This reef slopes gradually to sand at around 12 m and has moderate rugosity in the shallower parts and changing to high deeper. At 4 m the substrate comprises sand patches and sandy chutes interspersed with rock and live coral. There are patches of branching coral rubble that are consolidated by crustose coralline algae and a huge expanse of the reef crest and upper slope is formed of dead branching *Acropora* covered by turf and macro-algae (mat forming filamentous alga and *Halimeda*). Average cover of suitable substrate by live hard corals is 46% and higher at 10 m (75%) than 4 m (17.5%), by turf algae is 33% and higher at 4 m (45.5%) than 10 m (20%), by macroalgae is 16% and higher at 4 m (27%) than 10 m (4.5%), and by crustose coralline algae is 3%. At 10 m *Porites rus* and *P. cylindrica* dominate the slope, with *P. rus* overgrowing *P. cylindrica* and rapidly occupying all dead surfaces. *P. rus* forms massive, columnar and foliose growth forms with large patches of dramatic columnar growth. Massive *Porites* is deeply pitted by borers and full of lesions. Fishing lines and anchor damage are evident. Large *Porites* bommies occur on sand patch. The reef is dissected by sandy chutes and gullies. *P. cylindrica* and *P. rus* break off in chunks and fall down the slope. Sediment collects in pockets on the massive *Porites* colonies causing lesions in some cases. Most of the dead coral substrate was formed of toppled *P. rus* columns. There is a 600 sq m patch of soft coral. Lesion repair (recorded on >25 colonies) is very prevalent and almost all branching *Acropora* coral colonies exhibit this. There are few table *Acropora* corals across the depth range. Coral color is

generally good, but paling is occurring in 13% of the colonies. Coral recruitment is moderate and table and branching *Acropora* growth margins are moderately wide indicating active growth. Disease and predation levels are low. Evidence of dynamite fishing recorded.

Potential resilience:

Stress resistance and recovery indicators are strong and overall **potential resilience of this coral community is high.**

Conservation action:

This is an important reef that is representative of an inner reef near to a large island in Chuuk lagoon. And it is in relatively good condition, with strong potential resilience. Consequently, this valuable site should be established as a no-take area within a State-wide MPA network and managed to enhance its resilience. This can be achieved immediately by prohibiting fishing activities and all forms of anchoring directly on corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Fanochetiw-2; C-308 (7/31/2016)

Latitude: 7.53437°N; Longitude: 151.96867°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-48



General Description:

Reef progresses from a shallow (<1 m) reef flat down a very gradual slope in shallows and steepens below 4-5 m down to sand. Rugosity is high. This is a stunning coralscape formed of castellated *Porites rus* and massive species. The reef ends on sand at increasing depth from approximately 6 m to well below 20 m further along the reef. Above 2-3 m the reef structure is heavily calcified by crustose coralline algae (CCA) and the extreme shallows have abundant small *Acropora* colonies including bushy and table species. The slope is dominated by *Porites* spp, principally *P. rus*, but including massive species and *P. cylindrica*. The water here was hot at 32°C and there was constant mixing with cooler deeper water (30°C). Average cover of suitable substrate by hard corals is 62% with massive *Porites* dominating the slope, turf algae is 8%, macroalgae is 17% and CCA is 13%, with strong consistency of cover for all across the depths. Some paling of coral colonies is occurring and 16% of the colonies exhibit this. At 4 m, the horizontal upper surfaces of 40% of massive *Porites* colonies are pale in contrast to the sides and many anemones are near white. Massive corals reach large sizes (>3 m), one massive *Porites* reached 4 m in size, but table *Acropora* corals are entirely absent. Coral recruitment on average is moderately high, being high at 10 m and lower at 4 m. Coral disease is moderate with discoloration being the greatest indicator of distress: at 4 m over half of the massive *Porites* have discoloration and/or tissue loss occurring progressively across colony. Coral predation is high with crown of thorns starfish (COT) feeding scars in addition to the four COTs seen at 4 m. There is evidence

of dynamite fishing with clear blast craters in addition to dislodged corals. Two fishing lines and one rope are entangled in the coral and there is clear evidence of anchor damage. Sediment collects in pockets in the massive *Porites* colonies causing lesions in some cases. *Millepora* overgrows *Porites* and causes tissue loss in the areas of contact.

Potential resilience:

The stress resistance indicators are strong, but recovery indicators relatively weak; and the overall **potential resilience of this coral community is moderate.**

Conservation action:

Destructive fishing practices are degrading this reef. It is important to enhance the resilience of the coral reef community and its contribution to fisheries production by prohibiting all forms of destructive fishing, especially blast fishing and direct anchoring on corals.

