OCEAN TIPPING POINTS

Embedding the science of tipping points into ocean management

Rebecca Martone

PICES Annual Meeting, Yeosu, Korea
10-21-2014

OUR PARTNERS

UCSB
NCEAS
NOAA
CENTER FOR OCEAN SOLUTIONS
EDF ENVIRONMENTAL DEFENSE FUND
GORDON AND BETTY MOORE FOUNDATION

Project Team

National Center for Ecological Analysis and Synthesis
Ben Halpern
Carrie Kappel
Kim Selkoe
Mary Hunsicker
Courtney Scarborough
Jackie Mandoske

EDF
Rod Fujita
Willow Battista
Kendra Karr
Nicole Sarto

Stockholm Resilience Centre
Albert Norström
Magnus Nyström
Jean Baptiste Jouffray

Center for Ocean Solutions
Meg Caldwell
Larry Crowder
Ashley Erickson
Melissa Foley (USGS)
Ryan Kelly (UW)
Megan Mach
Rebecca Martone
Lindley Mease
Lisa Wedding
Kristen Weiss

University of Hawai‘i
Alan Friedlander
Kirsten Oleson
Mary Donovan
Kim Falinski
Joey Lecky

NOAA
Phil Levin
Jameal Samhouri
Melissa Poe
Adrian Stier
Jamie Gove
Ivor Williams

Cal Poly SLO
Crow White

Univ of Saskatchewan
Phil Loring

Additional Collaborators
Mike Fox (Scripps)
Nick Graham (JCU)
Steven Gray (UMass Boston)
Jack Kittinger (CI)
Clara Rowe (Yale)
Cynthia Stiles (NRCS)
Gareth Williams (Scripps)

Advisory Group Members

Management

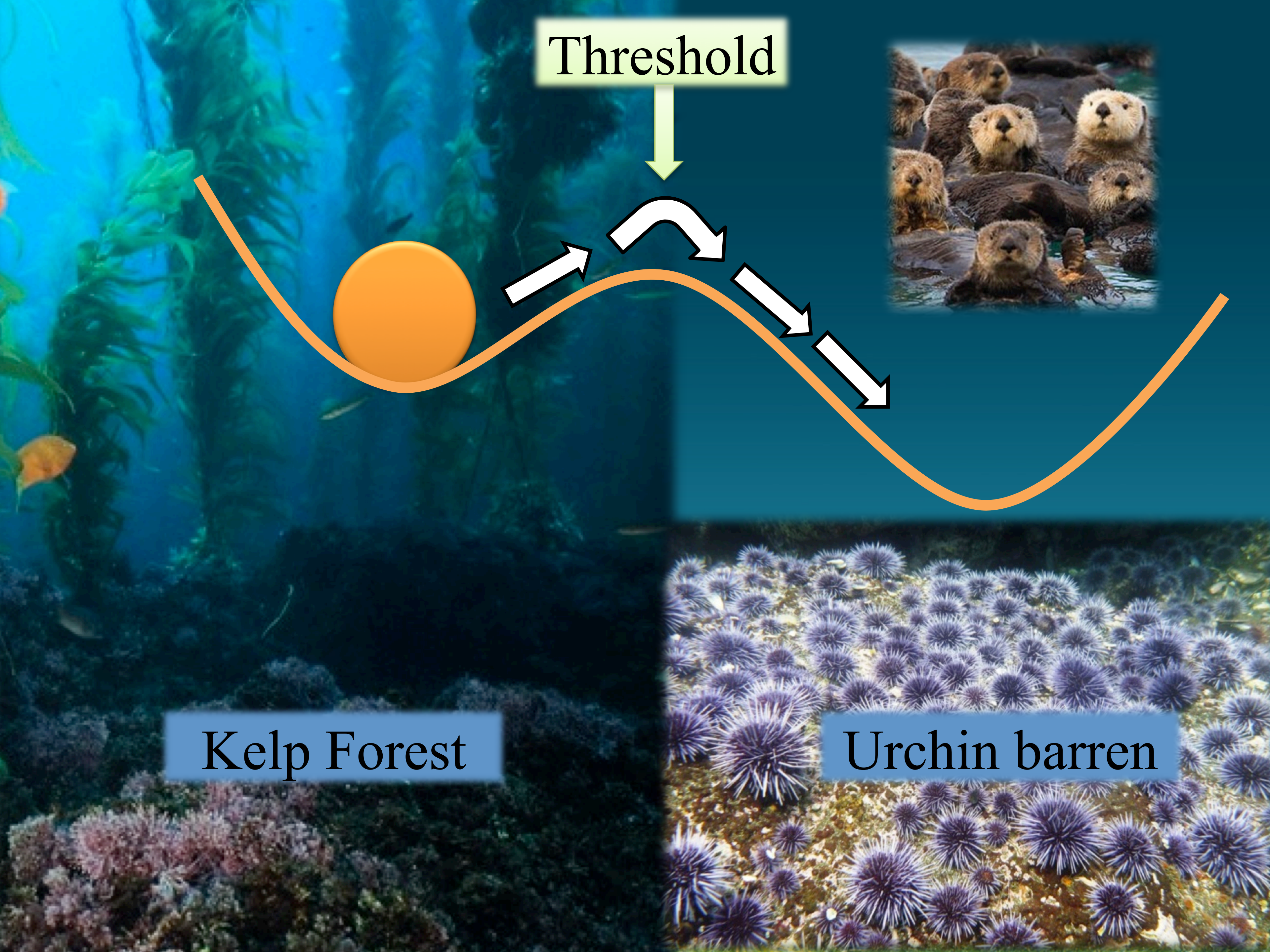
- **Cindy Boyko-** Archipelago Management Board, Gwaii Haanas
- **Malia Chow-** Superintendent, Hawaiian Islands Humpback Whale Sanctuary
- **William Douros-** West Coast Regional Director, NOAA Office of National Marine Sanctuaries
- **Ernie Gladstone-** Superintendent, Gwaii Haanas National Park Reserve and Haida Heritage Site
- **Elia Herman-** State Co-manager, Hawaiian Islands Humpback Whale Sanctuary
- **Martha Kongsgaard-** Chair, Puget Sound Partnership
- **Will Stelle-** Administrator, Northwest Region, National Marine Fisheries Service
- **John Weber-** Planning Director, Northeast Regional Ocean Council
- **Steve Weisberg-** Executive Director, Southern California Coastal Water Research Project
- **Frazer McGilvry-** Hawaii State Administrator for the Division of Aquatic Resources

Science

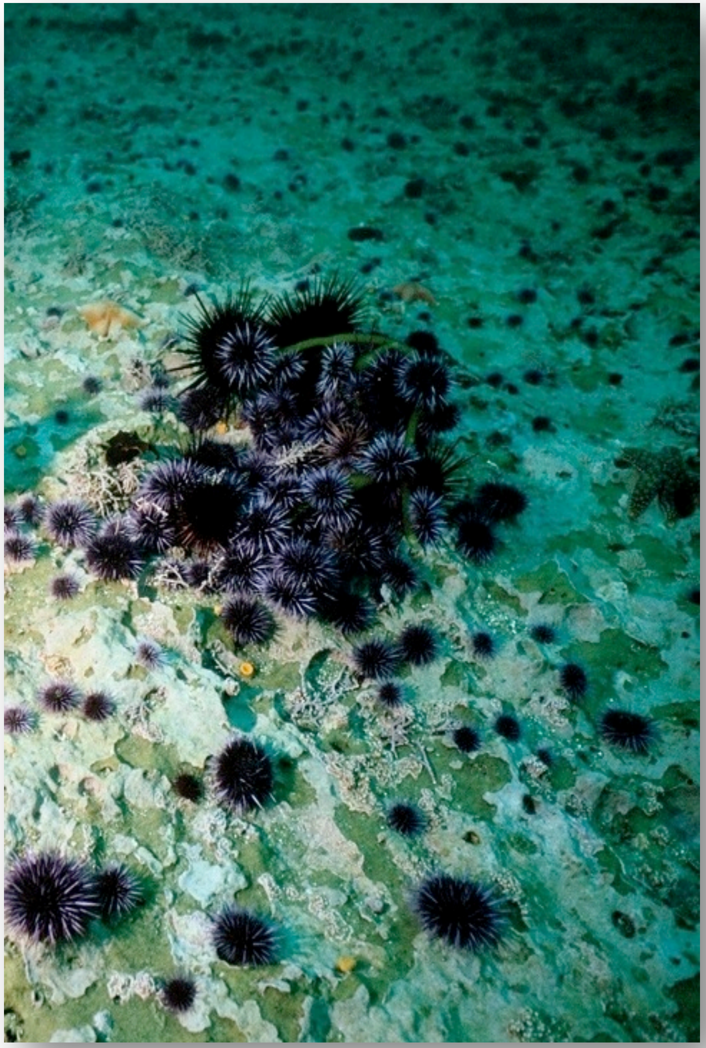
- **Tim Essington-** University of Washington
- **Jim Estes-** University of California, Santa Cruz
- **John Lynham-** University of Hawai‘I, Mānoa
- **Anne Salomon-** Simon Fraser University
- **Phil Williams-** Philip Williams and Associates, Ltd.
- **Joy Zedler-** University of Wisconsin-Madison
- **Nate Mantua-** NOAA Southwest Fisheries Science Center
- **Thorsten Blenckner-** Stockholm Resilience Centre

