Approaches to detect tipping points and estimate the resilience of marine populations and communities

Camilla Sguotti

Università degli Studi di Padova

MARIE CURIE ACTIONS

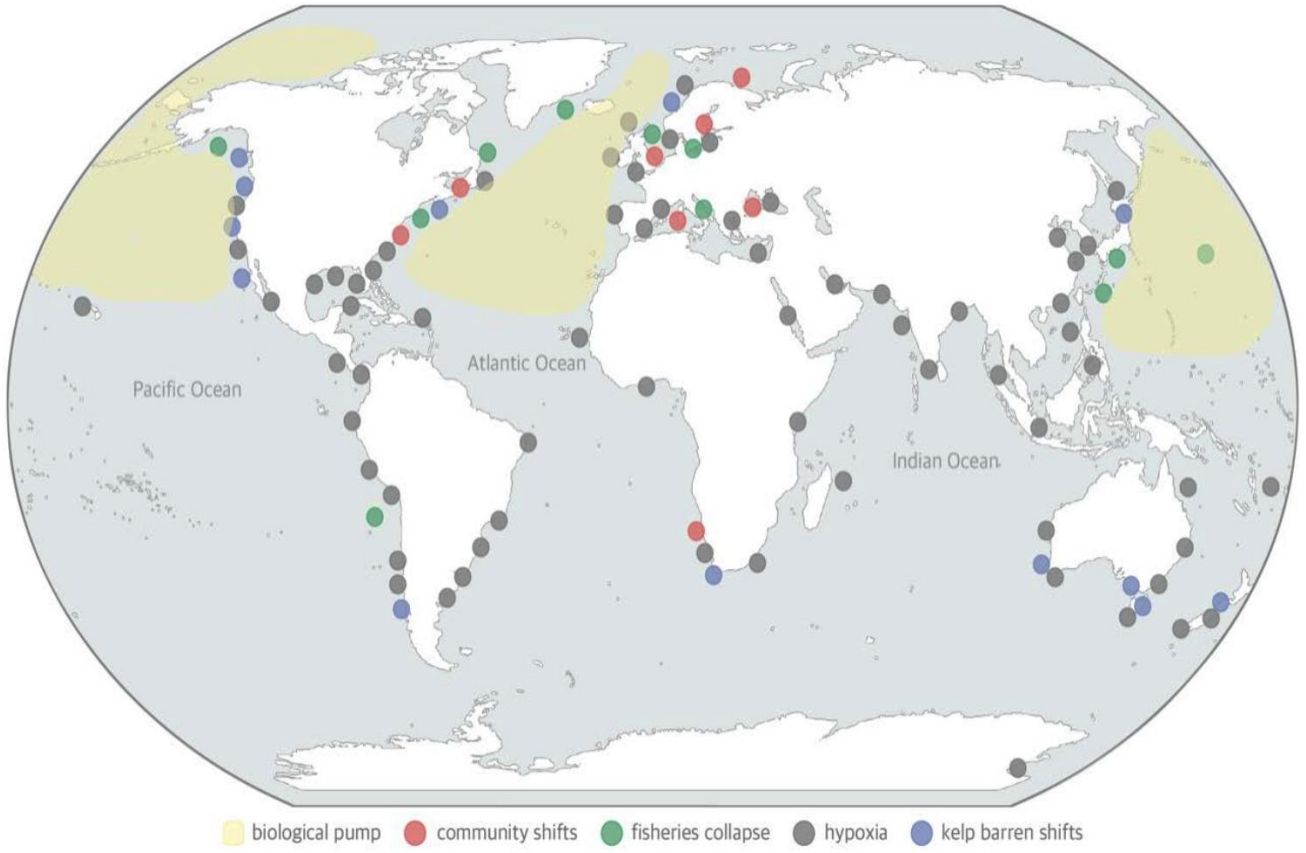
PICES

Living on the brinks of tipping points

Global Tipping Point Report 2023

Scheffer et al, 2001; Beisner et al., 2003; Sguotti et al., 2023

Tipping points are projected to increase with climate changes



Global Tipping Point Report, 2023

25 parts of biosphere present tipping points due to external pressures

5 major tipping systems at risks of crossing tipping pint in the immediate future