Site name: Mochanap; C-309 (8/1/2016)

Latitude: 7.67159°N; Longitude: 151.78377°E

Reef type: Channel; Transect heading: N/A

Current Online Database Code: CHK-49



General Description:

Shallow reef terrace covered by crustose coralline algae (CCA) and corals extends to 2.5 m deep and then slopes moderately steeply down to a sand channel at about 30 m and beyond. Rugosity is high. Average cover of suitable hard substrate by live hard corals is 47.5%, but is higher (up to 60%) at 4 m than deeper (35%), essentially 0% for turf algae, 30% for macroalgae (predominantly *Halimeda*, especially at 10 m), but this increases with depth from 10% to 50%, and 22.5% for CCA. There is some paling of corals (16.5%), *Acropora* and *Pocillopora* are noticeably brightening, and all *Seriatopora* white. There is vibrant new coral growth everywhere at both depths, recruitment is strong in both numbers and diversity of species, and branching and table corals are actively growing based on the width of their growth margins. Corals are a mix of healthy actively growing colonies and others affected by disease: the incidence of coral disease is high with discoloration and tissue loss on 20% of massive *Porites* species at 10 m; and one case each of *Diploastrea* white syndrome and *Porites* white syndrome recorded. Predation is also high with *Coralliophila*, fishes and burrowing organisms predominant; crown of thorns starfish feeding scars are old and covered with fine turf algae. There are many old dead corals and dying *Porites*. Large *Porites* colonies have what appear to be blast fishing scars on one side.

Potential resilience:

Stress resistance indicators are strong and recovery indicators moderately strong. The overall **potential resilience of this coral community is high.**

Conservation action:

It is important to maintain and reinforce the high resilience of this coral community. The reef is representative of a northern inner channel habitat of Chuuk atoll and is placed in a major channel where it can facilitate spatial ecological connectivity among the inner and outer coral reef based communities of the atoll. It should be established and managed as a no-take area and an essential component of a State-wide marine protected area network. This would benefit fisheries by spill-over and larval replenishment for the Pis Island community fishing nearby reefs. Special attention should be placed on enforcement by the Pis Island community of no-take and prevention of anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Site name: Sapan Anang-2; C-310 (8/1/2016)

Latitude: 7.61898°N; Longitude: 151.68613°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-50



General Description:

There is an extensive terrace dominated by a dense community of *Porites cylindrica* with crustose coralline algae (CCA) and *Halimeda*. The 2-4 m terrace slopes steeply to sand at 14 m and is dissected by gullies. A few large patches of soft coral are scattered in the *P. cylindrica* zone. First 2/3 of dive has a mix of mostly small corals and the last 1/3 almost all *P. cylindrica*. Average cover of suitably consolidated substrate by live hard corals is 28% and is consistent across depths, by turf algae is 9.5% and higher at 10 m (reaching 28%) where dead coral is more abundant, by macroalgae is 28%, and crustose coralline algae is 34%. Corals are stressed and 35% are paling or approaching bleaching, but across the depths *P. cylindrica* had good deep color and coral recruitment is strong in both numbers and diversity of species. Table *Acropora* has a broad range of size classes, is actively growing, but does not get larger than 2 m. At 10 m there are old dead corals, including table *Acropora* (>2 m) and massive species (*Porites*, *Diploastrea*, *Faviids*) that are covered by CCA and turf algae. Massive *Porites* sustain numerous lesions and many are deeply pitted by bioerosion; *P. cylindrica* colonies are split and broken away and collapse down the reef slope. *Millepora* is badly broken up by anchors and possibly storm damage. Large coral bommies lie separated from each other and main reef by 14 m deep gullies: the gully floors and slopes are covered by *P. cylindrica*. Disease levels are high and led by *Acropora* white syndrome. Predation is also high, with crown of thorns starfishes (7 seen), *Coralliophila*, fishes and burrowing organisms all contributing.

Potential resilience:

Stress resistance indicators are moderate and recovery indicators moderately weak. The overall **potential resilience of this coral community is moderate.**

Conservation action:

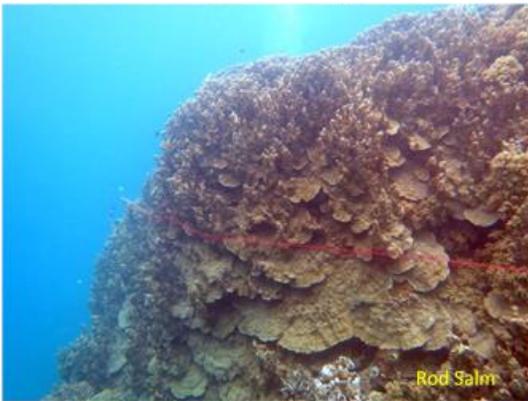
It is important to manage this reef to enhance its resilience. This will require management of the herbivore fisheries and all forms of destructive fishery practices, especially dynamite fishing and anchoring directly on corals.