Ocean Tipping Points

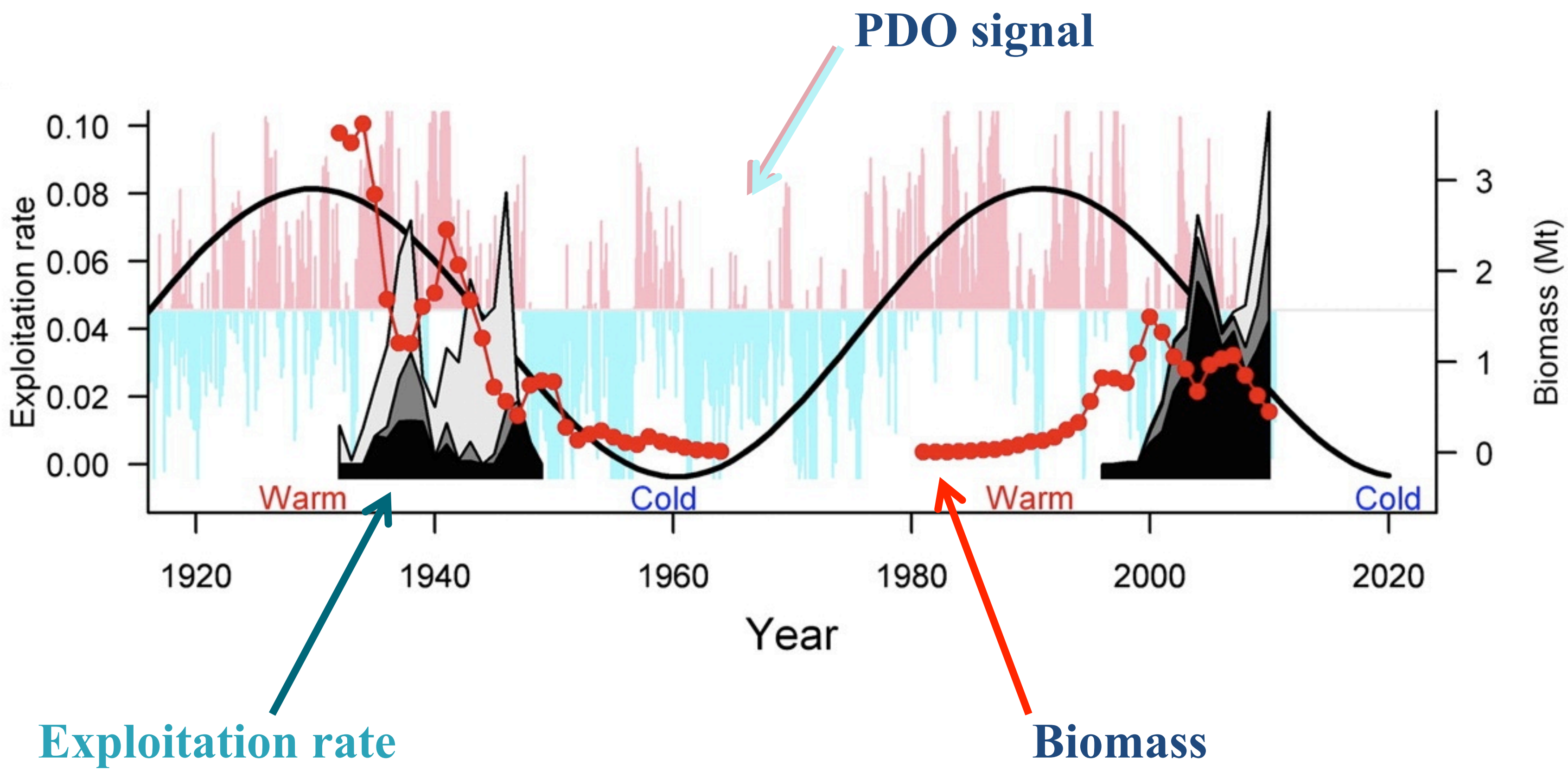
When incremental changes in human use or environmental conditions result in large, and sometimes abrupt, changes in ecosystem structure, function, and often, benefits to people


Threshold
Kelp Forest
Urchin barren

Tipping points change the rules



And alter benefits to people (e.g., West coast sardine fisheries)



Zwolinski & Demer 2012 PNAS

$7M loss in two years (>$93M today)

Women cannery workers on the line - 1949

Value of the fishery dropped from $12M to $5M in two years, displacing a whole industry.

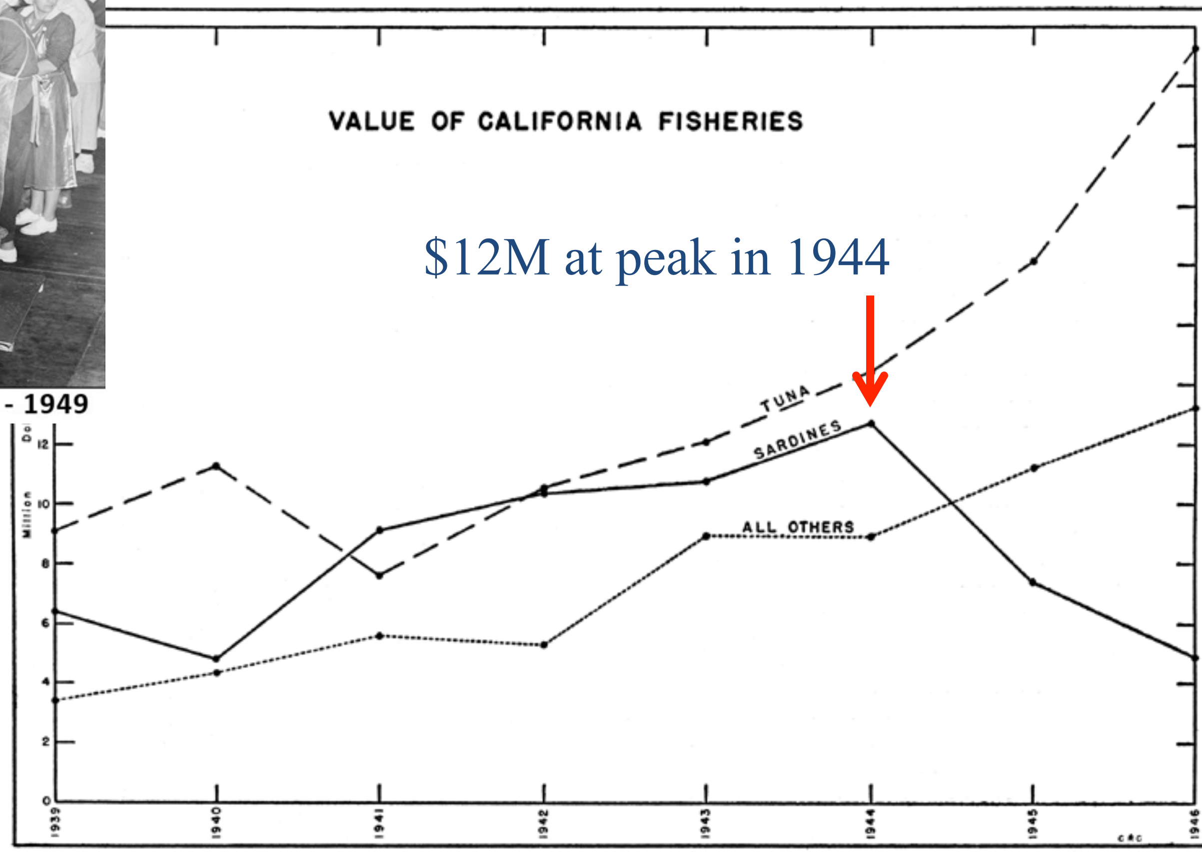
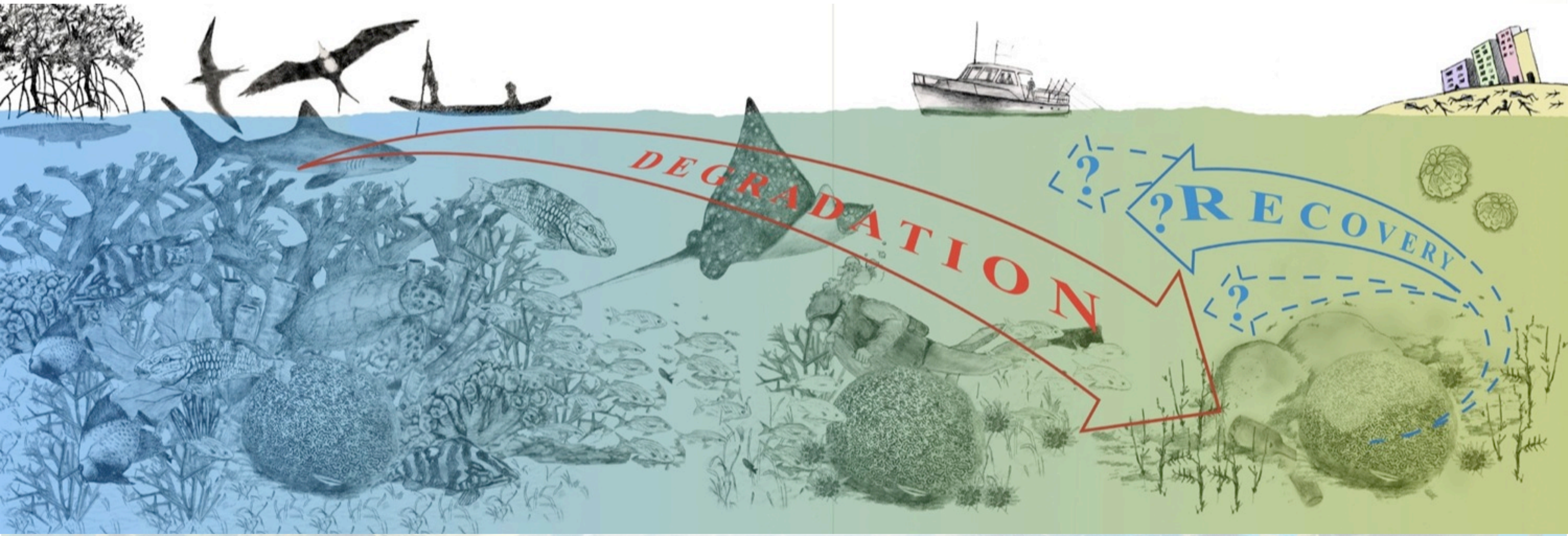


