







Developing indicators for monitoring coral reef resilience in Kenya

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Marine Socio-Ecological Systems Symposium

Climate change and coral reefs

100

80

Α

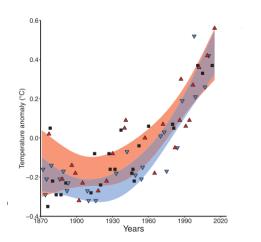
AUSTRALASIA

Year

Coral bleaching

- ✓ Increasing in frequency
- ✓ Geographically larger

Hughes et al 2018



□ Moderate % locations 6 09 60 40 20 20 2010 2016 1980 1990 2000 2016 1080 2000 2010 PACIFIC OCEAN WESTERN ATLANTIC 100 100 7 С D 80 80 % locations 60 20 20 2000 1980 1990 2000 2010 2016 1980 1990 2010 2016

100

80

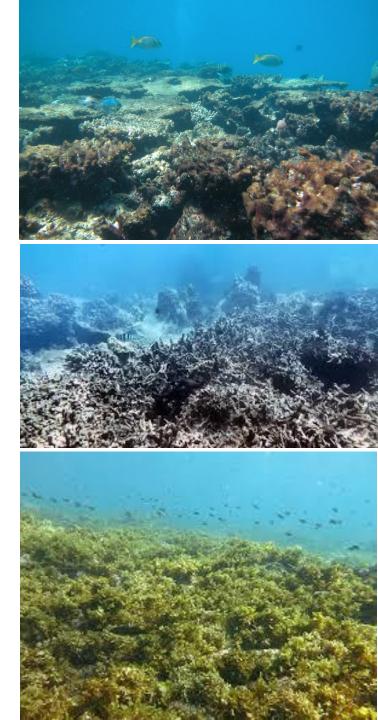
В

INDIAN OCEAN

Year

Severe

Geographic variation in the timing and intensity of coral bleaching from 1980 to 2016.



Global warming throughout ENSO cycles

Resilience-Based Management (RBM)

Ecosystem-based Single-species Management management management Manage single Manage multiple species, habitats, & ecosystem services current condition Manage for change Avoid natural Accept natural disturbances as part of ecosystem dynamics Plan for historical range of variability Humans are separated Humans are linked to

Resilience-Based

Manage ecosystem services to support human wellbeing

Manage for large-scale change, uncertainty, & surprise

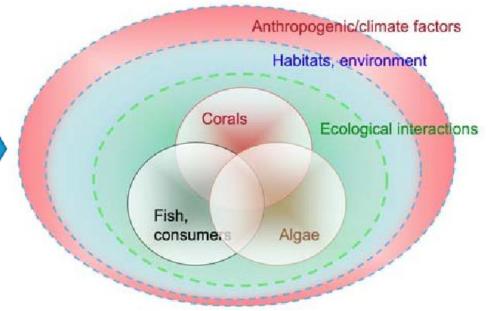
Shape change to sustain socialecological properties & apply adaptive management

Maintain variability, diversity, and redundancy

Humans are integrated w/ ecosystem; drive changes, adaptation, & transformation in socio-ecological system

Indicators to monitor ecological resilience

Obura and Grimsditch 2009 – 61 Broad-scale McClanahan 2012 – 11 Global indicators