Site name: Och; C-311 (8/3/2016)

Latitude: 7.3951°N; Longitude: 151.74774°E

Reef type: Patch_back; Transect heading: N/A

Current Online Database Code: CHK-18



General Description:

This patch reef comprises a bank of dead, branching, and partly consolidated coral rubble covered by turf and macroalgae and patches of corallimorphs. The reef falls quickly to coarse sediment comprising *Halimeda* and shell fragments with isolated bommies formed of massive *Porites* and large rock outcrops covered by various corals and invertebrates, including *Millepora* and *Dendronephthya*, and stands of branching *Acropora*. Recruitment is moderate: in general, large numbers of recruits in places, but no diversity of species. However, recruitment by bushy *Acropora* is very strong in less than 2 m, including areas with 75% cover of macroalgae, and by branching *Acropora* > 2 m in patches with 50:50 branching *Acropora* and macroalgae. *Pocillopora* and *Porites rus* are also prominent among recruiting corals, along with sponges and tunicates. Paling and bleaching of corals is underway, particularly of branching *Acropora*, averaging 62% of colonies but reaching as high as 90% at 4 m. Nearly 100% of massive *Porites* colonies are paling on the horizontal upper surface relative to the sides. At least one live table *Acropora* exceeds 2 m in diameter and massive corals exceed 3 m. Branching corals have sustained what appears to be extensive damage from the 2015 typhoon. Most *Porites* colonies have lesions that could be caused by blasting by coral rubble during the typhoon or pockets of sediment. Lesion repair is evident on branching *Acropora*.

Potential resilience:

Stress resistance and recovery indicators both are moderately strong. The overall **potential resilience of**

this coral community is moderate.

Conservation action:

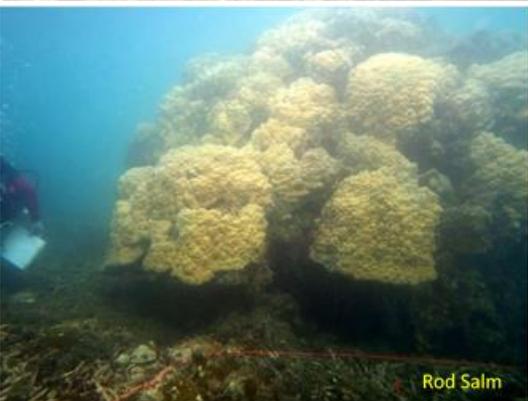
Recovery of this *Acropora* dominated community is underway. With protection from anchor damage and dynamiting and no additional heat stress this year, the potential for full recovery appears strong. If seawater temperatures rise to bleaching danger levels this year, this is a site to monitor the impact.

Site name: Truk Stop; C-312 (8/3/2016)

Latitude: 7.44277°N; Longitude: 151.83809°E

Reef type: Inner; Transect heading: S

Current Online Database Code: CHK-2



General Description:

This site comprises scattered *Porites* bommies on a wide sandy gradual slope extending out from shore. Nearer the Truk Stop jetty, 70% of the substrate is loose, branching coral rubble covered by macro and turf algae with huge *Porites* bommies on sand. A fine layer of silt and silty mucus is very common on the *Porites* colonies, many of which are deeply pitted and eroded, or have pockets of sediment that are causing lesions. Where the rubble forms banks 95% covered by *Halimeda*, branching *Acropora* is establishing itself and growing out strongly (5% cover). Almost all of the *Porites* colonies are paling on top. *Porites* colonies growing close to the water surface are dead centrally and covered by silt, macroalgae and some turf algae. Recruitment is low, disease levels are high (notably tissue loss, discoloration and growth anomalies on *Porites*) and predation primarily by burrowers also is high.

Potential resilience:

Stress resistance indicators are moderately weak and recovery indicators are weak. **The overall potential resilience of this coral community is low.**

Conservation action:

Restoration of this coral reef community will be challenging, but worthwhile: the coral community is a barometer of the water quality off one of the important hotels on Weno. Residents of the island and tourists will enjoy access to the corals and swimming in clean water. However, to achieve this, major action will be needed on land to address issues of runoff and discharge of polluted water into the nearshore area along this stretch

of coast. Improved water quality may be sufficient to enable strong recovery of a more diverse coral community that should be managed for tourism and recreation only and established as a no-take area.