FIG. 6. Value of California fisheries to the fisherman, 1939 through 1946. The five species of tuna are grouped, albacore, bluefin, bonito, skipjack and yellowfin. "All others" includes shellfish, fresh market fish and cannery species other than sardines and tuna.

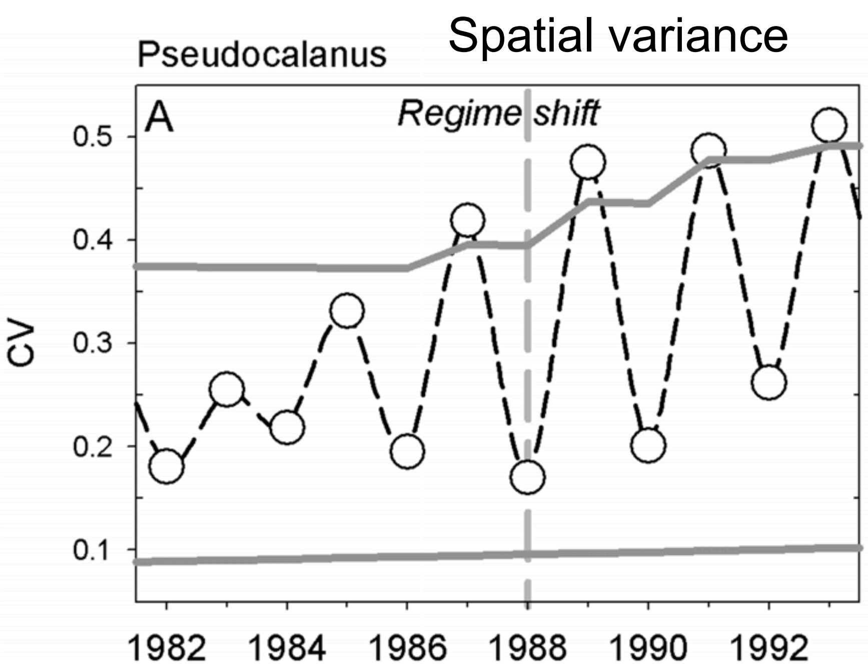
Recovery may be difficult and slow

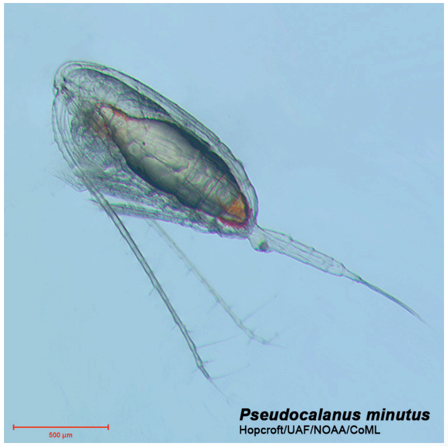


OCEAN TIPPING POINTS

Pandolfi et al. 2005 Science

Early warning indicators hold promise for anticipating tipping points





Lindegren et al 2012

Why we are engaged

- Ecosystem tipping points may be rapid, unexpected and difficult to reverse.
- Crossing tipping points can have negative consequences for people's livelihoods and well-being.
- The ability to predict and understand ocean tipping points can enhance ecosystem management.
- Despite a growing body of tipping point science, there is still a disconnect with management decisionmaking.

Project Goals

• Improve knowledge and understanding of ocean tipping points, their potential impacts, and their relevance to management.

• Co-develop and disseminate a toolbox of approaches for management of ecosystems prone to tipping points, which will allow managers to:

(1) Identify the “safe operating space” for decision-making
(2) Set targets, monitor using early warning indicators
(3) Evaluate and prioritize management strategies
(4) Identify regulatory and policy vehicles

How we are approaching this

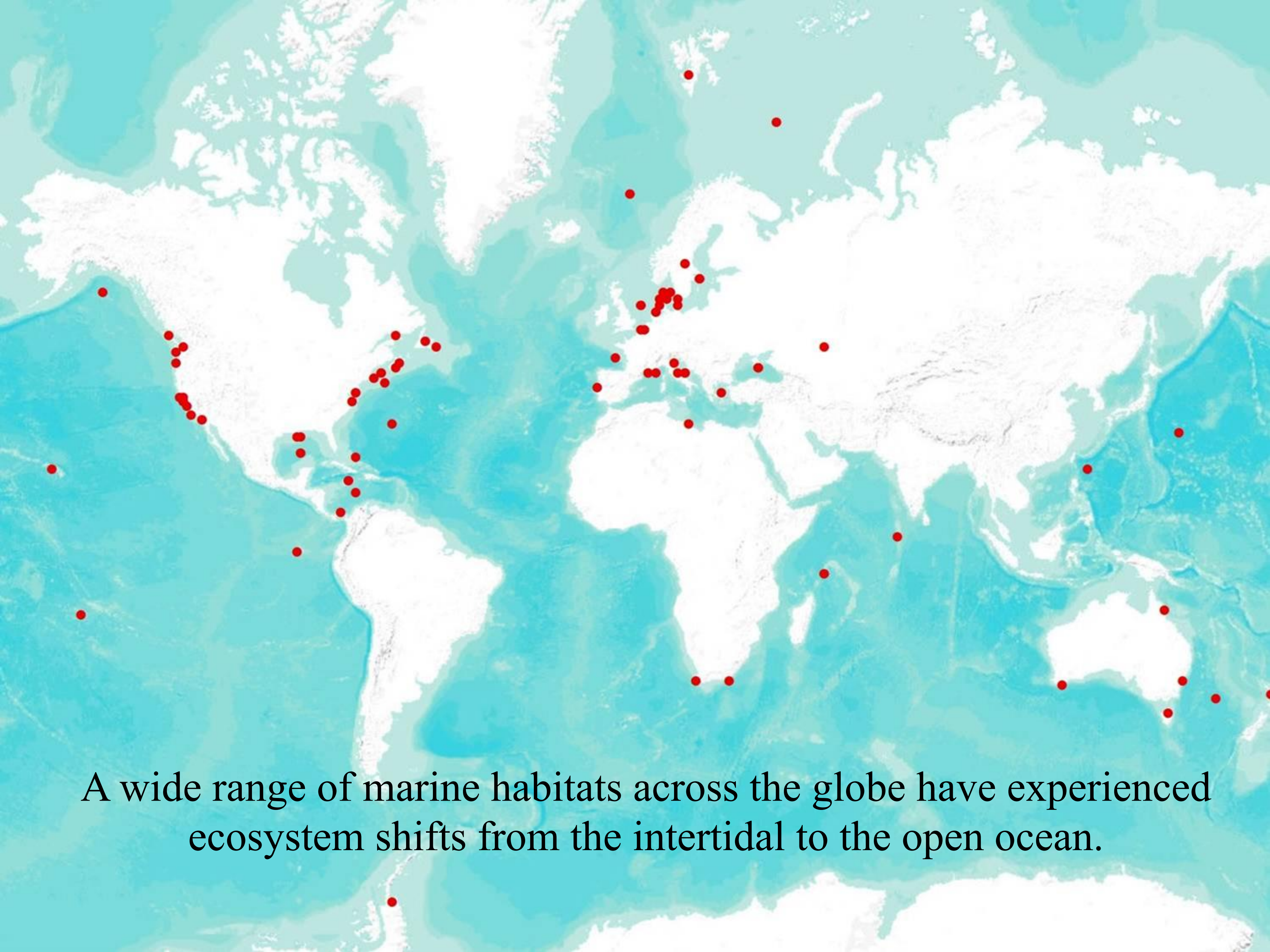
- RESEARCH: Synthesize and build upon our growing scientific understanding of ecological and socio-economic tipping points in marine ecosystems