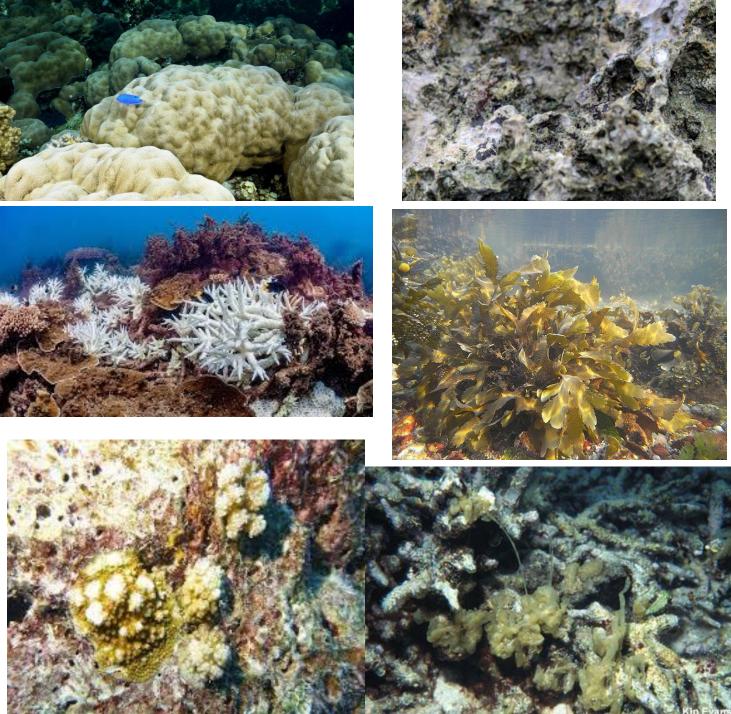


Definition of ecosystem resilience:

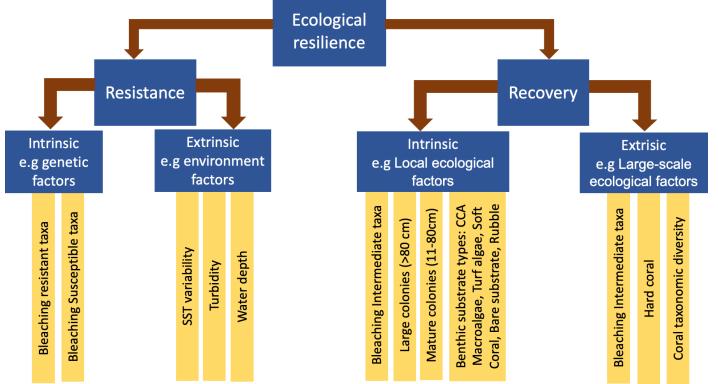
ability to resist, reorganize and reestablish from disturbance and still maintain structure and function. (Nystrom *et al.* 2000, Gunderson 2000)

Properties of reef resilience (West and Salm 2003)

- ➢ Resistance → ability of coral community to withstand/survive disturbance e.g bleaching
- ➢ Recovery → capacity of a reef system to maintain or return its coral assemblage and function after a disturbance/ bleaching event



A simple classification of resilience indicators



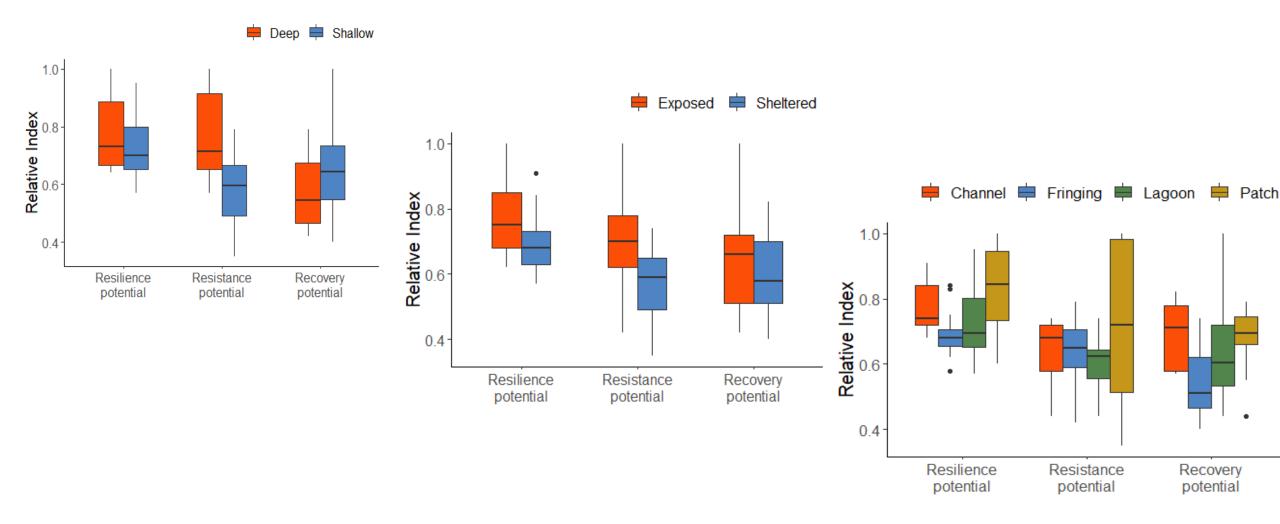
Resilience property	Rationale	Variable	Variable Code	Measure	Direction
Resistance	Bleaching resistance	Bleaching resistant	B-resistance	Density	1
Resistance	Bleaching resistance	Bleaching susceptible	B-susceptible	Density	-1
Resistance	Bleaching protection	SST-sd	SST-sd	°C	-1
Resistance	Bleaching protection	Depth	Depth	m	1
Recovery	Recolonization ability	Intermediate bleaching	B-intermediate	Density	1
Recovery	Substrate suitability	CCA	CCA	% cover	1
Recovery	Substrate suitability	Macroalgae	MA	% cover	-1
Recovery	Substrate suitability	Turf algae	TA	% cover	-1
Recovery	Substrate suitability	Soft Coral	SC	% cover	-1
Recovery	Substrate suitability	Bare substrate	BS	% cover	1
Recovery	Substrate suitability	Rubble	RB	% cover	-1
Recovery	Recolonization ability	Largest colonies (>80 cm)	L-colonies	Density	1
Recovery	Recolonization ability	Mature colonies (11-80cm)	M-colonies	Density	1
Recovery	Recolonization ability	Recruitment (1-10cm)	Recruitment	Density	1
Recovery	Recolonization ability	Hard coral	HC	% cover	1
Recovery	Recolonization ability	Genera richness	G-richness	No. of genera	1