With **climate change increase frequency**

IPCC 2023

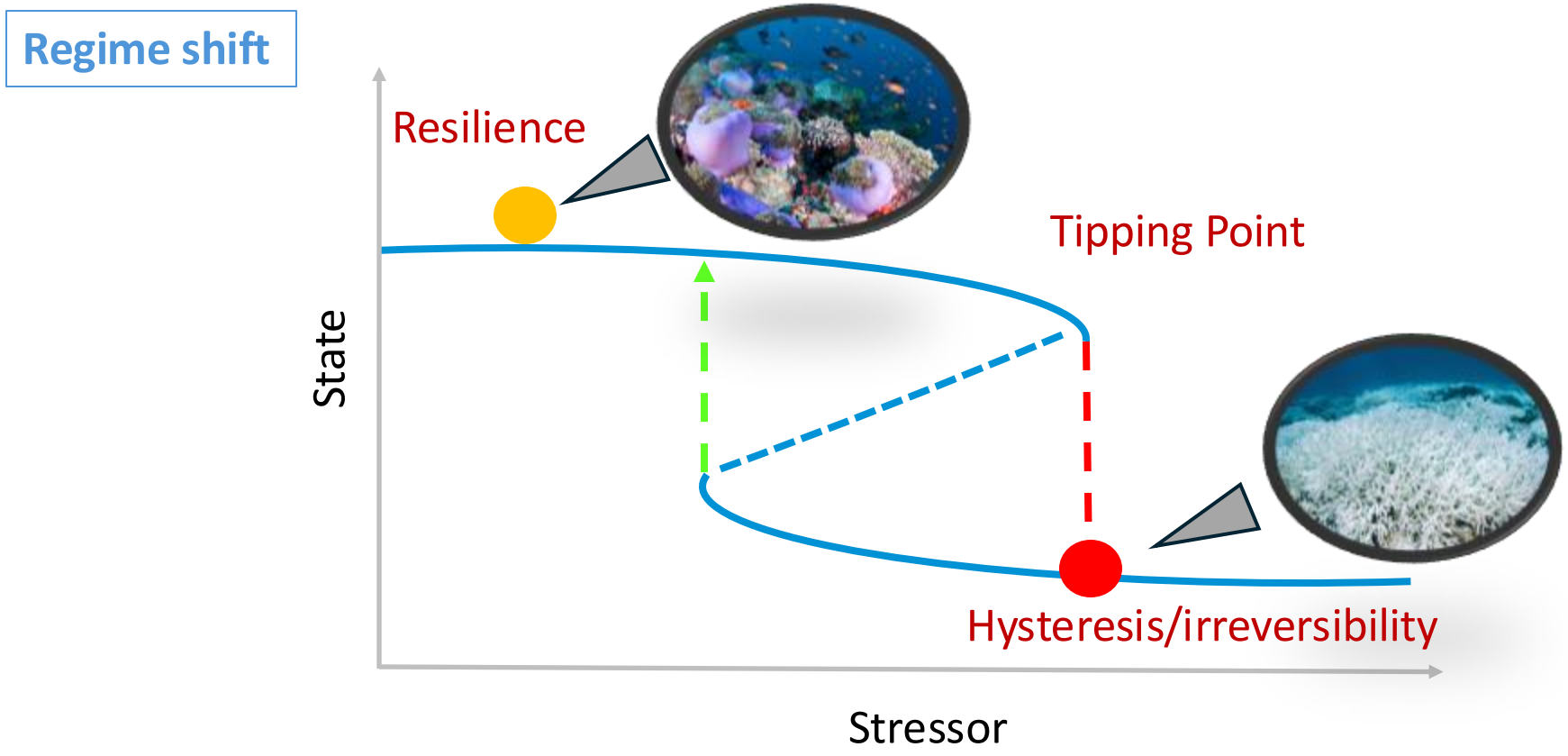
Fundamental to understand and anticipate these dynamics

Sguotti et al., 2023, invited chapter in Treatise on Estuarine and Coastal Science

Rockstrom et al., 2009; Richardson et al., 2023; Global Tipping Point Report 2023

