ARC Centre of Excellence
Coral Reef Studies

Social-ecological vulnerability of coral reef fisheries to climate change

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Introduction

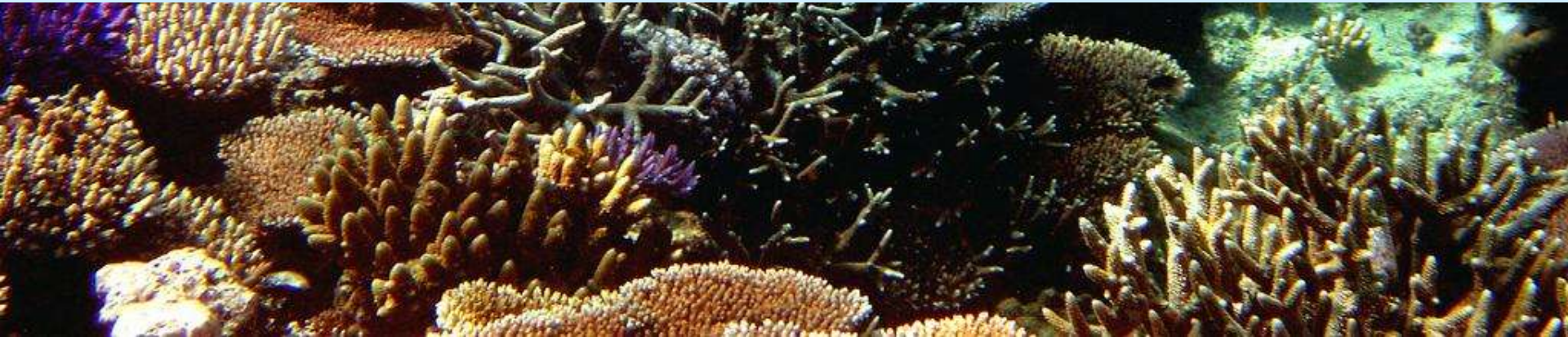
Coral reefs provide critical goods & services:

- » Fishing
- » Coastal protection
- » Tourism
- » Aesthetic and spiritual values

Climate change = key threat to coral reefs

sea surface temperature, ocean acidification

How are reef-dependant societies being affected by climate change impacts, and what capacity they have to adapt?



Introduction

Vulnerability =
The degree to which a system is susceptible to, and unable to cope with the adverse effects of a chronic or stochastic disturbance

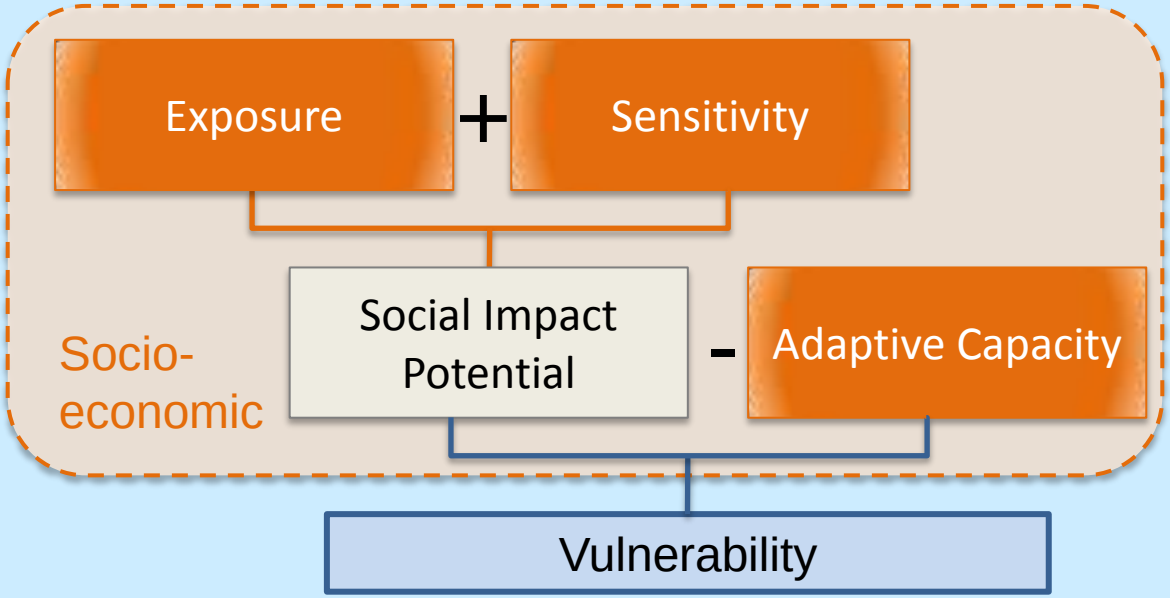
Varies across spatial & temporal scales & for different people within a society

Few studies on vulnerability in the context of changes specific to coral reef ecosystems

Introduction

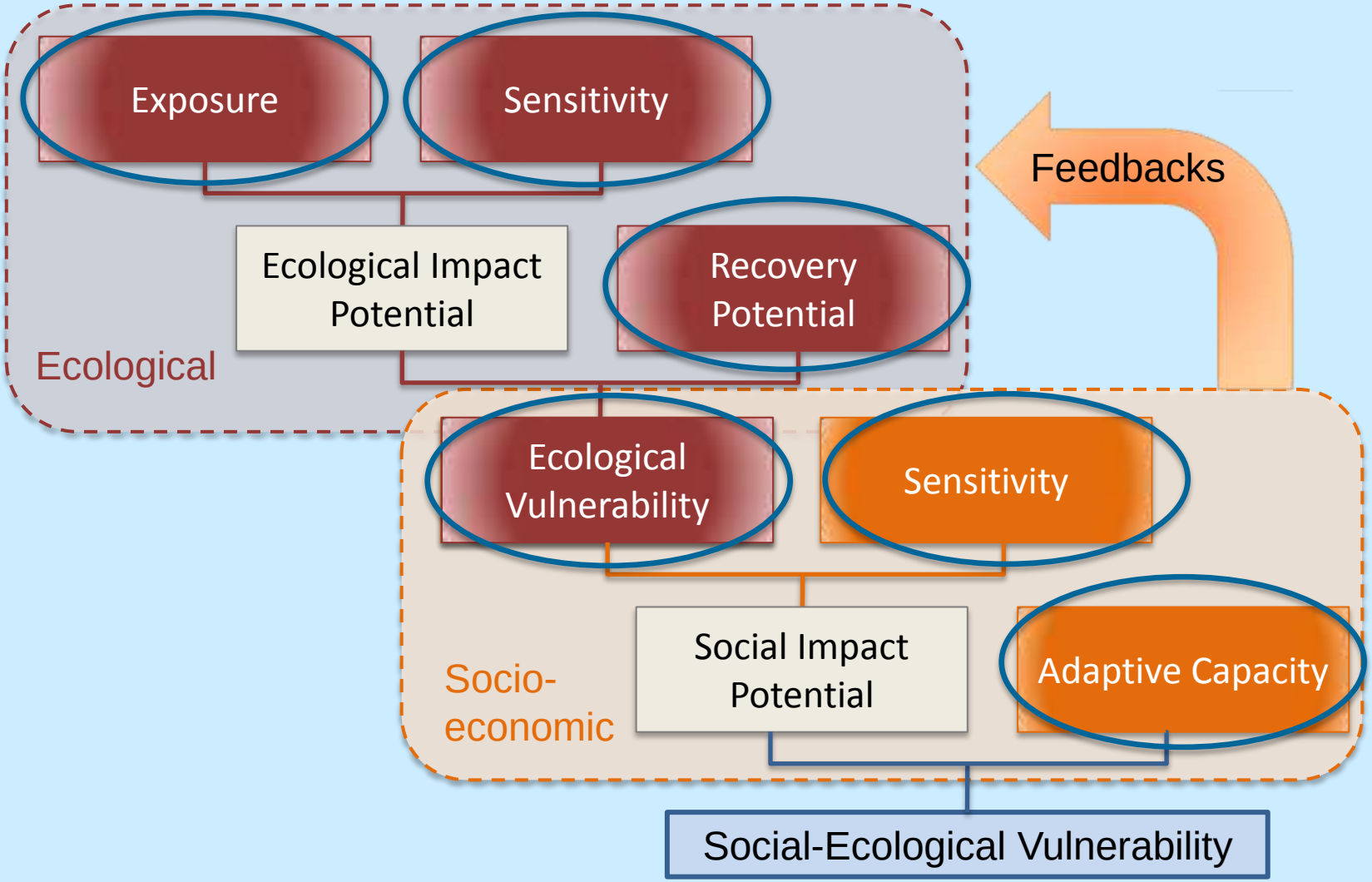
Vulnerability framework
V = (E + S) - AC

Ecological states and processes ???