- APPLICATION: Work with experts and practitioners to co-develop and test useful and usable approaches for integrating that information into ecosystem management

Global database of marine ecosystem shifts

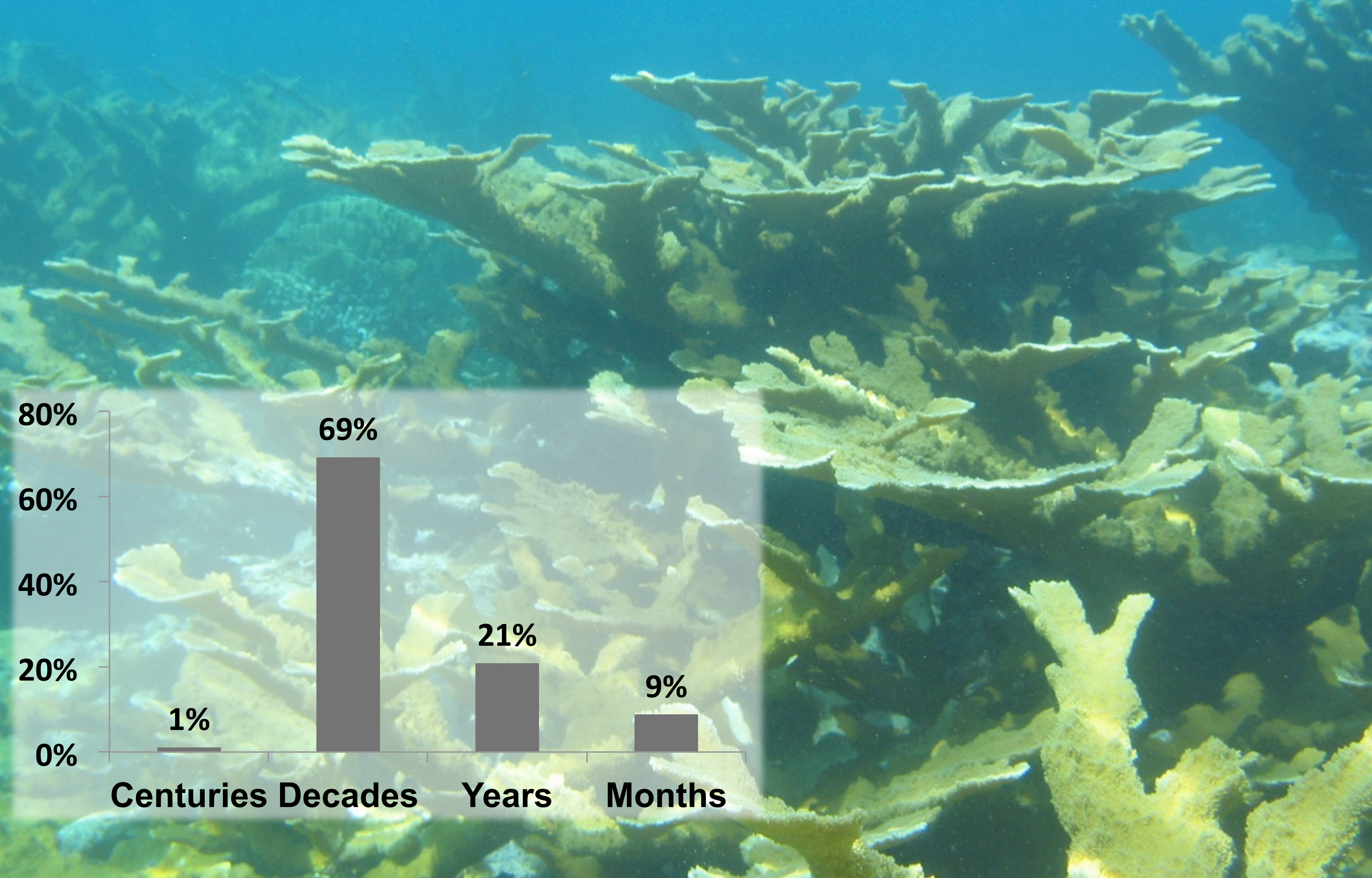
- Where and at what spatiotemporal scales have marine ecosystem shifts been observed, across habitat types, latitudes, and ocean basins?
- What drives shifts across systems and geography?
- Are there common mechanisms at play across shifts?
- Are these shifts typically reported to be reversible?


Kelp forests
Coral reefs
© UC Regents / LTER
© UC Regents / LTER
Oyster reefs
SCDNR
Sand dunes
Pelagic systems
Seagrass
© UC Regents / LTER
© Dave Ingram
© Orthia Marine
Mud flats
Saltmarshes
Rocky shores and reefs
Estuaries

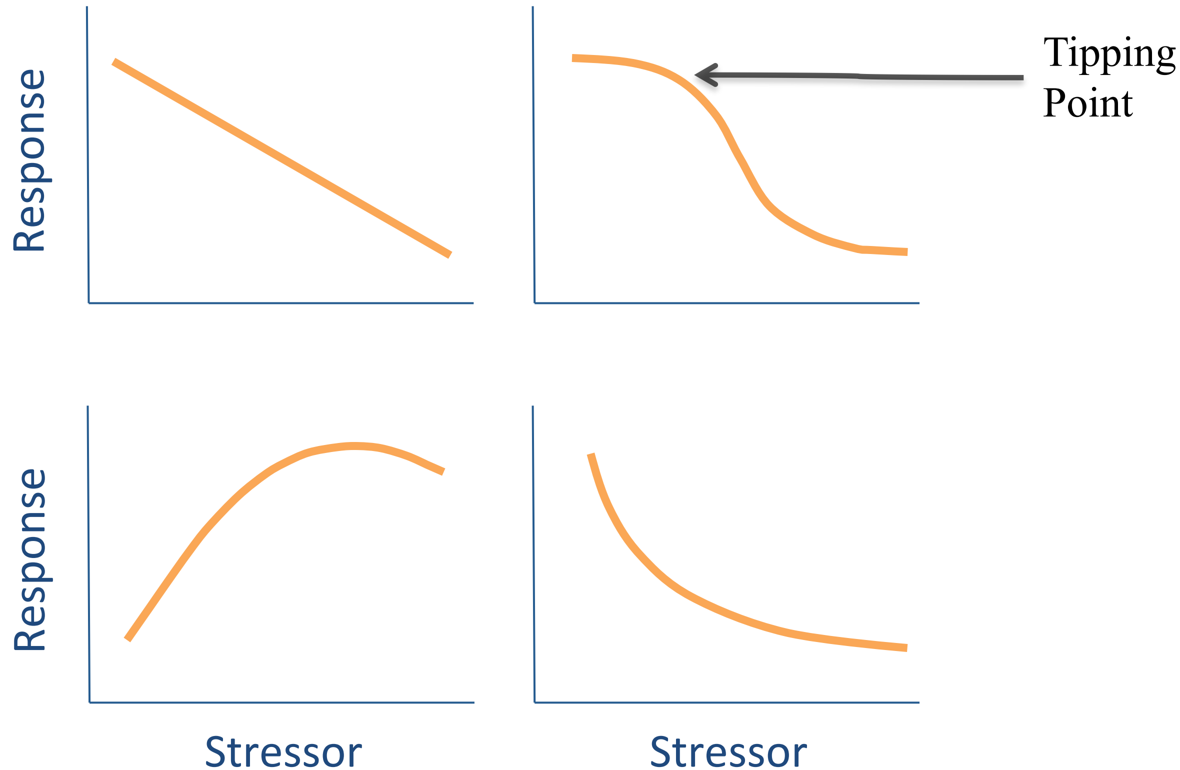

A wide range of marine habitats across the globe have experienced ecosystem shifts from the intertidal to the open ocean.