Site name: Parem; Parem (8/3/2016)

Latitude: 7.36566°N; Longitude: 151.78479°E

Reef type: Inner; Transect heading: N

Current Online Database Code: CHK-6

General Description:

Reef has gradual slope and moderate rugosity. Average cover of available hard substrate is high for live hard corals (60%), 10% for turf algae, 21% for macroalgae and 5% for crustose coralline algae. Table *Acropora* corals are absent. About 20% of the corals are paling. Coral recruitment is apparently non-existent or at least not detected. At 10 m massive *Porites* dominates and corals are largely or partly covered by mucus. *Padina* and *Halimeda* species dominate the macroalgae. There are possible old crown of thorns starfish feeding scars.

Potential resilience:

Stress resistance indicators are moderate and recovery is weak. The overall **potential resilience of this site is low.**

Conservation action:

No action prescribed. The cost and effort would be better expended at other locations.

Site name: Manukun; Uman (8/3/2016)

Latitude: 7.31202°N; Longitude: 151.87172°E

Reef type: Inner; Transect heading: SW

Current Online Database Code: CHK-16

General Description:

This site has a moderately steep slope and moderate rugosity. Average cover of the available substrate is 28% for live hard corals, 28% for turf algae, 28% for macroalgae and 15% for crustose coralline algae. *Porites* rus dominates and *Lyngbya majuscula* is present in masses indicating high nutrient loading. About 11% of the corals (*Acropora*) are bleaching. Coral recruitment is low but branching *Acropora* and the few table *Acropora* have wide actively growing margins. *Coralliophila* feeding scars seen on corals but the snails were scarce.

Potential resilience:

Resistance indicators are moderate and recovery indicators are strong due primarily to strong growth reorientation of dislodged or overturned foliose and massive corals. The overall **potential resilience of this coral community is high** but may be exaggerated by the growth reorientation value and incomplete documentation of corals diseases and predation.

Conservation action:

It is important to enhance the resilience of this coral community. The site is representative of a high island fringing reef and is well placed within the southern Chuuk lagoon to function as an important stepping stone for connectivity among these reefs. Therefore, it thus should be established and managed as a no-take area and an essential component of a State-wide Chuuk marine protected

area network. Special attention should be placed on enforcing no-take and preventing anchoring on the corals by visitors to the area, whether for tourism, recreation, or monitoring purposes.

Appendix 1. Lessons learned regarding citizen science activities

Citizen scientists provide valuable contributions to data collection in remote areas and engage people that are keen divers and observers. Some will continue to apply their learning and notice and document features of reef health and resilience at other sites and share this information with TNC contacts. To enable this, TNC scientists should maintain an open dialogue with the interested citizen scientists, sharing, receiving and commenting on each other's observations.

Building citizen science into reef assessments in remote locations is contributes effectively to raising the necessary funds to support such work and engaging interested donors directly in the activity.

Here are useful lessons learnt that will improve the quality and consistency of data collected, the efficiency of data analysis and reporting, and the experience for all:

1. Before the trip: if using a boat and crew that are new to TNC, always check this out in person
2. Before the trip: confirm citizen scientist commitment and provide ample briefings:
 - Prepare and distribute a manual detailing methods, illustrating examples of features to be measured, sample data sheets, and expectations of the citizen scientists
 - Have at least two thorough webex briefings that address administrative issues and duties of the citizen scientists and that illustrate, describe and discuss the various indicators to be measured
 - Require citizen scientists to bring their own computer for data entry and preferably not too bulky underwater camera
 - Attain citizen scientist commitment post trip to respond to enquiries, proofread and comment on the report, and provide images where needed
3. At the location: devote adequate time to citizen scientist calibration on site:
 - Half day snorkeling to identify and discuss indicators and practice identification of substrate type (e.g., live/dead coral, sponge, crustose coralline algae, algal turf, macroalgae) and percent cover of the substrate
 - At least two dives to practice using the data sheets and resolve difficulties in application
 - Review data immediately before the boat leaves the dive site (i.e., while calm and quiet)
 - Review all photo queries daily on data entry and discuss all questions
4. Have all computers connected through a remote wireless router to the master computer or separate server so that all data can be uploaded to the central database daily and discrepancies identified and resolved immediately.