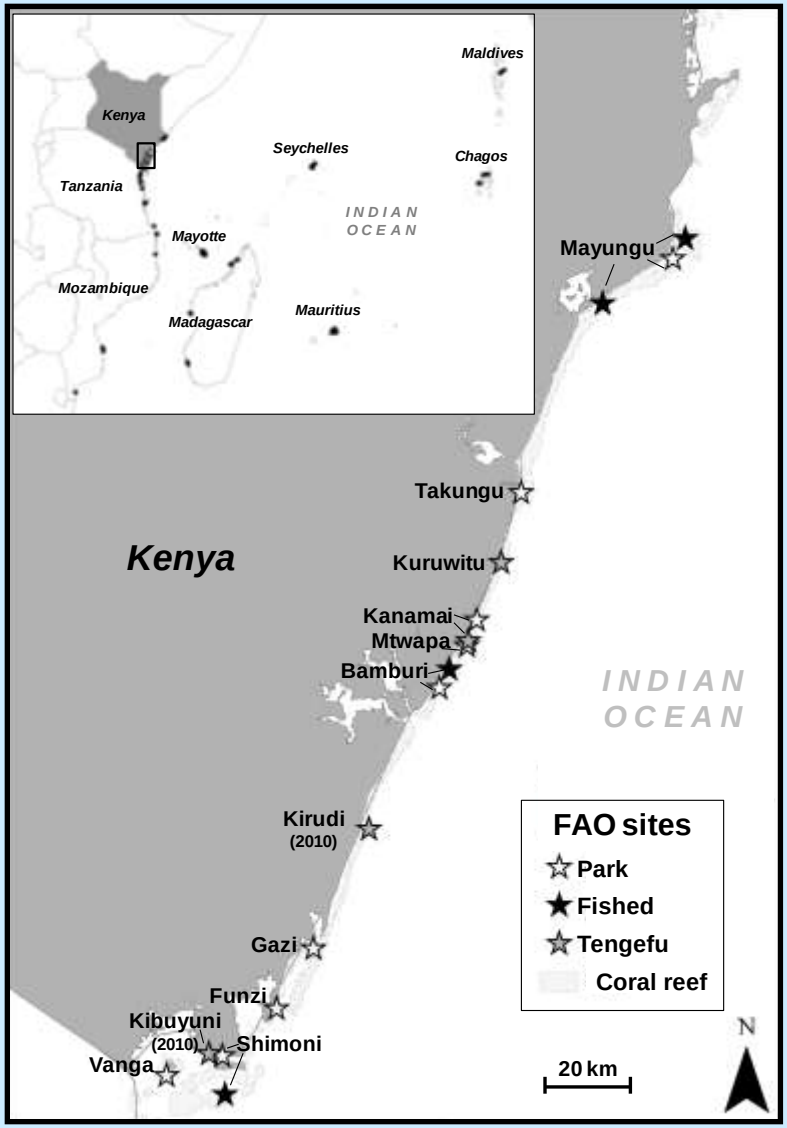
(Cinner et al. 2012 GEC)

Introduction



Introduction

Operationalizing the vulnerability of coastal communities to the impacts of coral bleaching on reef fisheries

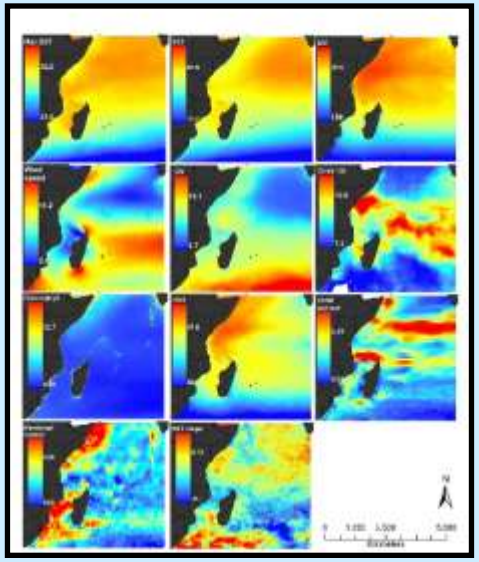


Kenya case study:

- ✓ Coral reefs extensively damaged by 1998 bleaching (up to 95% mortality)
- ✓ High dependence on natural resources
- ✓ Range of marine resource governance regimes

Introduction

Models

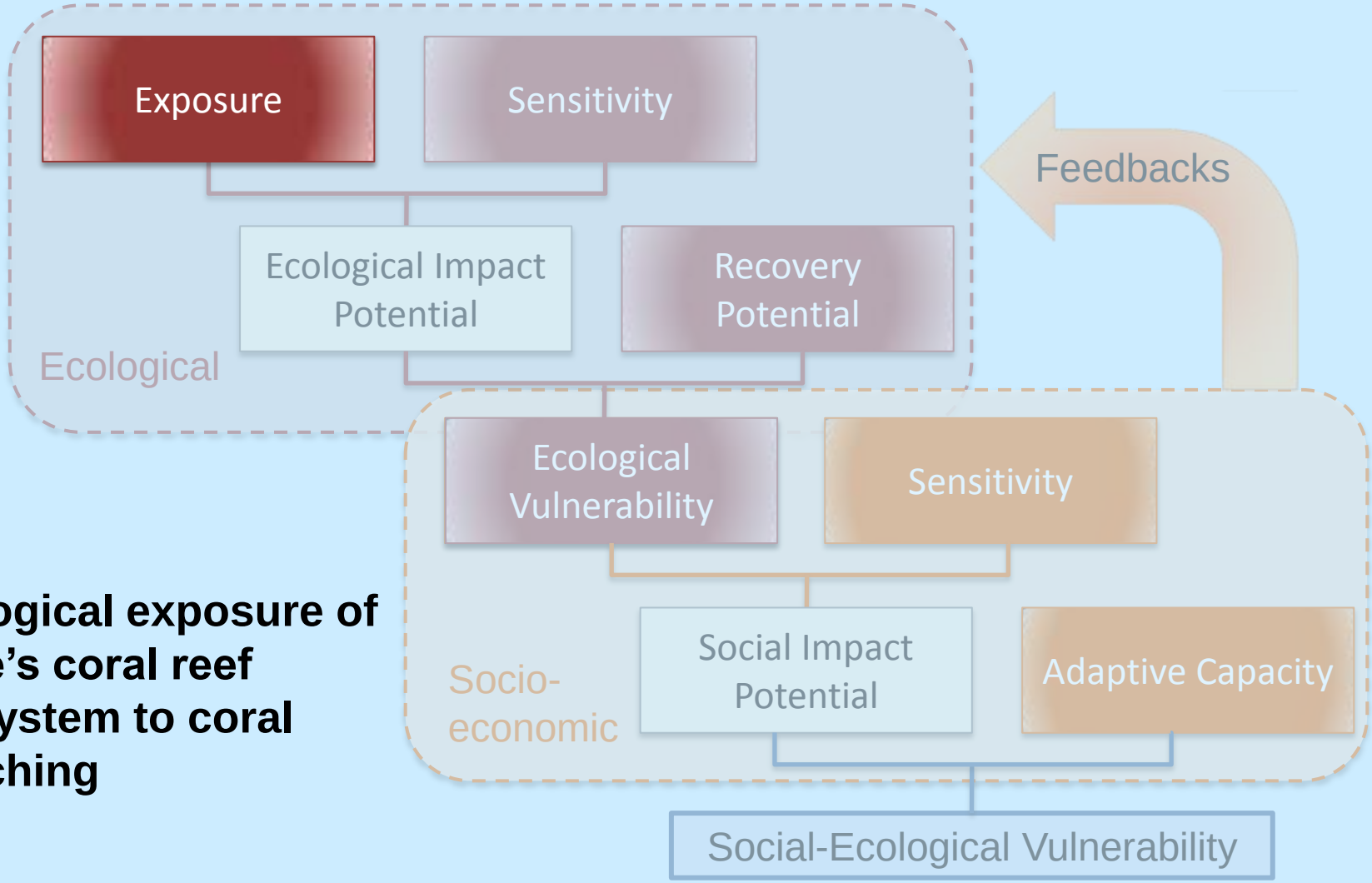


Ecological data

Socio-economic data

Workshop

Ecological Exposure

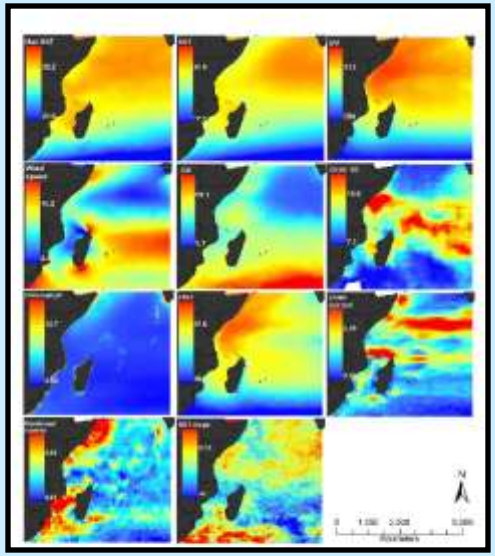


Ecological exposure of a site's coral reef ecosystem to coral bleaching

Ecological Exposure

Exposure = degree to which a system is stressed by climatic events and environmental conditions *(Cutter 1996 Prog. Hum. Geogr., Adger 2006 Glob. Env. Ch.)*