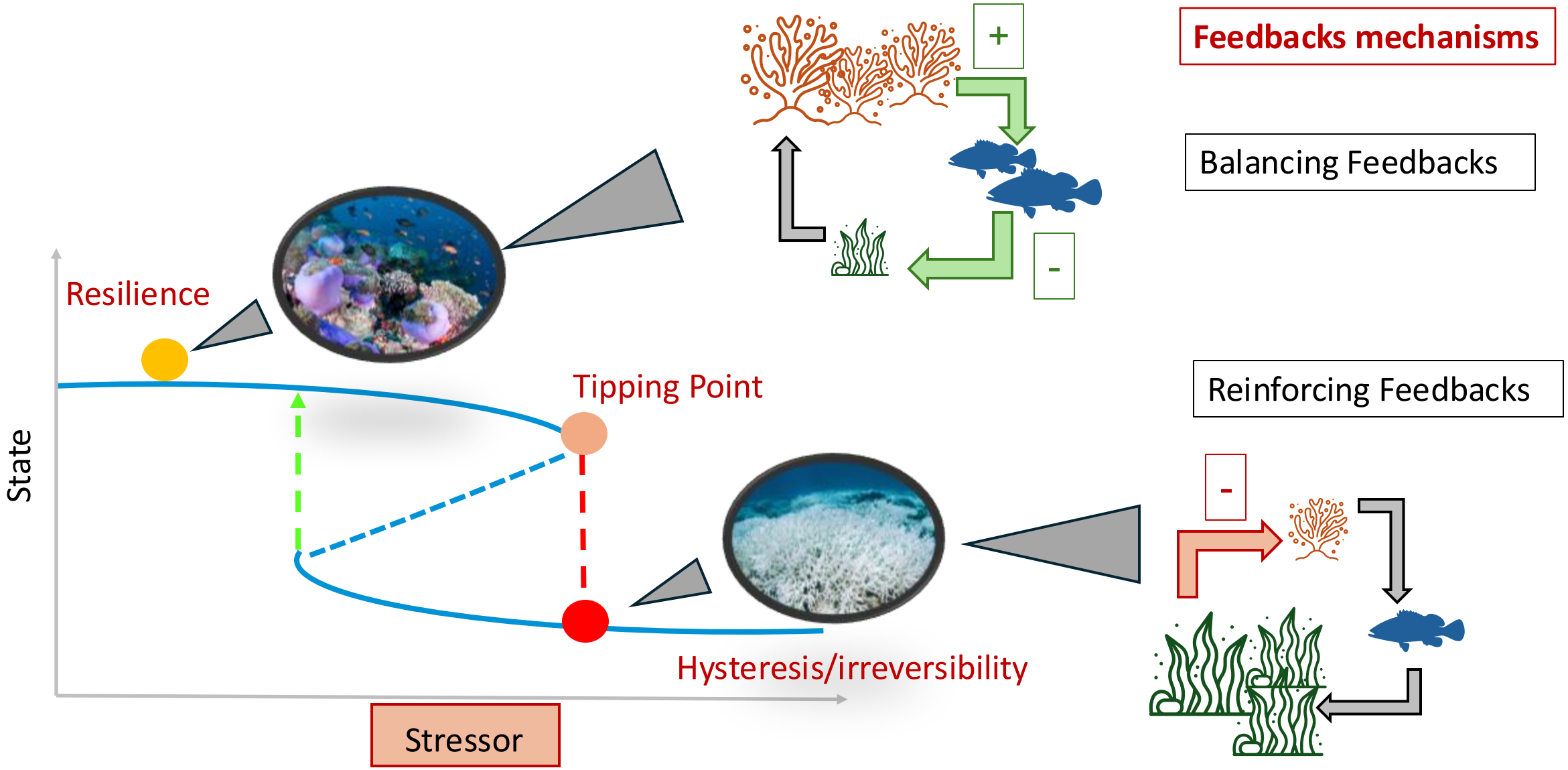
Tipping points can be irrevesible

*"**Critical thresholds** at which a small change in external conditions can lead to a dramatic and sometimes irreversible shift in the state or dynamics of a system."*