Spatial pattern - resistance and recovery potential

Effect of geography, habitat factor and management on resistance, recovery and resilience potential

(A). Response variable:	Type III	Mixed-Effects		North	Central
Resistance potential	NumDF	F value	Pr(>F)	North Shili	New Coral Gardens
Geographic zone	2	2.534	0.097	Boso	Old Coral Gardens
Depth	1	18.360	<0.001***	Chongo cha Bomani	5
Exposure	1	1.401	0.247	North	
Reef type	3	0.772	0.519		Bolphin
Management	2	0.274	0.762	Central	Richard- Bennette Drummers
				South	Turtle Reef
(B). Response variable:		Mixed-Effects			Watamu Coral Garden
Recovery potential	NumDF	F-value	Pr(>F)	Chongo cha Mwongo Shariff	Anthias
Geographic zone	2	0.765	0.475	Chole	Alundo
Depth	1	2.868	0.102	Mlango wa Muhindi	South
Exposure	1	6.911	<0.01*	- Chongo cha Mvundeni	
Reef type	3	3.874	<0.01*	Ze who Mkokoni	Kibuyuni
Management	2	0.591	0.560	Mikes Inner Mikes Outer	Mkwiro
				Chongo cha Chano	2
(C). Response variable:		Mixed-Effects		Shimo La Tewa	- d
Resilience potential	NumDF	F-value	Pr(>F)	Mabiyu	Upper Mpunguti Seaward
Geographic zone	2	1.053	0.362	N Resistance	Upper Mpunguti Leeward Kisite Leeward
Depth	1	3.848	0.060	Recovery	Kisite Seaward
Exposure	1	10.16	<0.001**	Fawacho Land	Makokokwe
Reef.type	3	5.474	<0.001**	0 2.75 5.5 11 16.5 22 Kilometers Coral reefs	
Management	2	0.742	0.485	41 ⁶ E	

Relative index of resilience, resistance & recovery potential across different habitats



Conclusion

- Using resistance and recovery indicators offers a better measure to quantify resilience
- Current MPAs are not necessarily located in areas with coral comunitities that's have high resistance or recovery potential
- Sites with high resistance potential- these are going to maintain coral cover even after bleaching and will be a source of larvae to other sites. Good to protect these.
- Sites with higher recovery potential These are also going to act as sinks for larvae coming from other sources. Good to protect these
- ✓ Sites with equal measure of resistance and recovery potential- prime sites to protect as they provide more opportunity to recover coral populations

Thank you