Region-wide model

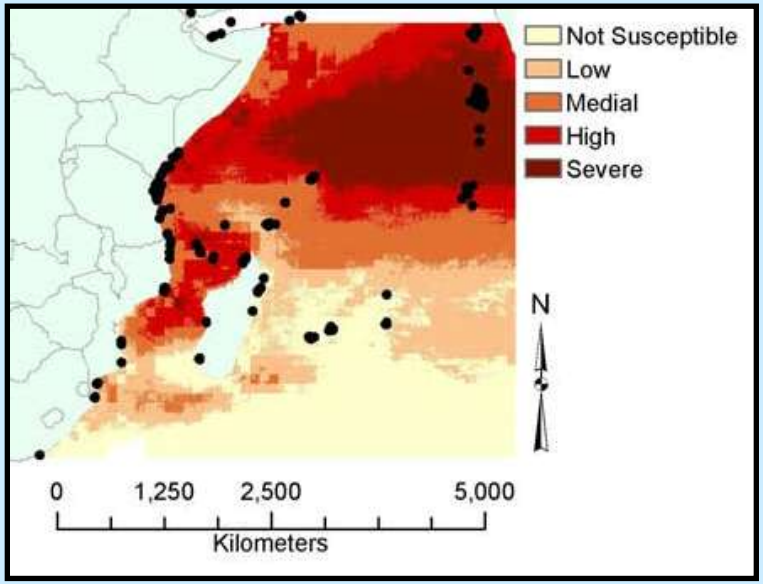


Oceanographic factors

- temperature
- light
- currents
- tidal variation
- chlorophyll
- water quality

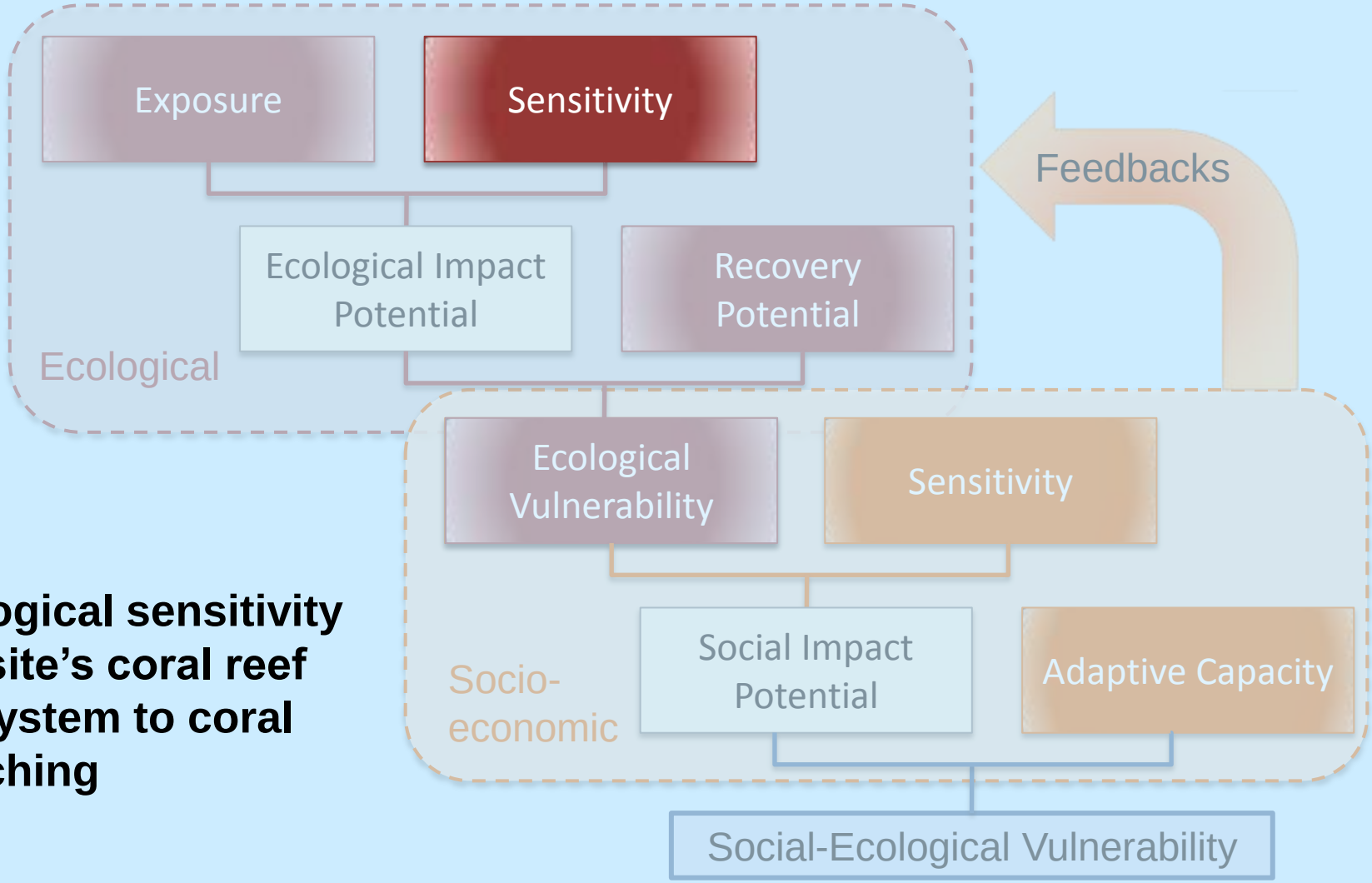
In situ **coral bleaching data** for 216 sites collected between 1998 and 2005

Site-specific index of bleaching stress



(Maina et al. 2008 Ecological Modeling)

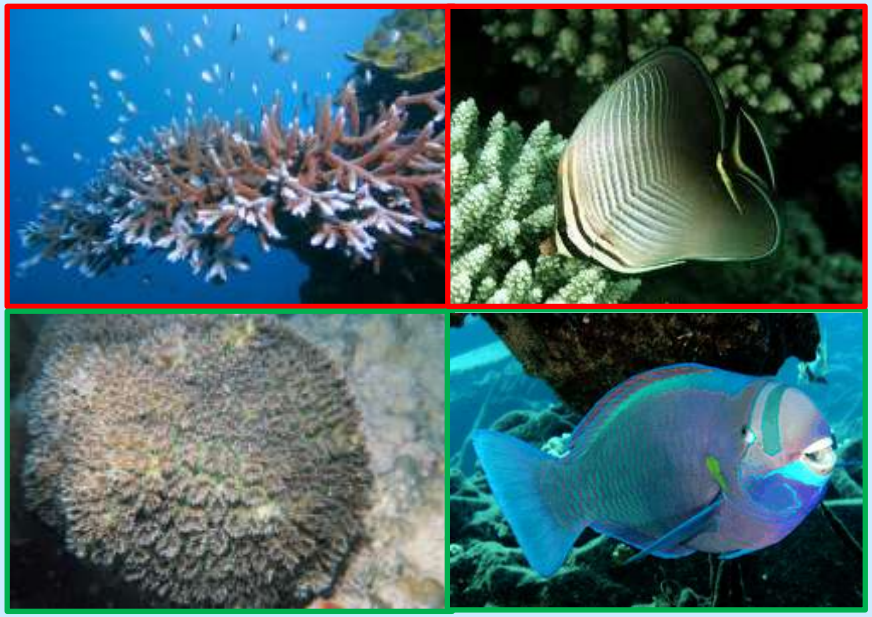
Ecological Sensitivity



Ecological sensitivity of a site's coral reef ecosystem to coral bleaching

Ecological Sensitivity

Used underwater ecological surveys to examine coral and fish community structure



2 indicators for each sites:

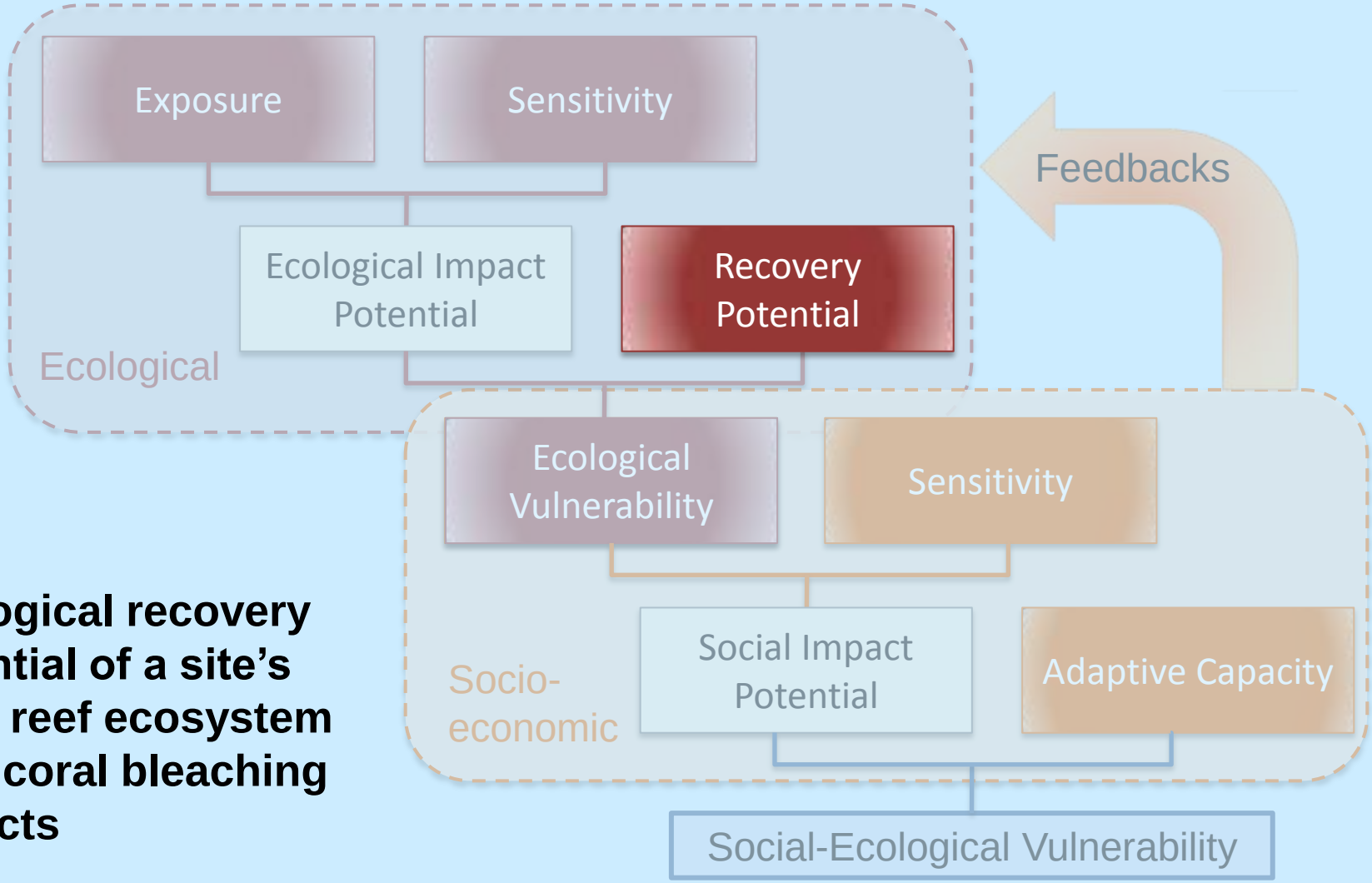
Susceptibility of coral community to bleaching

→ Using genus-specific bleaching sensitivity (*McClanahan et al. 2007 MEPS)*

Susceptibility of fish community to population declines associated with coral habitat loss from bleaching

→ Using species-specific climate vulnerability index *(Graham et al. 2011 Ecology Letters)*

Ecological Recovery potential



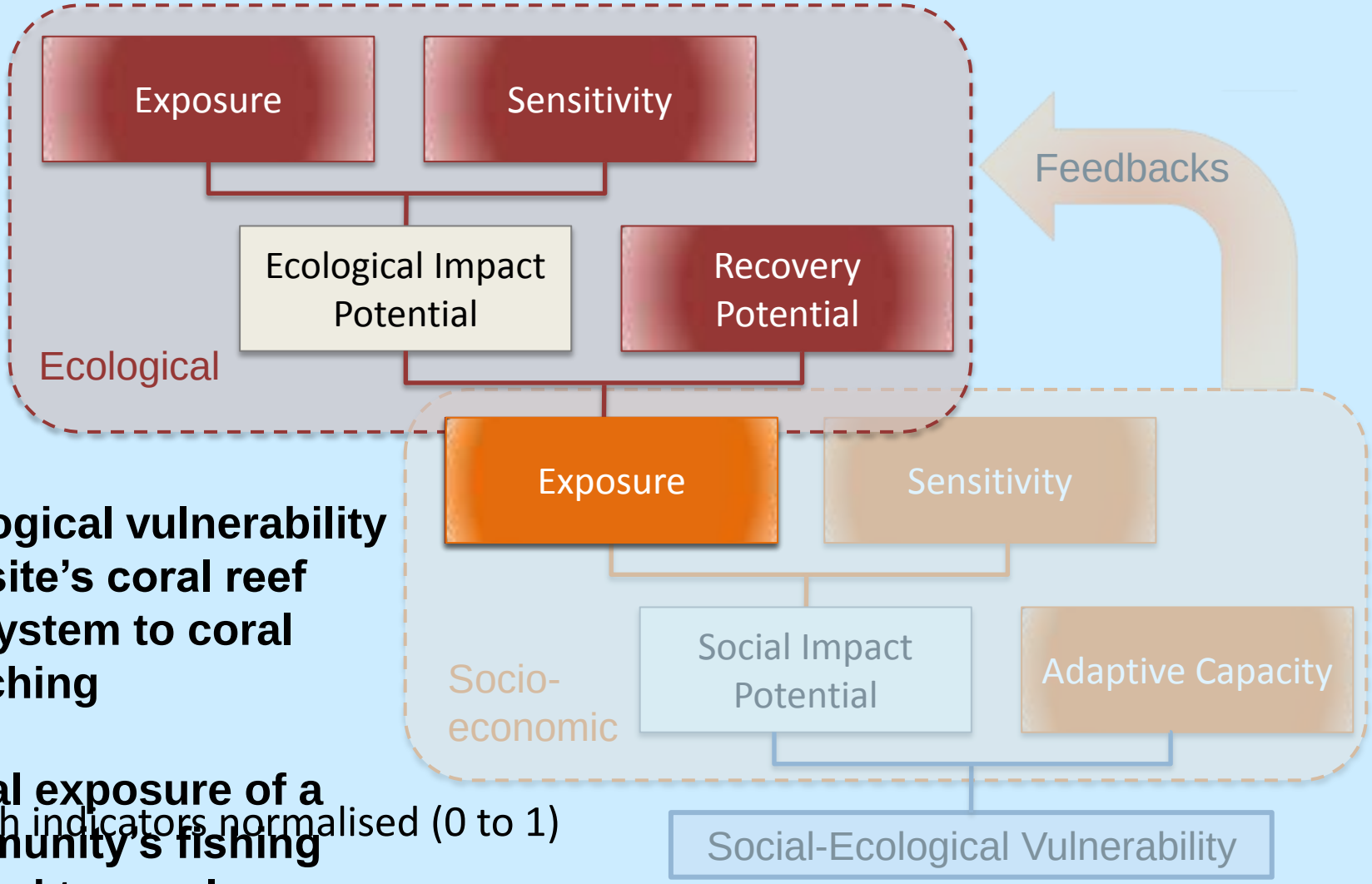
Ecological recovery potential of a site's coral reef ecosystem from coral bleaching impacts