Scheffer et al, 2001; Beisner et al., 2003; Sguotti et al., 2023

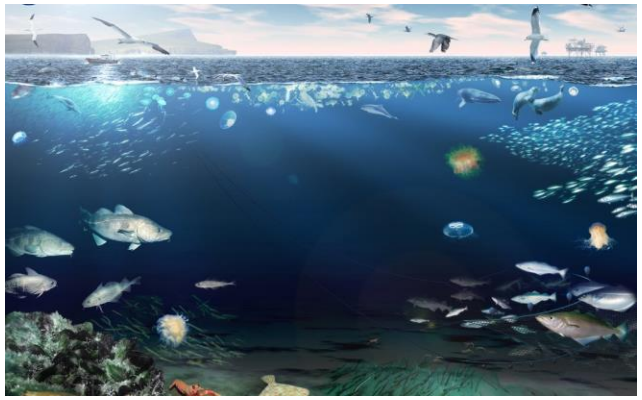
Regime shifts are complex dynamics



Scheffer et al, 2001; Beisner et al., 2003; Sguotti et al., 2023

Studying tipping points in complex systems

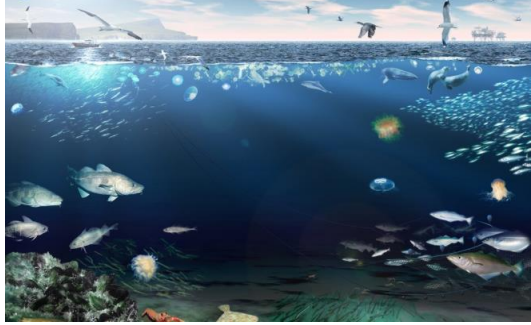
Relatively “small systems”
The two states are clearly visible
Experimentally manipulated



Large and heterogenous
“Invisible”
Impossible to experimentally manipulate
Impact by cumulative pressures

Sguotti et al., 2023

Studying tipping points in complex systems



Statistical modelling: **changes in structure**	Mechanistic modelling: **general feedbacks**
• Methodological limitations	• Difficult to model truly complex systems

Hinder a timely detection of tipping points and thus the possibility to mitigate and avoid them!

Sguotti et al., 2023

Objectives

Can we **detect and anticipate tipping point** in Large Marine Systems?

Develop a methodological framework to estimate resilience.

Model the resilience of the Northern Adriatic Sea and understand whether tipping points have occurred in the past.

Understand if Local Ecological Knowledge could be used to anticipate tipping points.

How could resilience be better integrated in management?

Methological framework: CUSPRA

Romain Frelat

Paris Vasilakopoulos

Vangelis Tzanatos

PROCEEDINGS B

royalsocietypublishing.org/journal/rspb

Research

Cite this article: Sguotti C, Vasilakopoulos P, Tzanatos E, Frelat R. 2024 Resilience assessment in complex natural systems. *Proc. R. Soc. B* **291**: 20240089.

Resilience assessment in complex natural systems

Camilla Sguotti[1,2], Paraskevas Vasilakopoulos[3], Evangelos Tzanatos[4] and Romain Frelat[5]

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[3]European Commission, Joint Research Centre (JRC), Ispra, Italy
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[5]PO Box 30709, International Livestock Research Institute, Nairobi 00100, Kenya