Appendix 2. Data sheets used by citizen science observers

Recorder name:

Day/Site No.	sampling day & site number: e.g., 1/1 for day1/site1; 2/3 for day2/site3, etc.
Coordinates	these were recorded by GPS, but each recorder entered the GPS waypoint #

The general observation recorders collected the following data onto preprinted sheets underwater (note: data in shaded rows were not included in the analysis because there was little or no variation or because the contribution to resilience was unclear):

Depth	depth at which observations made: 10 m for 8-12 m; 4 m for 3-5 m	
Slope	average angle of slope 4 m each side at each depth: 1 = >80°; 2 = 45-80°; 3 = 20-45°; 4 = 10-20° (scores: 1 = 3; 2 & 3 = 2, 4 = 1)	Potential resistance indicator
Rugosity	1 = flat to 30 cm high protuberances; 2 = 30 cm to 1 m high protuberances; 3 = >1 m rock/coral bommies, overhangs, caves	Potential resistance indicator
Mixing	1 = weak current/surge; 2 = moderate surge/current; 3 = strong swirling current/surge & local upwelling	Potential resistance indicator
Temperature variation	record highest & lowest temperatures over duration of the dive from dive computer	Potential resistance indicator
Hard bottom cover	estimated average cover (%) hard substrate at each depth over duration of dive	
Hard coral cover	estimated average cover (%) live hard coral on hard substrate at each depth over duration of dive (scores: <15%=1; 16-35%=2; >35%=3)	Potential resistance indicator
Soft coral cover	estimated average cover (%) soft coral on hard substrate at each depth over duration of dive	Potential resistance indicator
Turf algae cover	estimated average cover (%) of turf algae (T) or macroalgae (M) on hard substrate at each depth over duration of dive (scores: >40%=1; 10-40%=2; <10%=3)	Potential recovery indicator
Macroalgae cover	estimated average cover (%) of macroalgae (M) on hard substrate at each depth over duration of dive (scores: >40%=1; 10-40%=2; <10%=3)	
Other cover	crustose coralline algae (CCA) (scores: <5%=1; 5-20%=2; >20%=3)	Potential recovery indicator
Notes	additional observations or explanations of above & observation of damage from storms or other causes	

The reef health indicators recorders entered the following data onto preprinted sheets underwater:

Depth	depth at which observations made: 10m for 8-12m; 4m for 2-5m	
Lesion repair	enter hatch mark & growth form for each coral colony with 1 or more lesions being repaired (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Regrowth	enter hatch mark & growth form for each coral with active regrowth over dead portion (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Reorientation	enter hatch mark & growth form for each dislodged or overturned coral with reoriented growth (scores: 1 = <2, 2 = 2-5, 3 = >5)	Potential health & recovery indicator
Coral Recruits	abundance per 1 sq. m dead coral or rock surface: 0 = none seen; 1= 0-2 recruits; 2 = 3-10 recruits & 1-5 spp; 3= >10 recruits & >5 spp	Potential recovery indicator
Coral Color/bleaching	record %: 1 = near-white, bleached white, or blotchy color (max stress); 2 = paling/brightening (moderate stress); 3 = good/deep color (min stress) healthy	Potential resistance indicator
Growth margin	Growth margin is length of pale area at tips of branching (B) corals or outer perimeter of table (T) & foliose (F) coral: 1 = <2 cm; 2 = 2-3 cm; 3 = >3 cm	Potential recovery indicator
Table max	record estimated max diameter of live table coral: 1 = <2 m; 2 = 2-3 m; 3 = >3 m	Potential resistance indicator
Table size range	Record range of table coral colony sizes: 1 = no intermediate size colonies; 2 = few intermediate size colonies (size classes skewed toward large or very small); 3 = broad range of intermediate sizes from large to very small	Potential resistance indicator
Massive max	record estimated max diameter of live massive coral: 1 = <2 m; 2 = 2-3 m; 3 = >3 m	Potential resistance indicator
Disease	enter hatch mark for each kind: BB = black band; AWS = <i>Acropora</i> white syndrome; T = tissue loss; FB = focal bleaching; D = discoloration) (scores: <3=3; 3-10=2; >10=1)	Stress, health, & potential resistance indicator
Predation	enter hatch mark for each sighting: crown-of-thorns starfish (COT), <i>Drupella</i> (D), fish (F), other/undetermined (O), burrower infestation (B) (scores: <3=3; 3-10=2; >10=1)	Stress & potential recovery indicator
Notes	additional observations or explanations of above & observation of damage from storms or other causes	

Appendix 3. Summary reef health and resilience data (see Appendix 2 for definitions of data element measurements)