Ecological Recovery potential

Recovery potential indicators	Weight of scientific evidence (-5 to 5)
Autotrophs/Corals	
Coral cover	2.27
Coral to macroalgae cover	3.37
Calcifying to non-calcifying cover	1
Coral size distribution	2.5
Coral richness	2.5
Heterotroph/Fish	
Fish biomass	4.5
Herbivore grazing rate relative to algal production	3.32
Fish species richness	3.5
Substrate complexity (rugosity)	1.52
Fish size distribution	4
Herbivore functional diversity	2.46

(Adapted from McClanahan et al. 2012 PLoS One)

Ecological Vulnerability



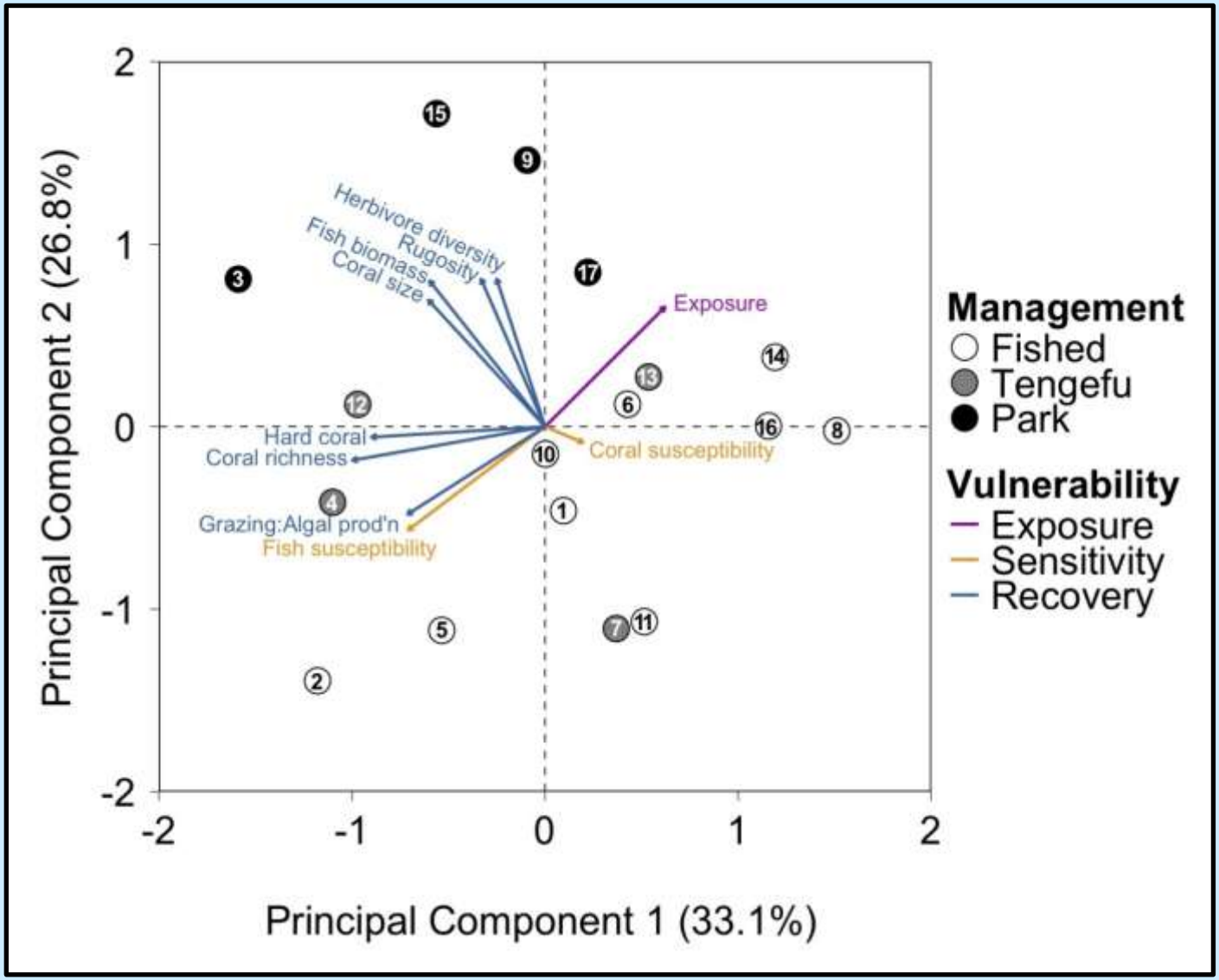
Ecological vulnerability of a site's coral reef ecosystem to coral bleaching

=

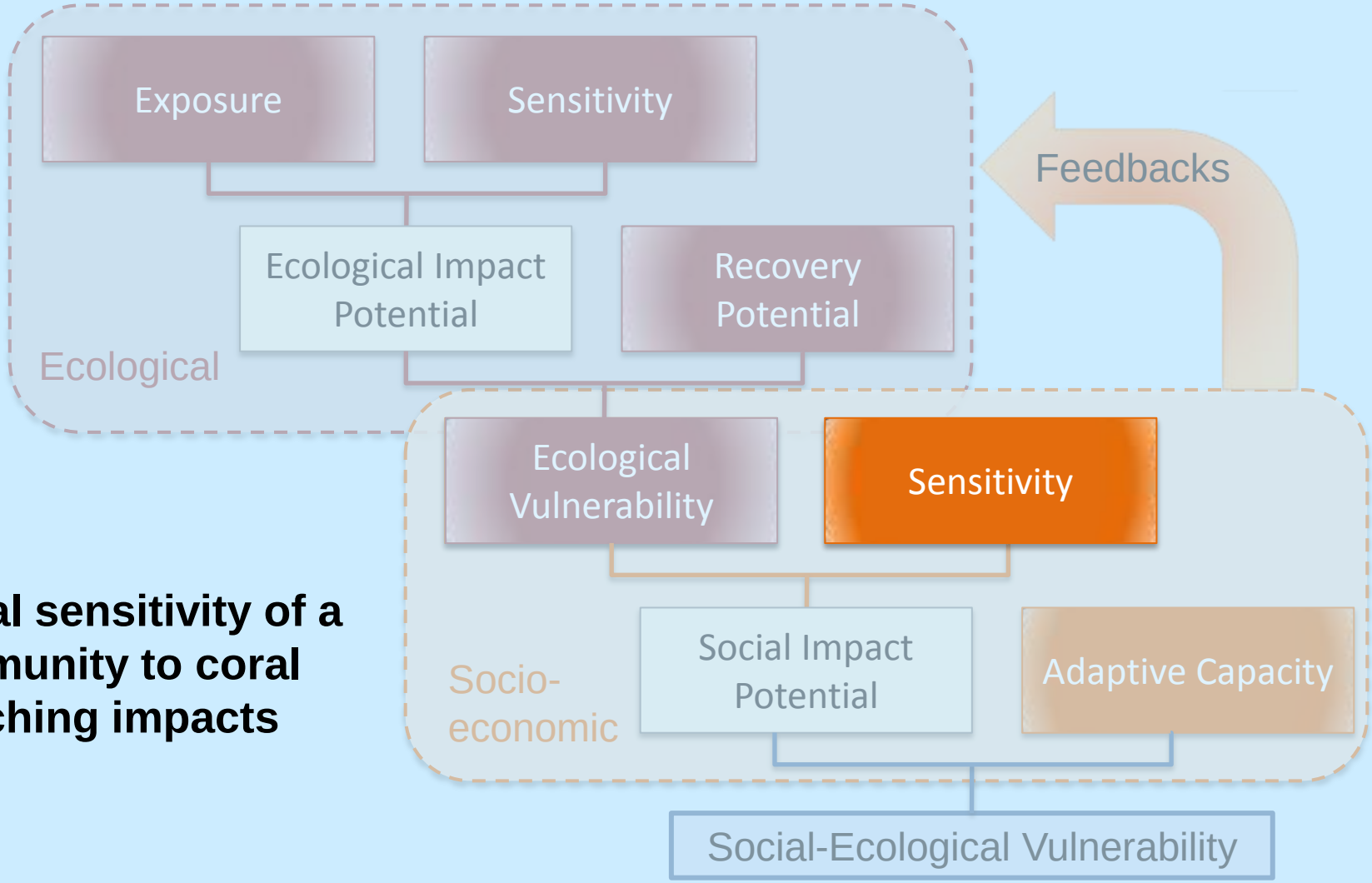
Social exposure of a community's fishing ground to coral bleaching impacts

- Each indicators normalised (0 to 1)
- Composite variables of ecological sensitivity and recover potential = weighted average (weight of scientific evidence based on expert opinion (-5 to 5))