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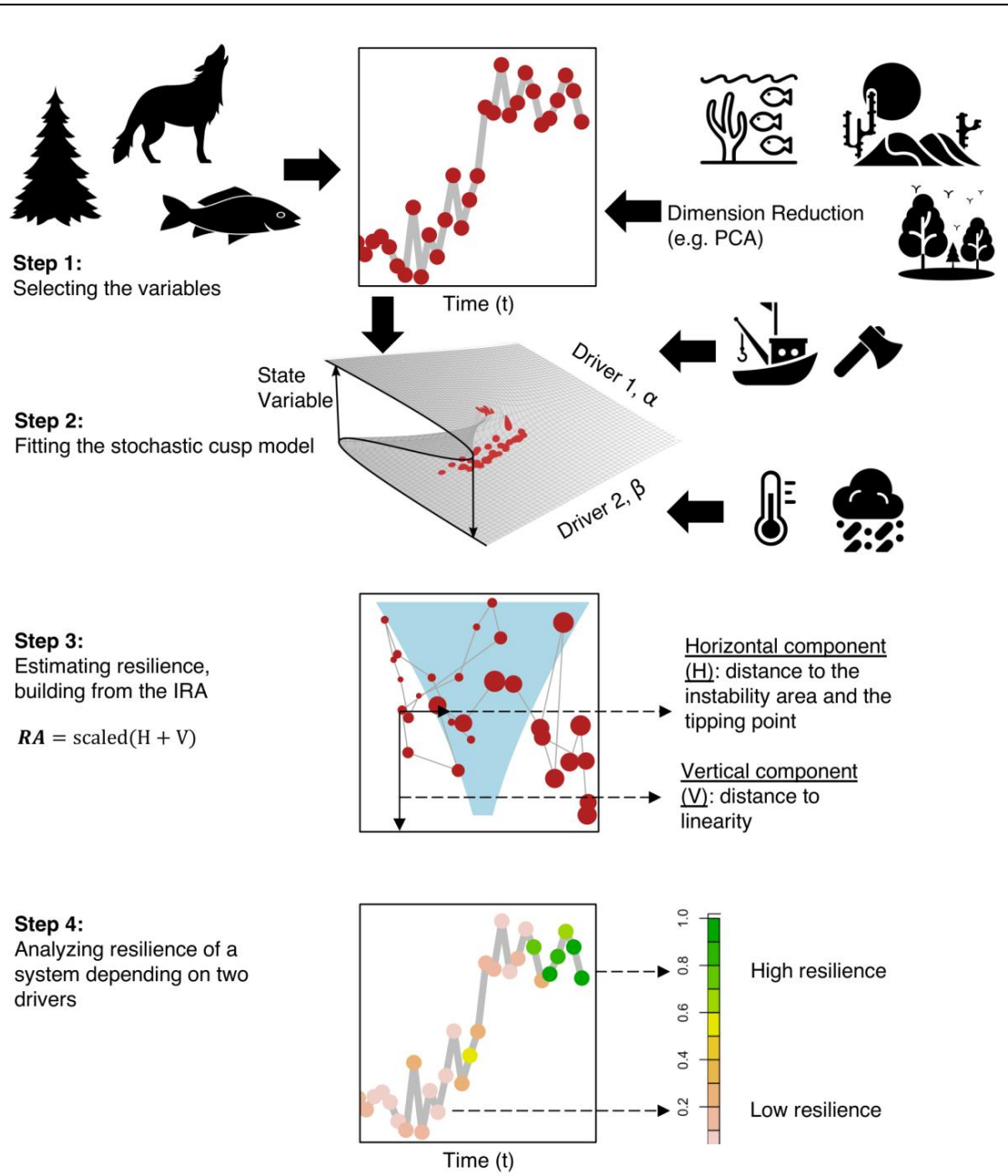
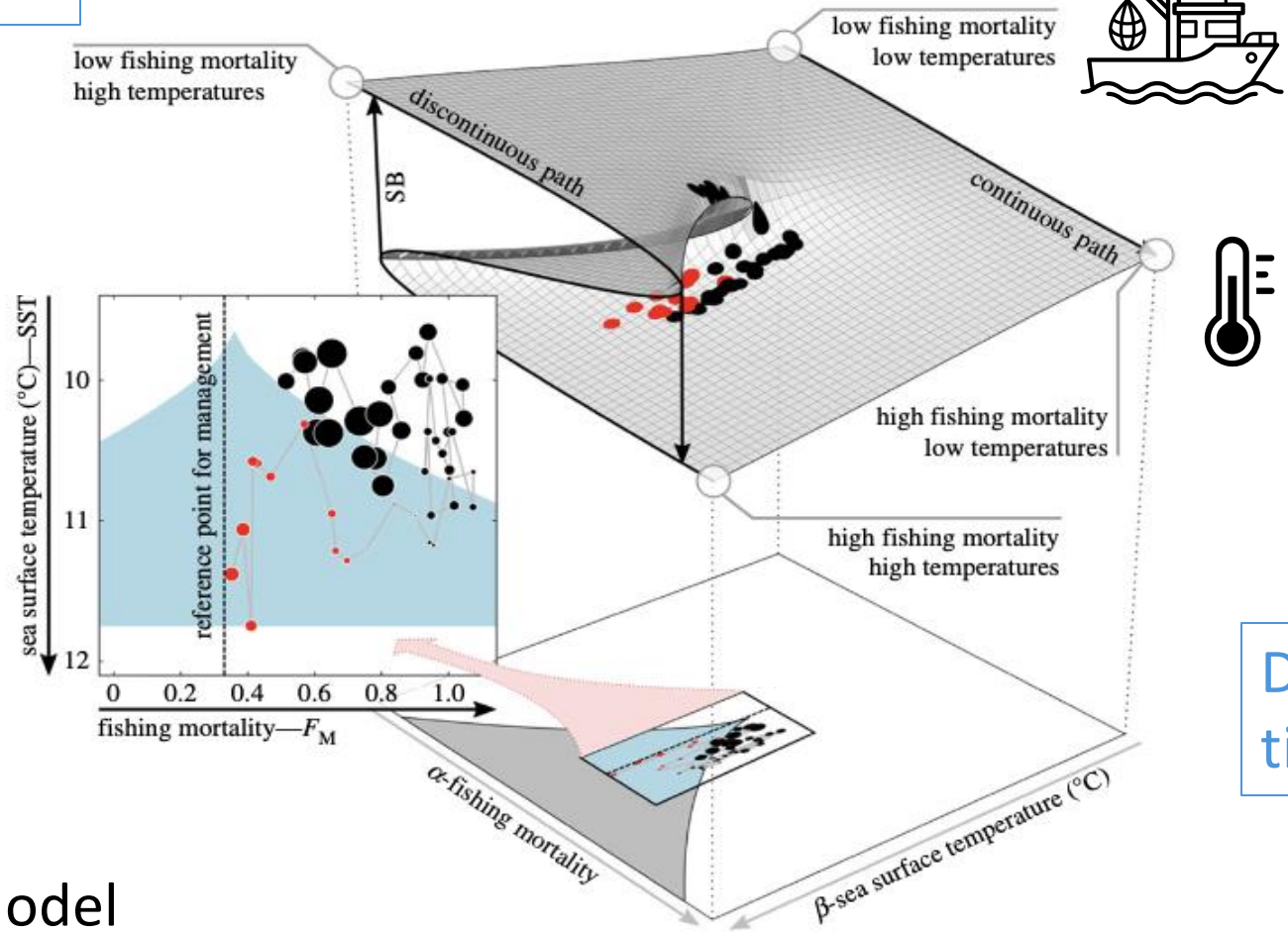