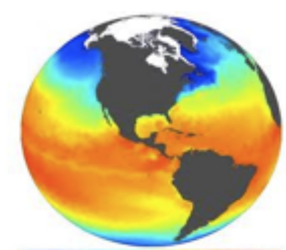
Over-harvest, eutrophication, and climate are the top drivers of ecosystem shifts and often act in concert

Although recovery may be possible, ecosystems that have crossed a threshold tend to remain in an altered condition for decades



Meta-analysis of functional responses to individual stressors





Approach

1) Literature search using Web of Knowledge

- Keywords (I): habitat type (marine ecosystem, pelagic, subtidal, continental shelf, demersal, benthopelagics, etc.) and regime shift, switchpoint, tipping point, nonlinear state change

✓ 1731 papers

- Keywords (II): habitat type (marine and pelagic) and stressor type (fishing, pollution, climate, temperature, predation, pressure)

✓ 3511 papers

Approach

1) Literature search

2) Selection criteria

- Field study in pelagic marine ecosystem
- Statistical analysis (regression, correlation) used to identify the relationship between stressor and response
- Sign. relationships identified by p-value and model selection
- Extract data from paper

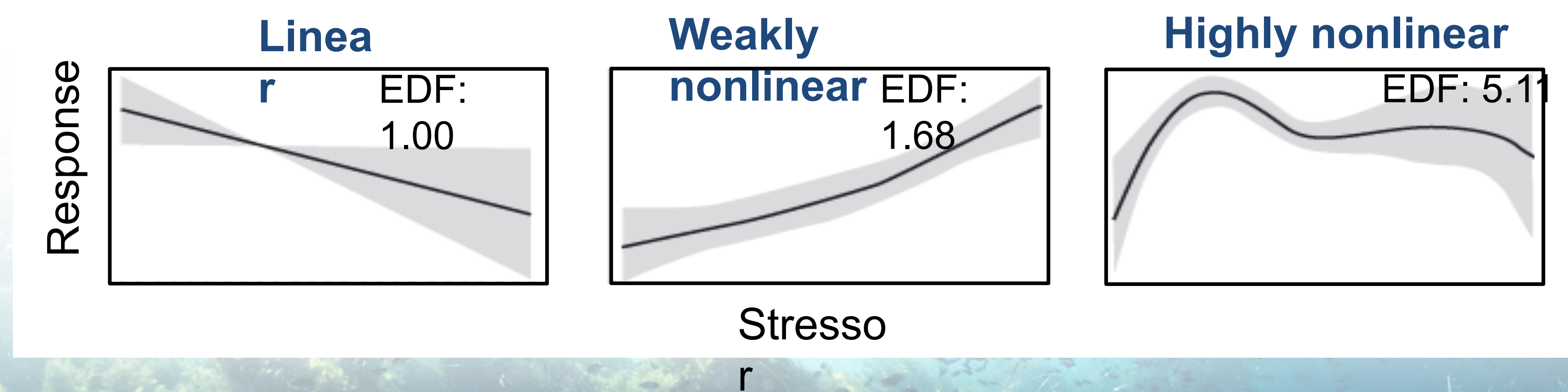
➢ 75 papers; 736 relationships

Approach

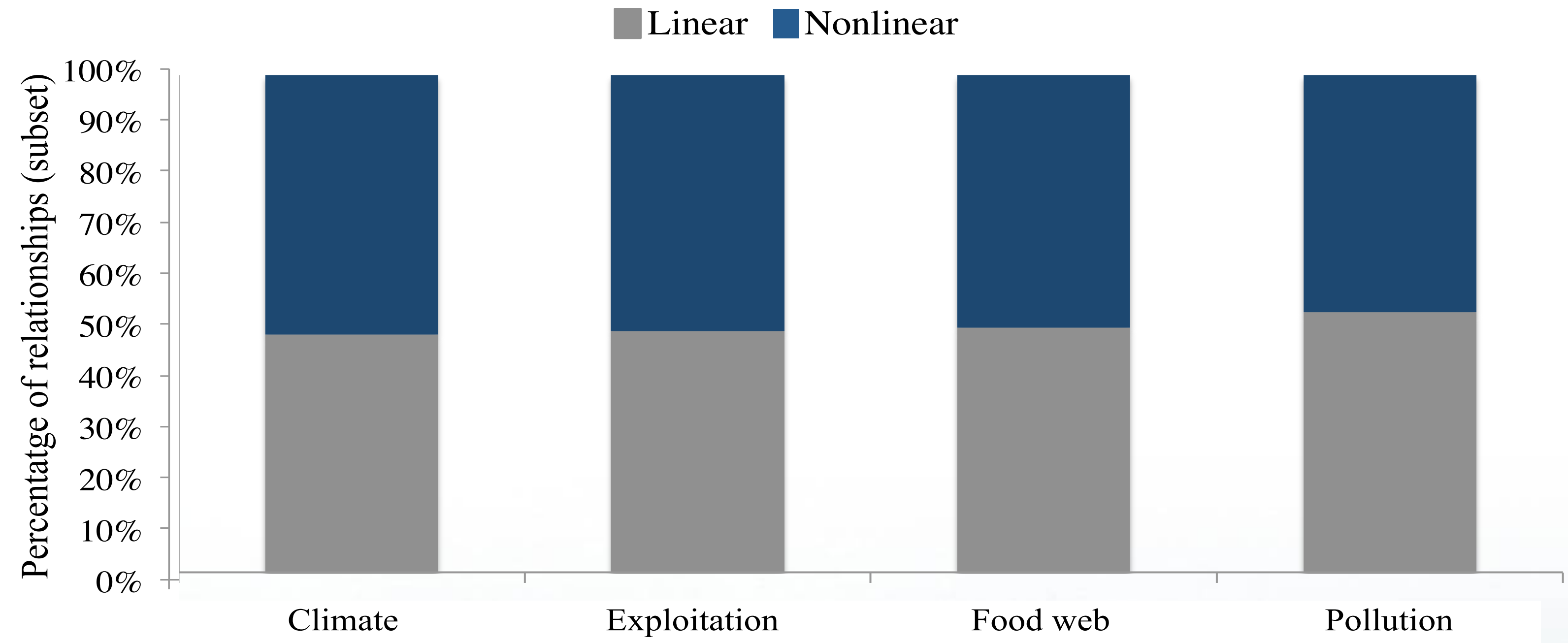
1) Literature search

2) Selection criteria

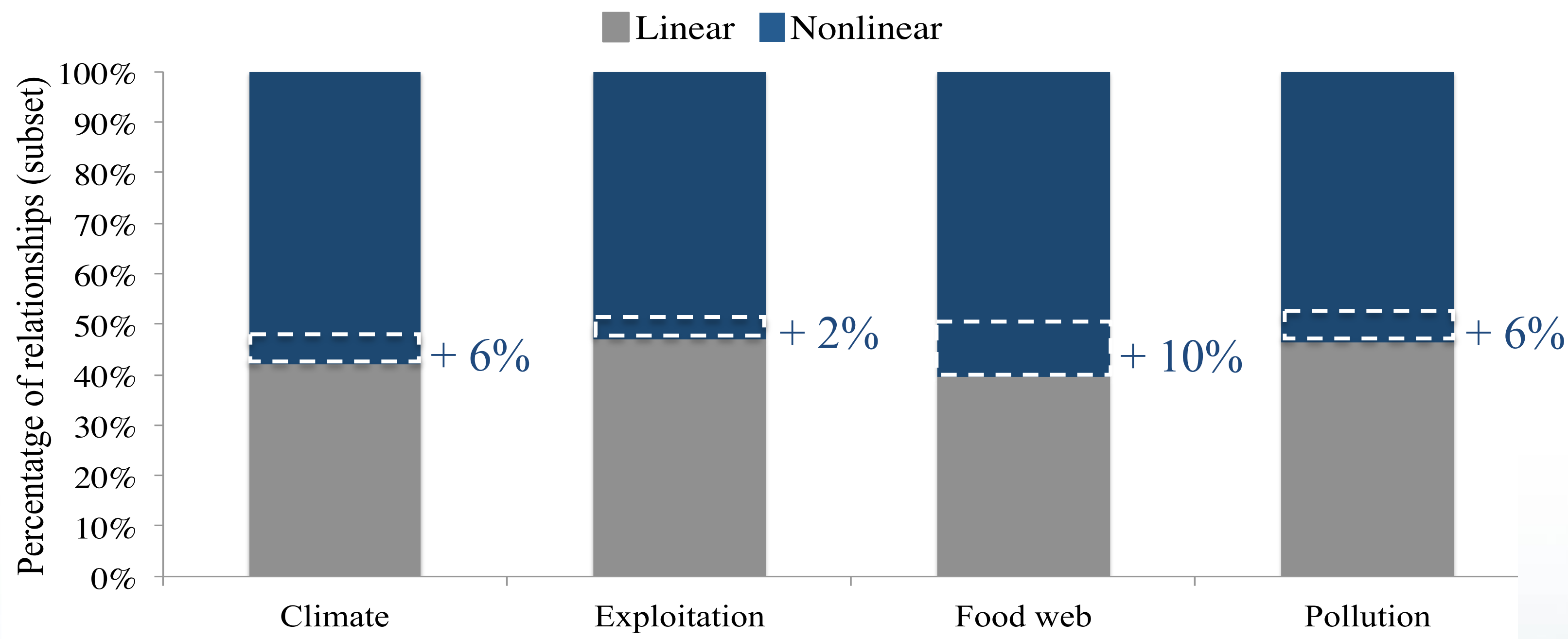
3) Published or derived effective degrees of freedom (EDF) from GAMs are a measure of degree of nonlinearity