Ecological Vulnerability



Social Sensitivity



Social sensitivity of a community to coral bleaching impacts

Social Sensitivity

Sensitivity = state of susceptibility to harm resulting from exposure to stresses

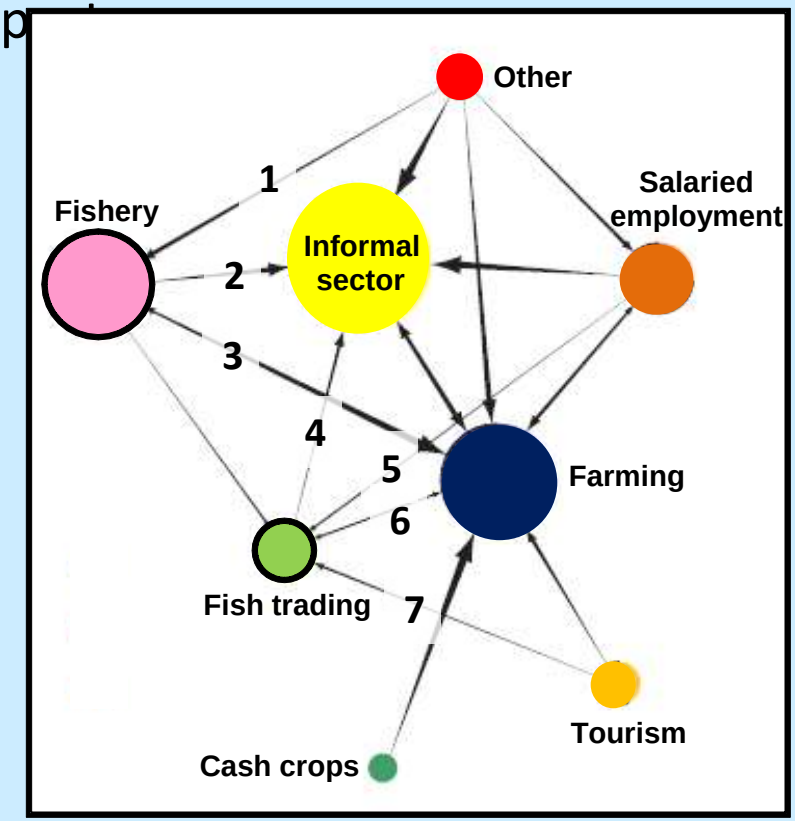
2 indicators:

1) **Livelihood sensitivity**: the level of dependence on marine resources
2) **Gear sensitivity**: data on how susceptible the catch composition of different gears are to coral bleaching imp

Livelihoods landscape

Network-based approach that incorporates:

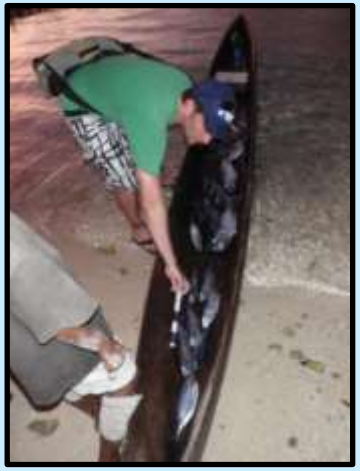
- ✓ **Proportion** of households engaged in a secor *(size of bubble)*
- ✓ **Linkages** between sectors = whether these households also engage in other occupations *(presence and thickness of arrows)*
- ✓ **Directionality** of these linkages = based on ranking of occupations by households *(direction of arrows)*

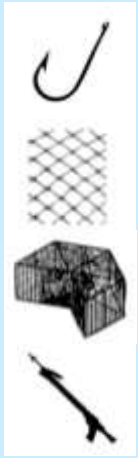


(Cinner & Bodin 2010 PLoS ONE)

Social Sensitivity

2) Gear sensitivity: Data on how susceptible the catch composition of different gears are to coral bleaching impacts





Catch abundance data and gear used
(McClanahan & Hicks 2011 Fish Managt & Ecol)

positive

neutral

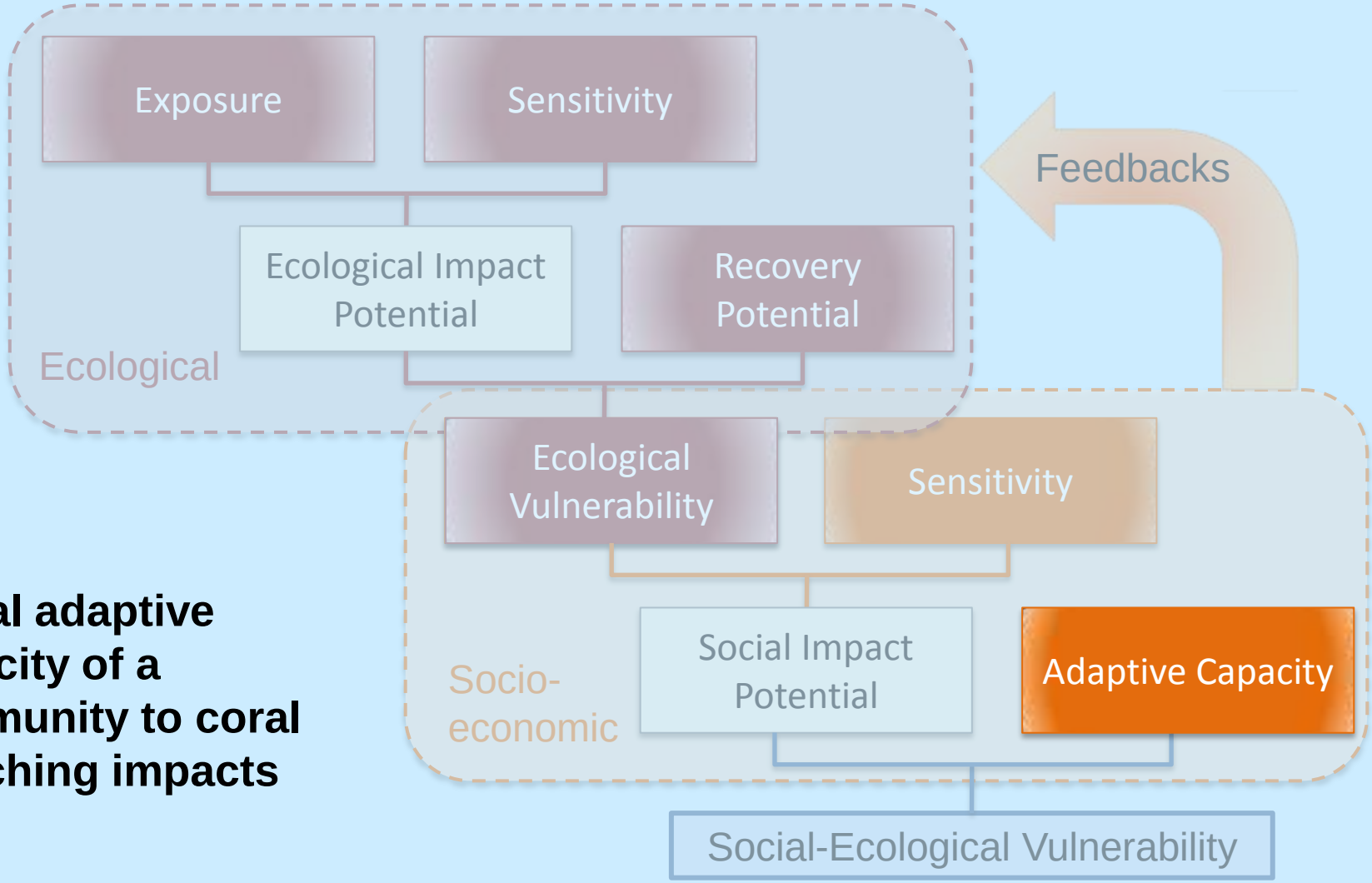
negative

Global database of species-specific responses of fishes to coral bleaching
(Pratchett et al. 2011 Diversity)

Gear average response to coral decline

Beach seine	-0.29 (±0.08)
Line	0.60 (±0.09)
Net	0.27 (±0.10)
Spear	0.17 (±0.09)
Trap	-0.08 (±0.06)