The stochastic cusp model

Christian Möllmann

Dynamic



Interaction between 2 drivers

Distance to the tipping point

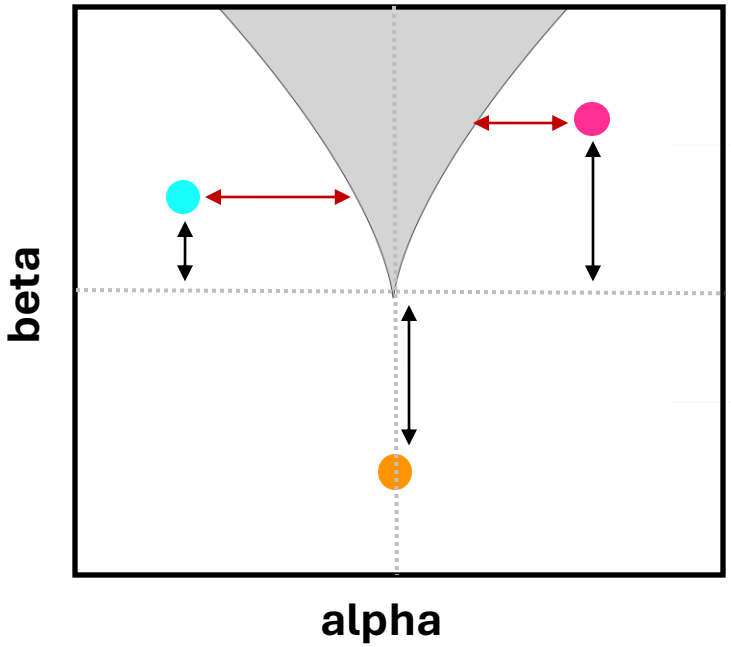
Validate the model
4 criteria to be passed