Half of the studied relationships between drivers and ecosystem components in the open ocean are nonlinear

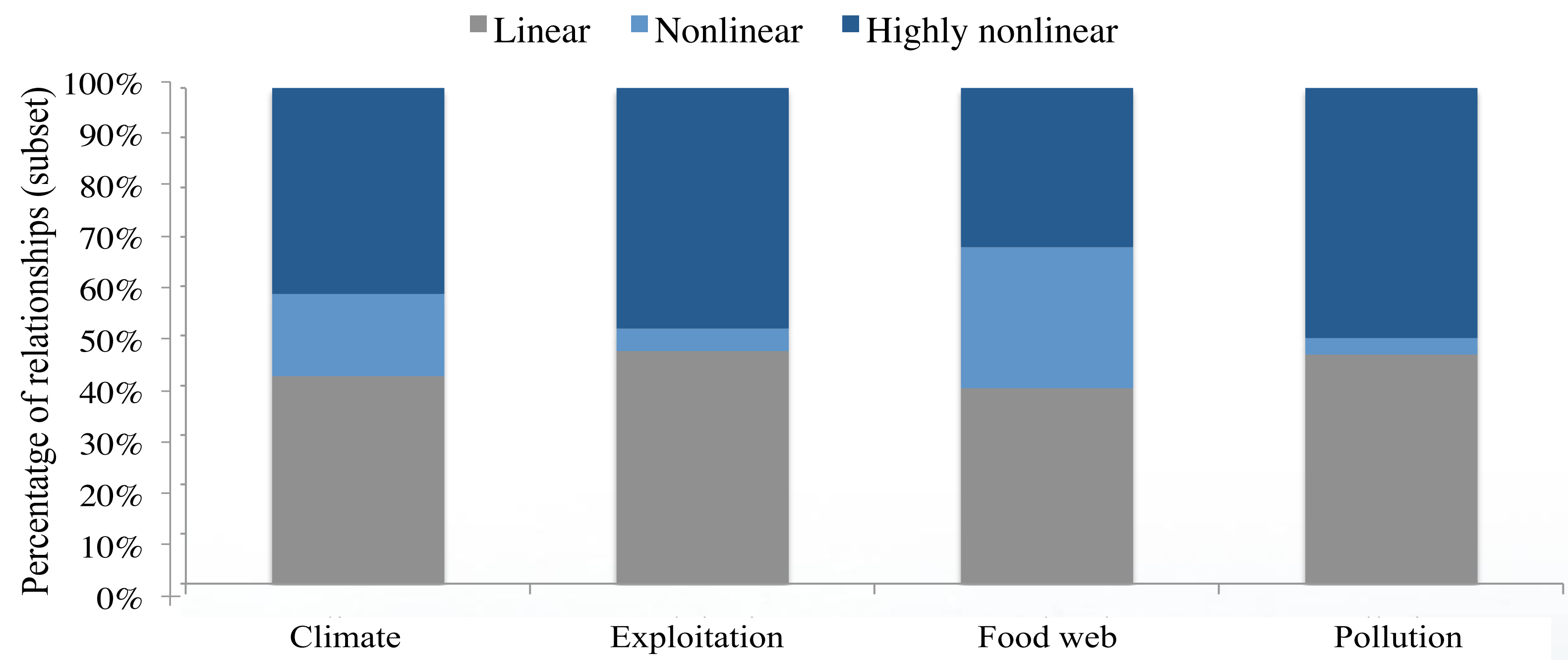


Half of the studied relationships between drivers and ecosystem components in the open ocean are nonlinear



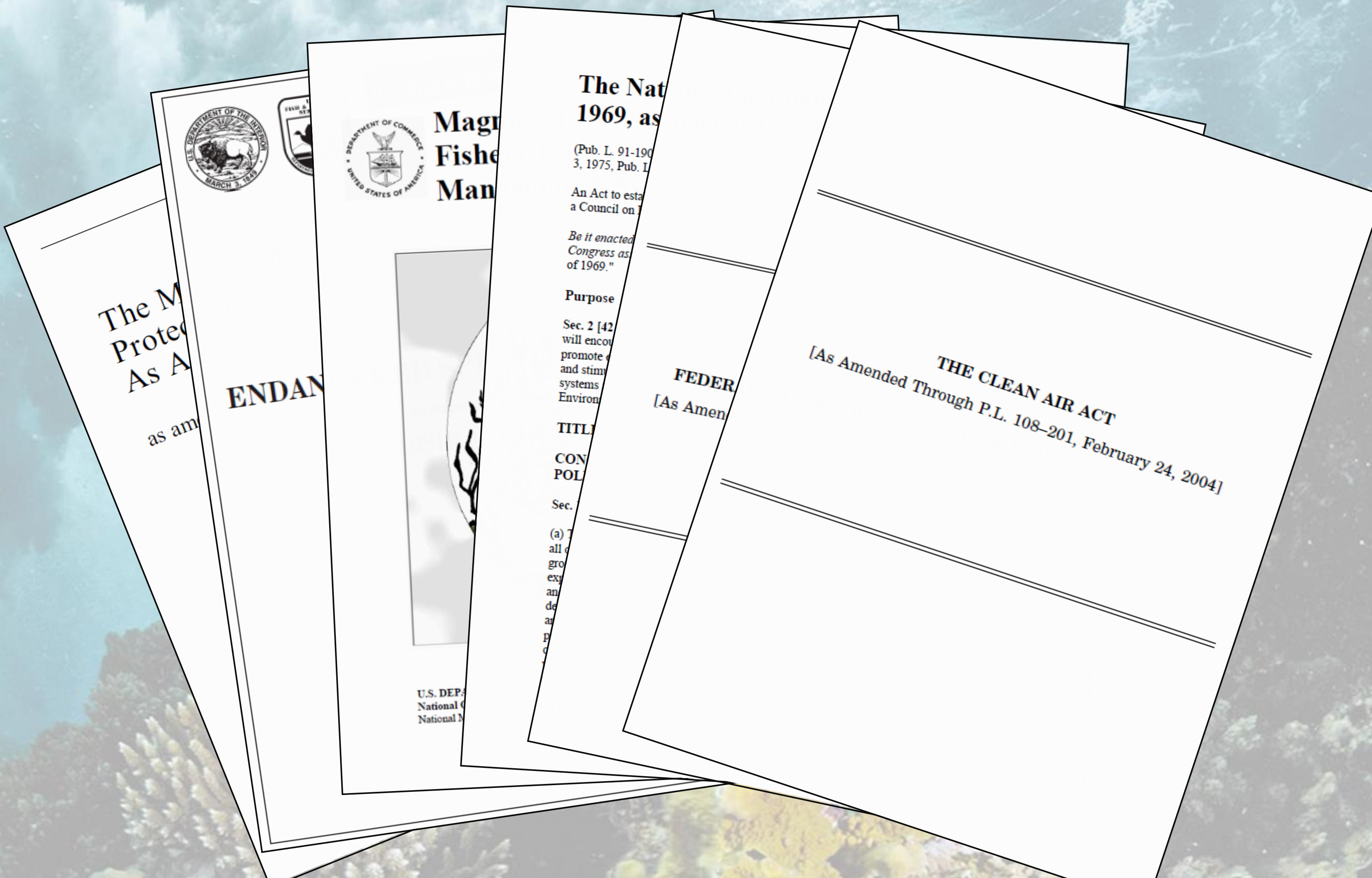
Non-linear relationships may also be under-reported in published literature

In the open ocean, highly nonlinear relationships are common



And thus may have detectable thresholds that could inform target-setting

A number of the most widely applicable federal and state environmental laws and regulations allow for threshold-based science decision making.



Law review found that…

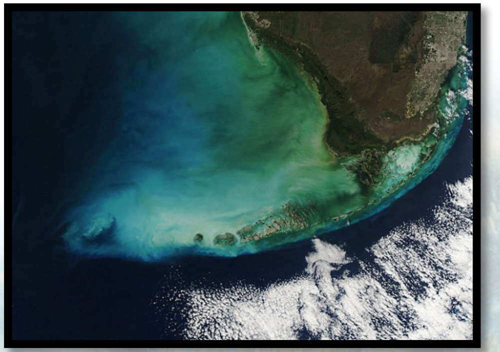
- Where thresholds exist, explicit regulatory targets on them yield better outcomes
- Cost benefit analysis may favor threshold based management
- This approach is likely to minimize conflicts by providing explicit endpoints for env. regs.