Social Adaptive Capacity



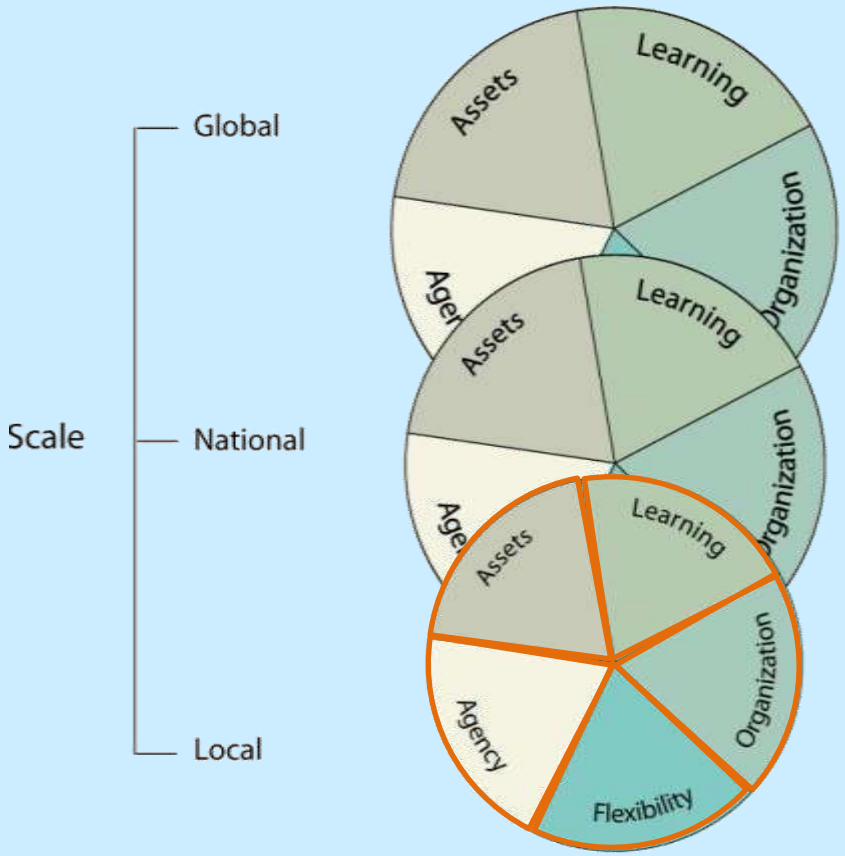
Social adaptive capacity of a community to coral bleaching impacts

Social Adaptive Capacity

Preconditions that enable adaptation to change

Adaptive Capacity =
the ability of households to anticipate and respond to changes in coral reef ecosystems and fisheries, and to minimize, cope with, and recover from the consequences

Social Adaptive Capacity



1. the **assets** that can be drawn upon in times of need
2. **learning** to recognize change, attribute this change to their causal factors, and assess potential response strategies
3. a society's ability to **organize** and act collectively
4. the **flexibility** to change strategies
5. the **agency** to determine whether to change or not

(Cinner et al. 2012 GEC)

Social Adaptive Capacity

Assets
- Infrastructure
- Material assets
- Access to credit
- Technology

Learning
- Capacity to anticipate change and to develop strategies to respond
- Recognition of causal agents impacting marine resources

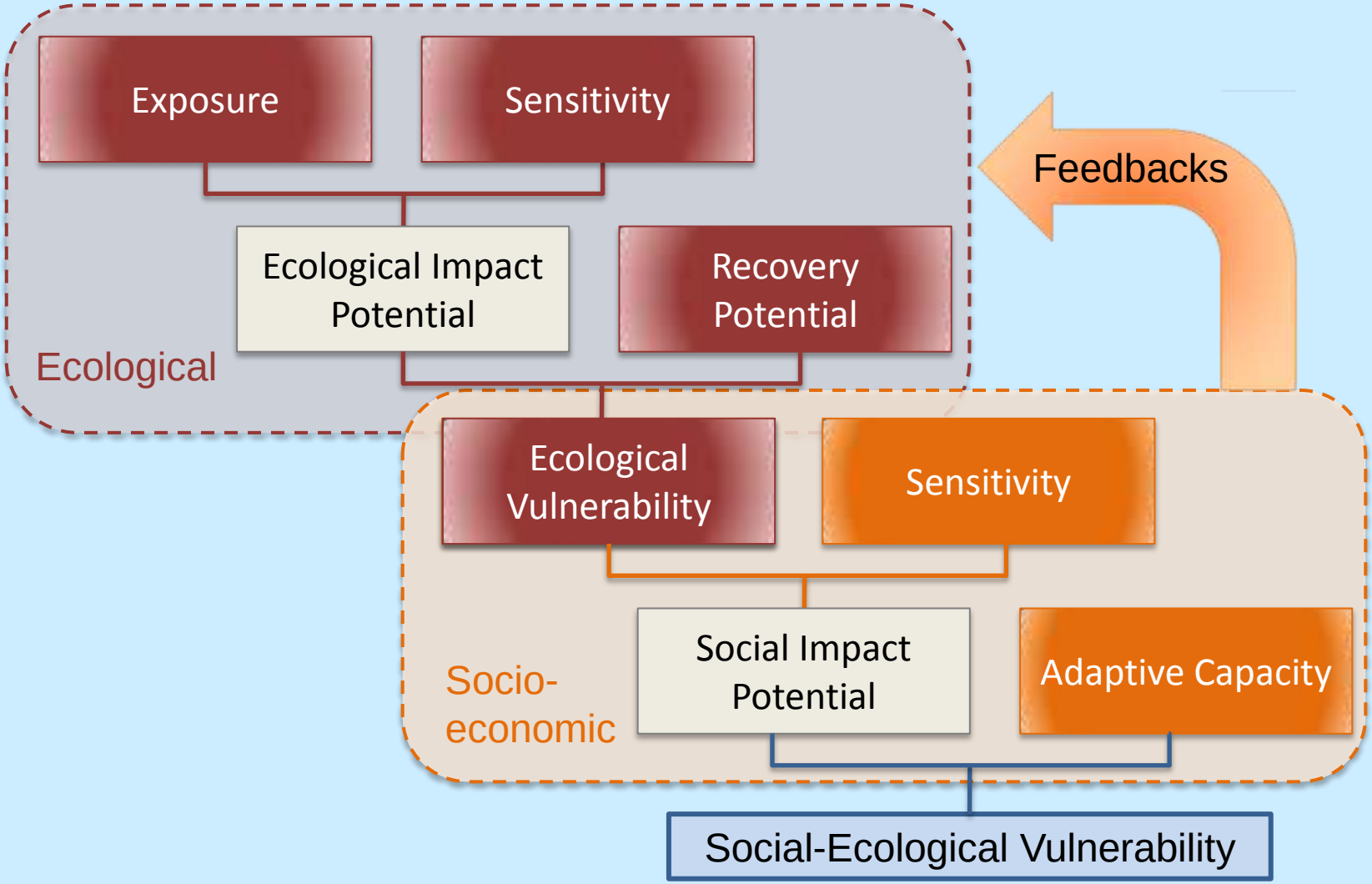
Organization
- Social capital
- Trust of community members, local leaders, police