2016 REA site #	C-1	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18
Slope	1	1	1	1	1	2	1	2	2	1	1	2	1	2	2	1	1
Rugosity	2	2	2	3	2	2	3	3	3	3	3	2	3	3	3	3	1
Mixing	1	1	2	1	1	2	1	2	1	1	2	2	1	2	1	1	1
Hard coral cover	2	2	2	3	1	3	1	3	2	3	2	2	3	3	3	1	1
Turf Algae cover	1	2	2	2	2	2	3	2	3	2	3	2	2	2	2	2	1
Macroalgae cover	3	2	2	3	2	2	3	3	2	3	3	2	3	2	2	1	2
CCA cover	3	2	3	3	3	2	3	2	3	3	3	3	2	2	3	2	3
Coral Color/ bleaching Level 1	3	2	2	3	2	3	3	3	3	3	3	2	3	3	3	2	3
Coral Color/ bleaching Level 2	2	3	1	2	1	2	2	1	3	3	2	1	2	1	1	1	1
Coral Color/ bleaching Level 3	3	3	2	3	2	3	3	2	3	3	3	2	3	2	2	2	3
Table max	1	2	1	2	1	1	1	1	1	1	1	0	1	0	0	0	0
Table range	1	2	2	3	2	1	1	1	1	1	1	0	1	0	0	0	0
Massive max	3	3	1	3	3	3	3	2	3	3	1	3	1	3	3	3	2
Total lesion repair	0	1	2	1	2	1	1	1	0	1	2	1	1	1	1	1	1
Total regrowth	3	2	3	3	3	3	2	1	2	1	2	2	2	1	3	2	2
Total reorientation	1	0	0	1	0	2	0	1	2	1	1	0	1	2	0	1	1
Coral Recruits	2.00	1.00	2.00	2.00	1.25	1.00	2.50	2.50	1.50	2.75	2.50	1.50	2.75	1.00	1.75	1.00	1.50
Growth margin Branching	1.00	1.50	1.25	1.25	1.25	1.25	0.75	1.00	0.00	0.25	1.00	0.50	1.25	1.00	1.00	1.00	1.00
Growth margin Table	0.50	0.25	1.25	1.00	0.50	0.50	1.25	1.00	1.00	1.00	0.75	0.50	0.75	0.00	0.00	0.00	0.00
Growth margin Foliose	0.00	0.00	0.75	0.25	0.50	1.00	0.75	1.00	0.00	0.75	0.25	0.50	0.50	1.00	1.50	0.75	1.00
Total Disease	3	3	3	2	2	3	3	2	3	2	2	3	2	2	2	2	2
Total Predation	3	3	3	3	3	3	1	1	3	1	2	3	2	3	2	2	2
Potential resilience	39.50	38.75	39.25	46.50	36.50	43.75	40.25	38.50	42.50	40.75	41.50	35.00	39.25	37.00	37.25	29.75	30.50

2016 REA site #	Onei MPA	Onei Ref	Onei3	C-33	C-34	C-35	C-36	C-37	C-38	C-39	C-40	C-41	C-42	C-44	C-45	C-46	C-47
Slope	2	1	1	1	1	2	2	2	1	2	1	1	1	1	1	1	1
Rugosity	3	3	1	3	2	3	1	3	2	3	2	2	2	2	3	2	3
Mixing	1	1	1	2	2	3	2	2	1	1	1	1	1	1	2	2	1
Hard coral cover	2	1	1	2	1	2	1	2	2	2	2	2	2	3	2	3	3
Turf Algae cover	3	2	2	2	1	2	2	1	2	2	2	2	1	2	2	2	2
Macroalgae cover	1	1	1	3	3	2	3	3	3	1	2	3	3	3	3	3	3
CCA cover	1	1	2	3	3	2	3	2	3	2	3	3	2	2	3	3	2
Coral Color/ bleaching Level 1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Coral Color/ bleaching Level 2	3	1	1	1	1	3	1	1	3	2	3	3	1	3	2	3	1
Coral Color/ bleaching Level 3	3	1	2	2	2	3	1	2	3	3	3	3	1	3	3	3	2
Table max	0	0	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1
Table range	0	0	1	0	1	1	1	1	1	1	3	3	0	1	3	1	0
Massive max	2	3	3	3	1	3	1	3	3	3	3	1	2	3	1	1	3
Total lesion repair	3	0	1	2	1	1	1	1	1	1	2	2	1	1	2	2	1
Total regrowth	1	2	0	1	1	1	2	2	1	1	2	2	2	3	2	2	1
Total reorientation	2	0	0	0	1	1	0	1	2	0	1	0	3	3	0	1	2
Coral Recruits	1.00	1.00	2.50	1.25	2.75	2.25	2.25	1.25	2.00	1.75	1.75	3.00	1.75	1.25	1.88	2.25	3.00
Growth margin Branching	0.50	1.00	1.50	0.75	0.50	0.50	1.00	1.25	1.25	1.50	2.00	1.00	1.25	1.75	1.75	1.25	1.00
Growth margin Table	0.00	0.00	0.50	0.50	0.50	0.75	0.75	1.25	2.25	1.75	2.00	2.00	0.50	1.75	0.25	1.00	1.25
Growth margin Foliose	0.50	1.00	0.00	0.75	0.00	1.00	0.00	0.75	0.75	0.25	0.50	0.00	1.00	2.00	0.50	0.50	0.00
Total Disease	2	2	2	2	3	2	3	2	3	2	3	2	3	3	2	3	3
Total Predation	1	1	3	3	1	1	2	1	3	2	3	2	2	3	3	3	3
Potential resilience	35.00	26.00	30.50	37.25	32.75	40.50	34.00	37.50	44.25	37.25	47.25	42.00	35.50	47.75	43.38	44.00	40.25