OCEAN TIPPING POINTS

Kelly et al. *in press,* Ecology Law Quarterly

Management Review

- Analyzed ~50 case studies from around the world
- Categorized each based on attributes:
  - Biophysical (e.g. area, location, reversibility of shift)
  - Science (e.g. quantitative threshold, measurable variables)
  - Enabling (e.g. match in scale, jurisdiction, market forces)
  - Institutional (e.g. relevant mgt objectives, time to act)



OCEAN TIPPING POINTS

Kelly et al. *in press* Phil. Trans. Roy. Soc. B

We found that…

- **Threshold management works.** More explicit use of thresholds in management is strongly associated with better environmental outcomes.
- **Responsive monitoring is key**. Good outcomes are also associated with routine monitoring requirements in both retrospective and prospective cases.
- **Scale matters.** Threshold-based systems with smaller geographic areas are more likely to have good management outcomes.

Kelly et al. *in press* Phil. Trans. Roy. Soc. B

What comes next?

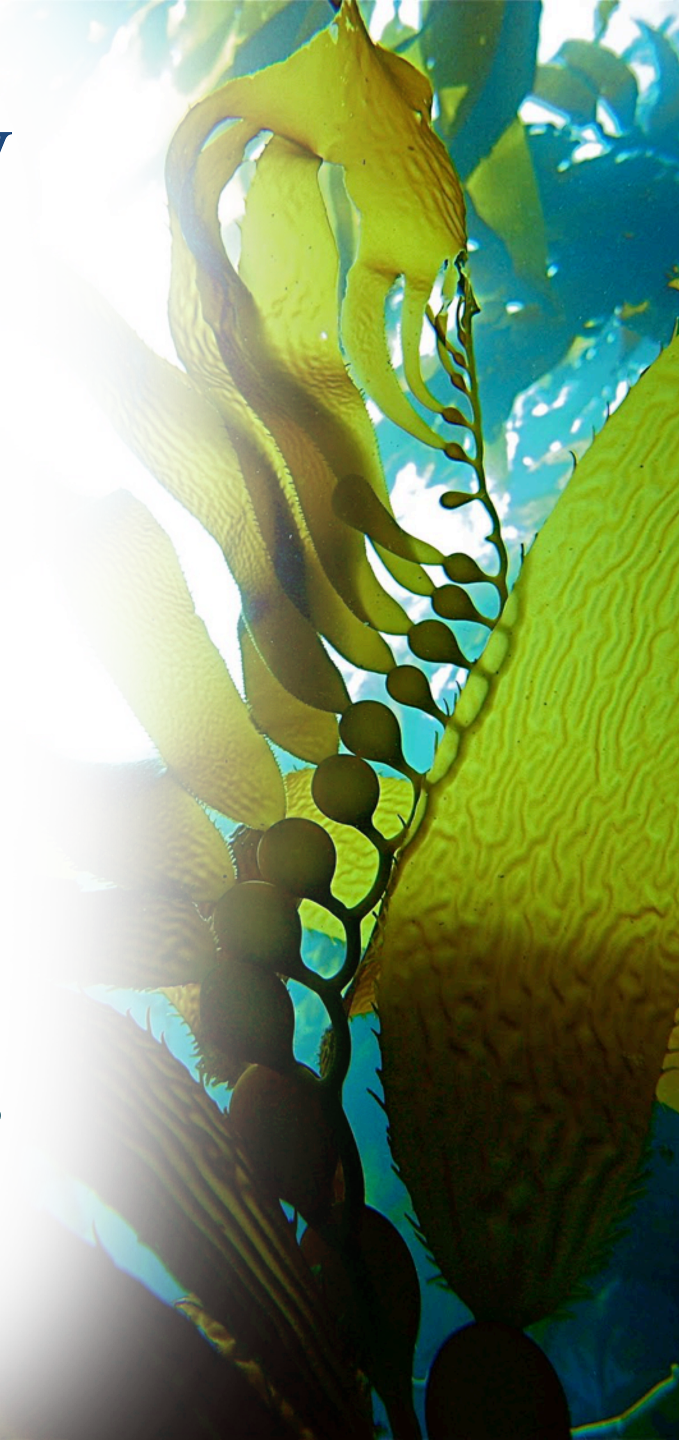
How we are approaching this

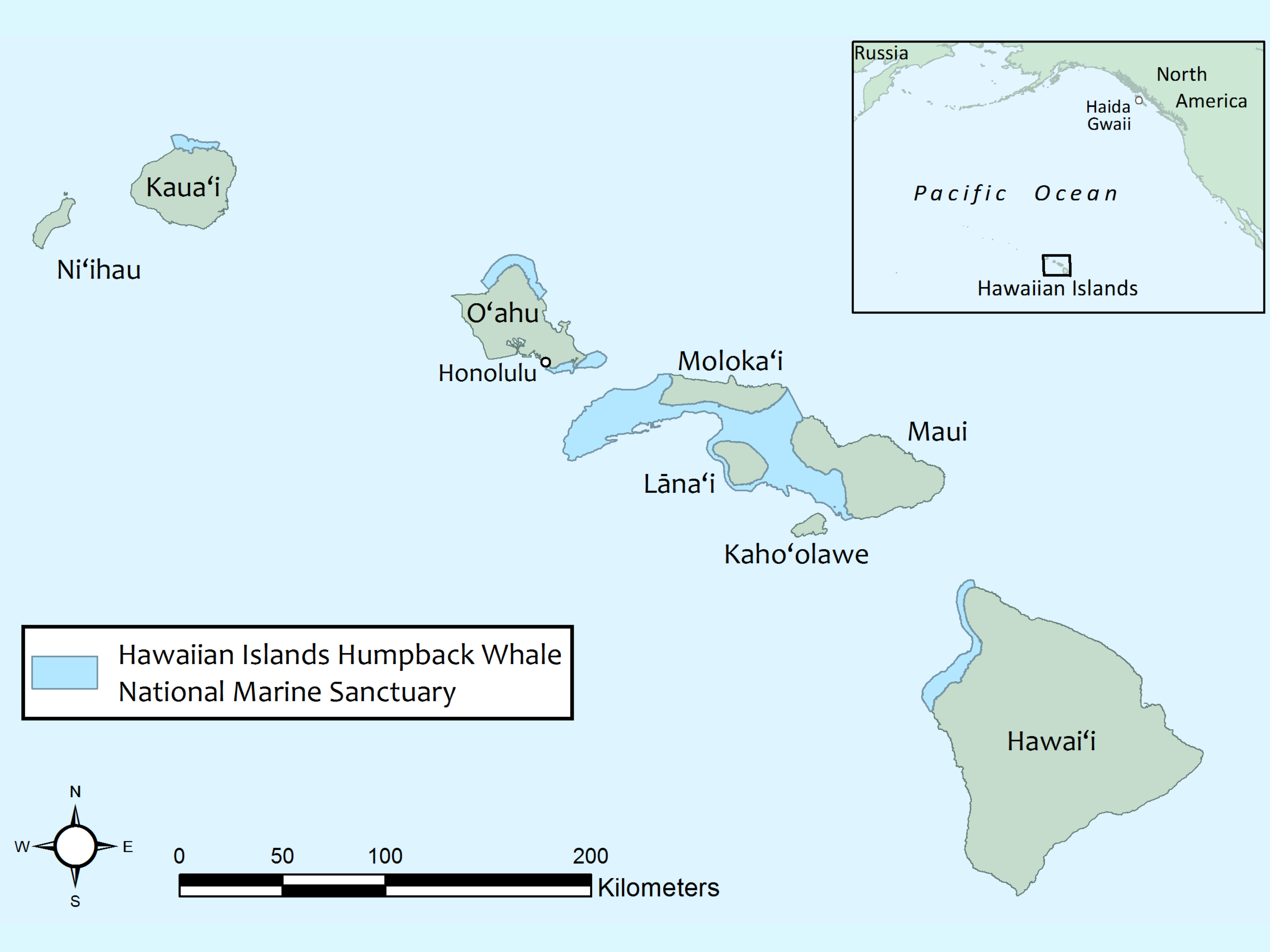
- RESEARCH: Synthesize and build upon our growing scientific understanding of ecological and socio-economic tipping points in marine ecosystems

- APPLICATION: Work with experts and practitioners to develop and test useful and usable approaches for integrating that information into ecosystem management, including two case study regions: Hawai‘i and Haida Gwaii