Flexibility
- Occupational mobility
- Occupational multiplicity

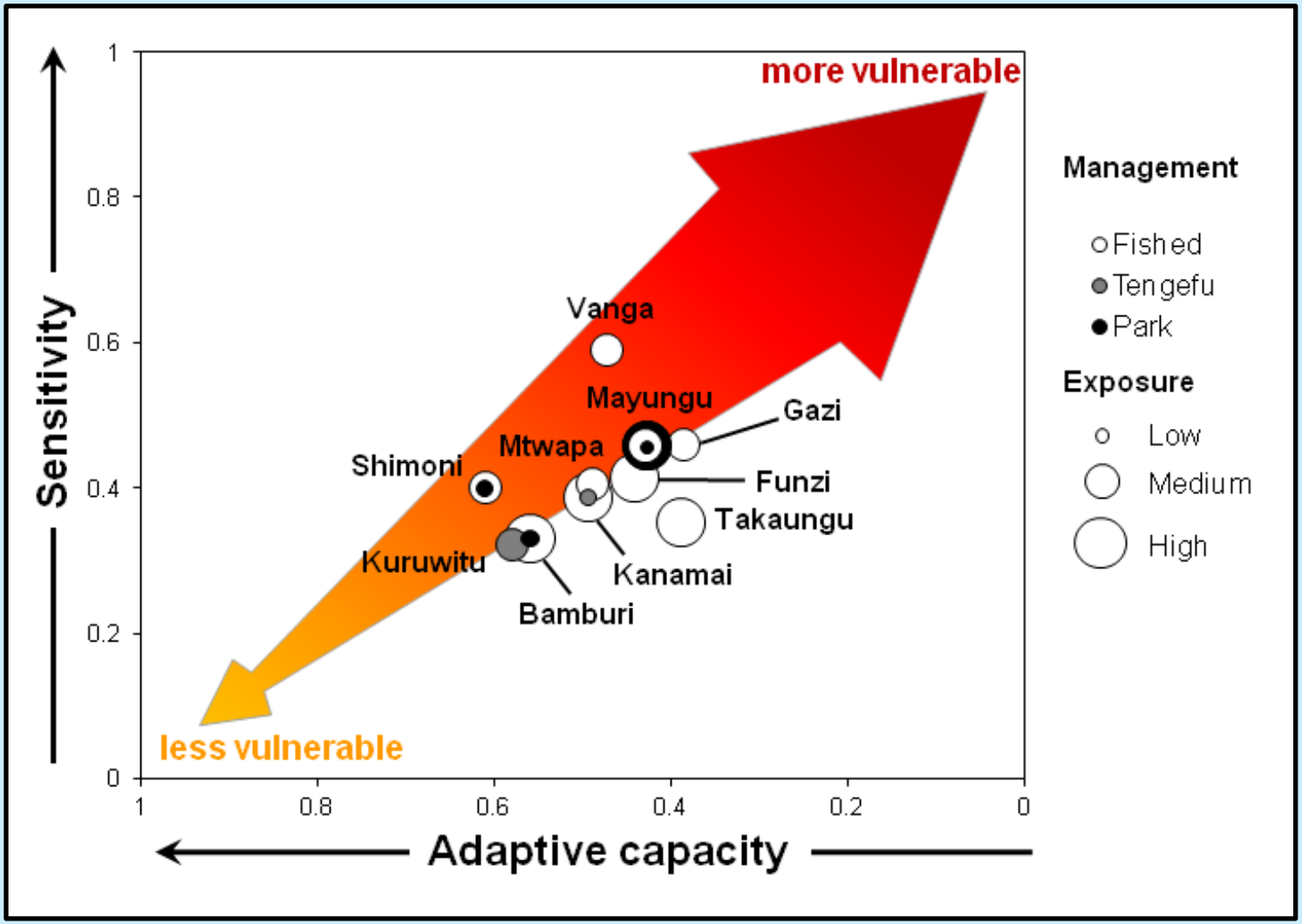
Agency *(Béné et al. 2011 GEC)*

(Cinner et al. in review PLoS ONE)

Social-Ecological Vulnerability



Social-Ecological Vulnerability



Policy implications

Reducing sensitivity

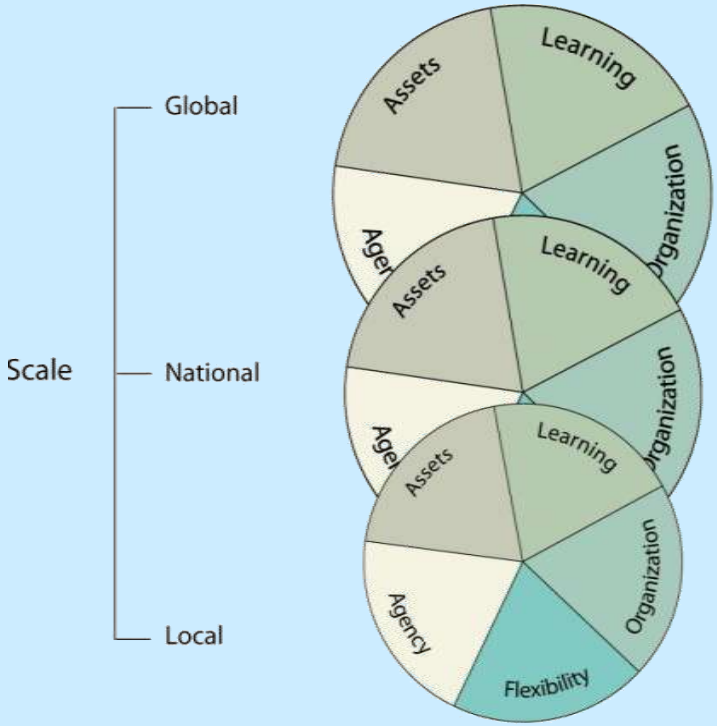
Examples of key policy actions to reduce aspects of vulnerability at different spatial and temporal scales.

Spatial scale	Short-term	Medium-term	Long-term
International			
National	**Flexible regulations that allow for rapid transitions during extreme events** (S, AC)	**Management measures to make reef ecosystems more resilient**	**Developing new industries**
Local	**Diversification within the fishery**	**Supplemental livelihood activities (increase linkages to other economic sectors)**	**Alternative livelihoods (transition out of fishing)**

Temporal scale

Policy implications

Building adaptive capacity



At the local scale, building adaptive capacity often overlaps with key components of sustainable development:

- poverty reduction,
- improving literacy,
- adding value to products,
- good governance

No blueprints: Not every community will need the same aspects of adaptive capacity enhanced

- May already have diverse livelihood portfolios or effective governance

- Attempts to diversify or strengthen governance, may have low marginal returns, be futile, or undermine existing sources of resilience

Policy implications and limitations

Wider applications:

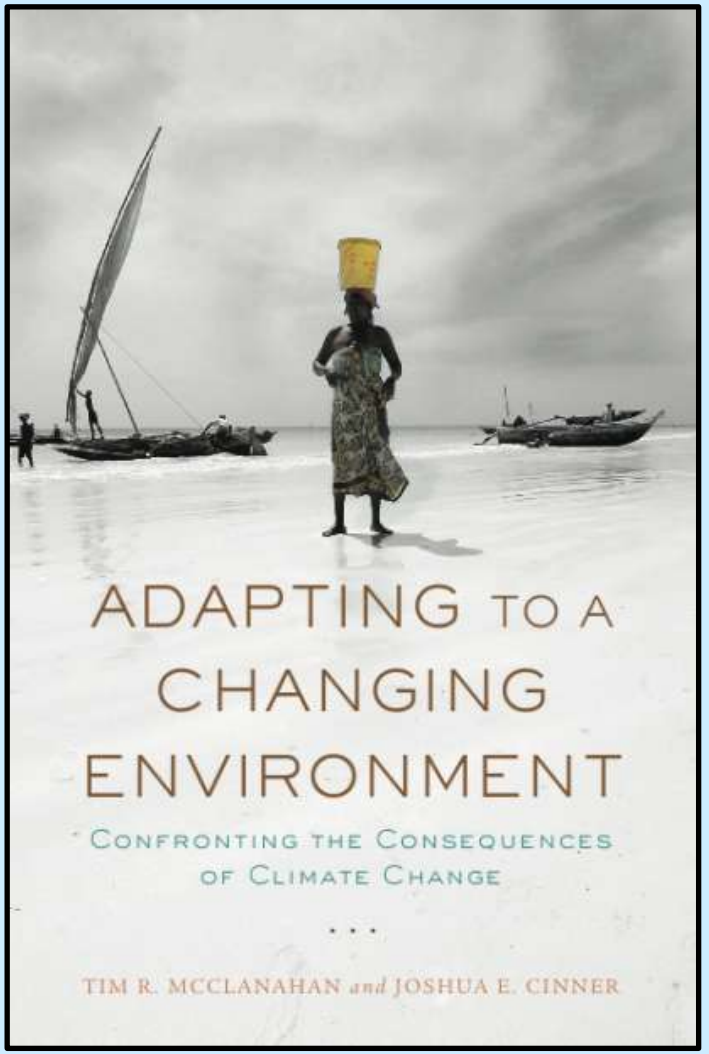
- **adapted/expanded** to other areas and other climate change impacts
  → development of new indicators

- consideration of **positive impacts** such as novel possibilities for exploitation

Limitations:

- the use of **current** conditions to predict **future** sensitivity and adaptive capacity

- **uncertainties** around all indicators/components



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Social Sensitivity - equation

$$S = \frac{\left(\frac{F}{(F+NF)} \times \frac{N}{(F+NF)} \times \frac{(\frac{r_{fn}}{2}+1)}{(r_{fn}+r_{nf}+1)} \right) + \sum_{i=1}^{n} G_i}{2}$$

S = sensitivity

F = number of households relying on fishery-related occupations

NF = number of households relying on non-fishery-related occupation

N = Number of households

r_{fn} =The number of times fisheries related occupations were ranked higher than non-fishing occupations (normalized by the number of households)

r_{nf} = The number of times non-fisheries related occupations were ranked higher than fishery occupations (normalized by the number of households).

G = sensitivity of each gear type

n = number of gears used

(Cinner et al. in review Global Env. Change)