2016 REA site #	C-48	C-49	C-50	C-52	C-53	C-55	C-57	C-58	C-59	C-60	C-61	C-62	C-75	C-77	C-201	C-202
Slope	1	1	2	1	2	1	1	1	1	1	2	1	2	1	1	2
Rugosity	2	3	3	2	3	2	3	2	3	3	3	2	3	3	2	3
Mixing	1	1	1	3	2	2	3	1	1	2	3	2	2	1	2	2
Hard coral cover	1	3	2	1	1	2	1	2	2	2	3	2	1	2	2	1
Turf Algae cover	1	2	2	2	2	2	1	2	2	2	2	2	2	2	1	2
Macroalgae cover	3	3	3	3	2	2	3	2	3	2	2	3	2	3	3	2
CCA cover	2	3	3	3	3	3	3	2	2	3	2	3	2	3	2	3
Coral Color/ bleaching Level 1	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3
Coral Color/ bleaching Level 2	2	3	1	3	3	3	2	2	3	1	2	2	1	2	2	2
Coral Color/ bleaching Level 3	3	3	2	3	3	3	3	3	3	3	3	3	2	3	3	3
Table max	0	1	1	0	1	1	2	2	1	1	2	1	0	1	1	0
Table range	0	1	0	0	1	1	3	3	1	2	3	1	0	1	1	0
Massive max	1	2	3	1	1	2	2	3	3	1	3	1	2	2	2	1
Total lesion repair	1	1	0	1	0	1	2	2	2	1	0	1	0	1	2	1
Total regrowth	1	2	1	1	1	1	2	2	2	3	1	2	2	2	2	1
Total reorientation	0	0	1	1	0	0	0	1	2	0	1	0	0	0	1	0
Coral Recruits	2.25	2.00	1.00	1.50	2.25	2.50	2.25	2.00	1.50	2.75	2.50	2.75	1.00	1.25	1.75	1.00
Growth margin Branching	0.00	1.00	0.25	0.50	0.25	1.50	1.25	1.25	1.00	2.00	1.50	1.00	1.00	0.75	1.50	0.50
Growth margin Table	0.25	1.00	0.00	0.00	0.25	1.00	1.50	1.75	1.75	1.25	1.50	0.75	0.00	0.25	1.50	0.00
Growth margin Foliose	0.00	0.00	0.00	0.50	0.25	0.50	1.00	0.75	1.25	0.00	0.00	0.75	0.00	0.50	1.00	1.00
Total Disease	3	2	3	3	3	3	3	2	3	2	2	2	2	2	3	3
Total Predation	3	1	3	3	1	1	2	2	2	1	2	1	3	1	2	2
Potential resilience	30.50	39.00	35.25	36.50	35.00	38.50	45.00	42.75	44.50	39.00	44.50	37.25	30.00	35.75	40.75	33.50