Phase Two: Case Study Application

- Allow us to test and refine our approach in a real-world context
- In both places:
  - past or potential ecosystem tipping points lead to interesting scientific questions and challenges
  - there are important policy windows of opportunity where this science could be useful to management




Russia
North
America
Haida
Gwaii
Pacific Ocean
Hawaiian Islands
Kaua‘i
Ni‘ihau
O‘ahu
Honolulu
Moloka‘i
Maui
Lāna‘i
Kaho‘olawe
Hawai‘i
Hawaiian Islands Humpback Whale
National Marine Sanctuary
N
W
E
S
0
50
100
200
Kilometers

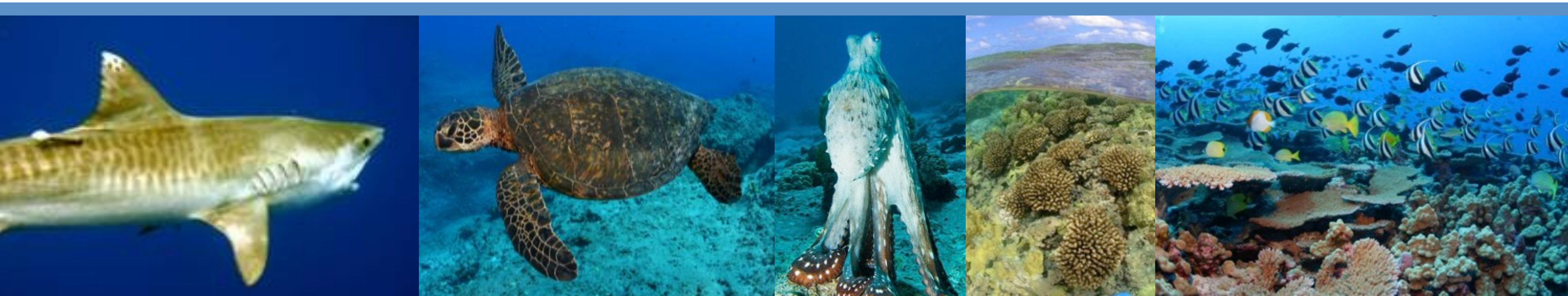
Hawai'i Case Study Overview

a) Characterize and map ecological regimes, drivers, and cumulative impacts across the archipelago.

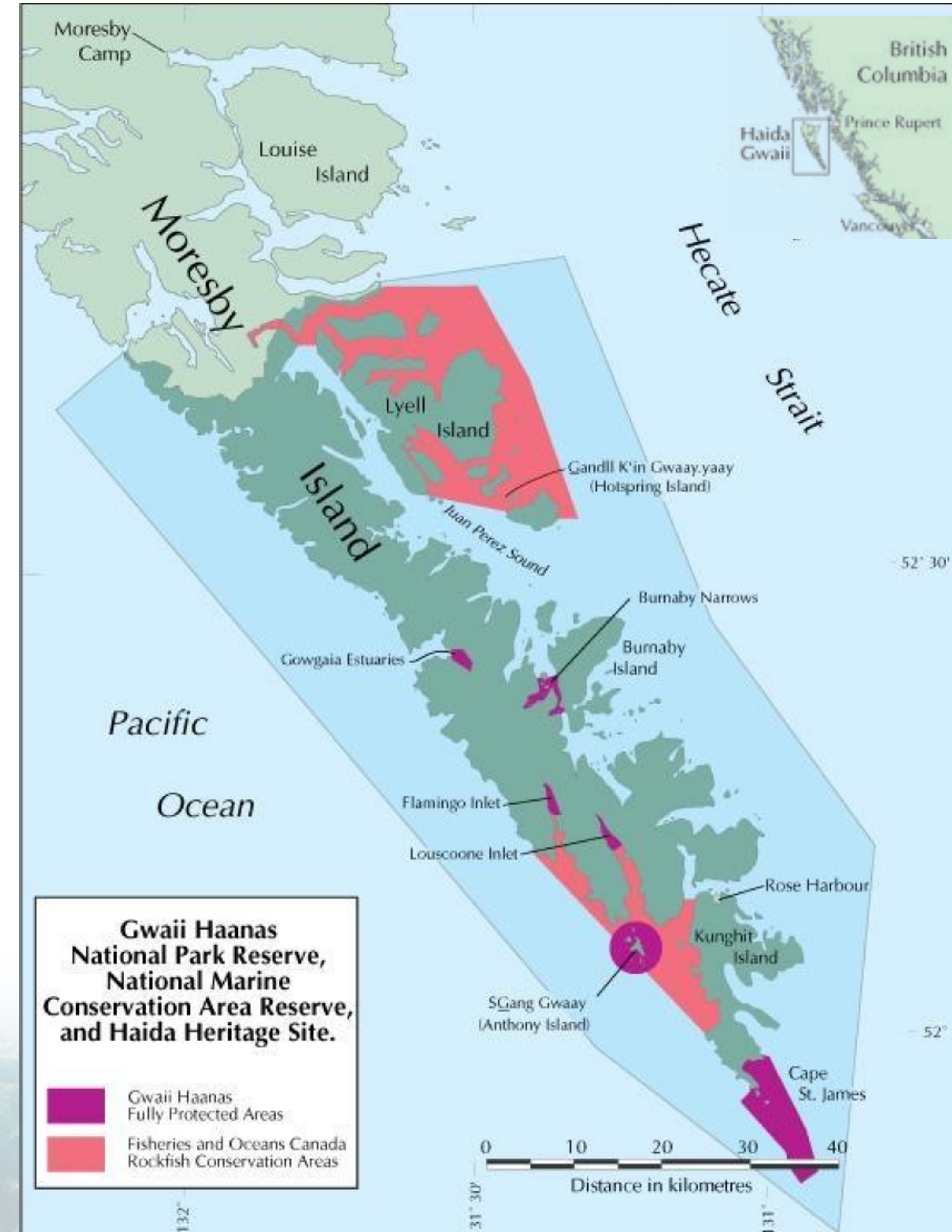
b) Estimate threshold activity levels that define safe operating space for healthy reefs, and develop early warning indicators for regime shifts.

c) Assess tradeoffs associated with managing multiple stressors across the land-sea interface, focused in West Maui.

d) Create guiding principles and toolkit for managing with a tipping points perspective, tailored to the management setting and research findings.



Gwaii Haanas National Marine Conservation Area Reserve and Haida Heritage Site



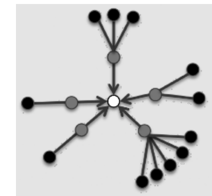
Focus on pelagic ecosystem and connected services and sectors

Lead:

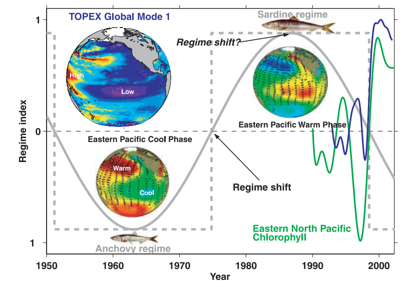
Phil Levin

Understanding ecosystem changes in Gwaii Haanas and Northern BC

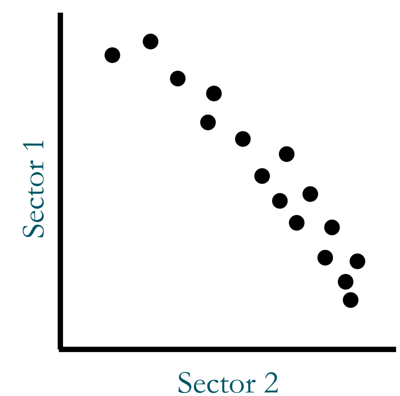
1. Expert perceptions of ecosystem interactions



2. Characterization of historical ecosystem shifts



3. Evaluation of socioeconomic and ecological trade-offs



The opportunity to improve management

- New science is converging with a paradigm shift toward ecosystem-based management of our coasts and oceans.
- Existing laws and regulations allow for and even require thresholds-based management.
- Knowledge of thresholds and use of indicators improves ecological outcomes.
- Preventing a shift may be less costly than attempting to recover from one.
- Understanding the drivers and feedbacks that impede recovery can prioritize restoration actions.

www.oceantippingpoints.org

OUR PARTNERS

Cal Poly San Luis Obispo
Hawaiian Islands Humpback Whale National Marine Sanctuary
University of Hawaii
NOAA's Coral Reef Ecosystem Division
NOAA's Coral Reef Conservation Program
Stockholm Resilience Centre
Fisheries and Oceans Canada
DFO SPERA Program
Parks Canada
Council of the Haida Nation
Gwaii Haanas Archipelago Management Board
Gwaii Haanas Marine Team
Haida Ocean Technical Team

Rebecca Martone
rmartone@stanford.edu

info@oceantippingpoints.org

Threshold targets can be used as simple metrics for protecting ecosystem resilience and identifying safe operating spaces for human activities