2016 REA site #	C-203	C-204	C-205	C-206	Kuop Acrop Garden	C-207	C-208	C-209	C-210	C-211	C-212	Pisinini Inner	C-213	C-300	C-301
Slope	1	2	1	1	1	1	1	1	1	2	1	1	1	1	3
Rugosity	2	2	3	3	1	2	3	1	2	2	2	2	2	3	2
Mixing	1	1	1	3	1	2	2	2	1	1	1	1	1	1	1
Hard coral cover	1	1	3	3	3	3	3	1	1	1	2	2	2	3	1
Turf Algae cover	2	3	3	3	2	2	2	1	1	2	2	1	2	2	1
Macroalgae cover	2	2	3	3	3	3	3	3	2	1	2	2	2	3	3
CCA cover	3	3	3	3	2	2	3	3	3	2	3	2	3	3	3
Coral Color/ bleaching Level 1	2	1	3	3	2	3	3	3	3	3	3	3	3	3	3
Coral Color/ bleaching Level 2	2	1	3	3	1	2	2	2	2	2	3	3	2	1	3
Coral Color/ bleaching Level 3	2	2	3	3	1	3	3	3	3	3	3	3	3	2	3
Table max	0	0	1	1	1	1	3	1	1	1	2	1	2	1	1
Table range	0	0	2	2	0	2	3	1	1	2	3	1	2	1	0
Massive max	1	2	1	1	1	2	1	2	1	3	3	2	3	3	1
Total lesion repair	1	0	3	1	3	2	2	1	1	1	2	0	2	2	1
Total regrowth	1	1	2	1	3	3	3	2	2	1	3	3	3	1	0
Total reorientation	0	0	1	2	0	2	2	1	1	1	1	3	3	1	0
Coral Recruits	1.50	1.75	3.00	2.75	2.00	3.00	3.00	1.75	1.25	1.50	2.67	3.00	2.25	3.00	3.00
Growth margin Branching	1.00	1.00	0.75	0.00	1.00	1.75	1.50	2.00	1.00	1.00	2.00	1.00	1.75	1.00	1.00
Growth margin Table	0.00	0.00	1.75	1.25	1.00	2.50	2.00	1.50	1.75	1.50	2.00	1.00	2.00	0.25	0.50
Growth margin Foliose	0.00	1.50	1.25	0.75	0.00	0.00	0.00	0.50	1.50	0.50	1.33	1.00	0.75	0.50	1.25
Total Disease	3	3	2	2	3	3	1	3	2	3	2	2	2	2	3
Total Predation	2	1	1	1	3	2	2	2	3	3	2	1	2	1	1
Potential resilience	28.50	29.25	45.75	43.75	35.00	47.25	48.50	38.75	36.50	38.50	48.00	39.00	46.75	38.75	35.75

2016 REA site #	C-302	C-302 Ext	C-303	C-304	C-305	C-306	C-307	C-308	C-309	C-310	C-311	C-312	Parem	Uman
Slope	3	2	2	2	1	1	2	1	2	1	1	1	1	2
Rugosity	3	3	3	1	2	2	3	3	3	3	3	3	2	2
Mixing	1	1	1	1	2	1	1	2	1	1	1	1	1	2
Hard coral cover	2	1	3	1	2	2	3	3	3	2	2	1	3	2
Turf Algae cover	3	3	2	2	3	3	2	3	3	3	2	2	2	2
Macroalgae cover	1	1	3	2	2	1	2	2	2	2	2	2	2	2
CCA cover	2	1	3	3	3	1	1	2	3	3	1	2	1	2
Coral Color/ bleaching Level 1	3	3	2	3	3	3	3	3	3	3	3	3	3	3
Coral Color/ bleaching Level 2	1	1	1	2	2	2	2	2	2	1	1	1	2	2
Coral Color/ bleaching Level 3	2	1	2	3	3	2	3	3	3	2	2	2	3	3
Table max	1	1	1	1	2	1	1	0	1	1	2	0	0	1
Table range	2	2	3	0	1	1	2	0	2	3	1	0	0	0
Massive max	2	3	3	1	2	3	3	3	3	1	3	3	3	2
Total lesion repair	2	0	1	0	1	1	1	1	1	1	1	1	0	0
Total regrowth	2	0	2	0	1	0	3	1	1	2	3	1	1	3
Total reorientation	0	0	0	0	0	1	2	1	1	0	1	1	3	3
Coral Recruits	2.00	2.00	1.75	2.00	1.75	1.25	1.50	2.25	2.75	2.67	1.83	1.00	0.00	1.00
Growth margin Branching	0.75	1.00	0.75	1.00	1.75	1.00	1.25	1.00	1.50	1.33	1.33	1.00	1.00	2.00
Growth margin Table	1.75	2.00	0.75	1.00	0.75	1.00	1.50	0.00	2.00	1.17	1.00	0.33	0.50	1.00
Growth margin Foliose	0.75	1.00	1.00	1.00	1.00	0.25	1.00	0.75	0.50	0.00	0.83	0.00	1.00	2.00
Total Disease	2	2	1	2	3	2	3	2	1	1	2	1	2	3
Total Predation	1	2	1	1	2	3	2	1	1	1	2	1	2	3
Potential resilience	38.25	33.00	38.25	30.00	40.25	33.50	44.25	37.00	42.75	36.17	37.99	28.33	33.50	43.00