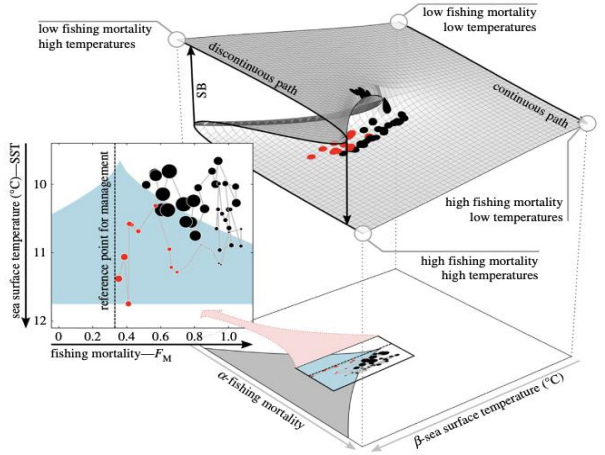
Modified from Sguotti et al., Proc. R. Soc. B 2019,

Methodological framework: CUSPRA

Thom, 1972; Grasman et al., 2009; Sguotti et al., 2019, 2022, 2023

Developing the resilience indicator





Vertical component:
Distance to linearity

+

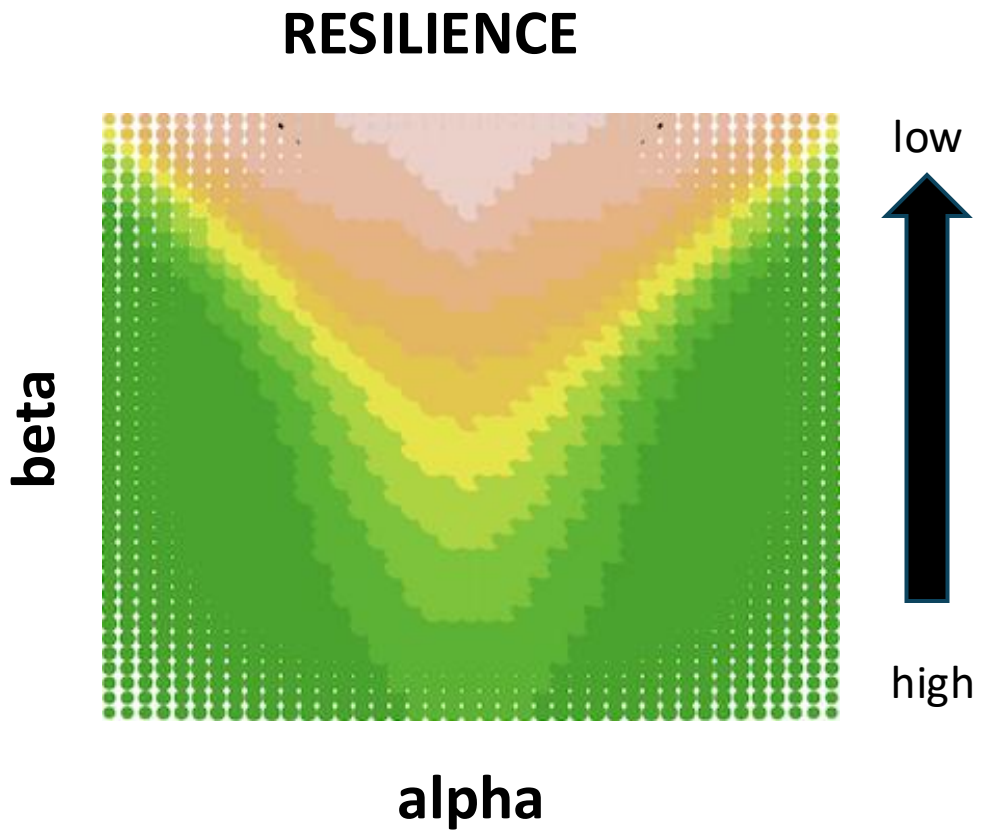
Horizontal component:
Distance to transition area

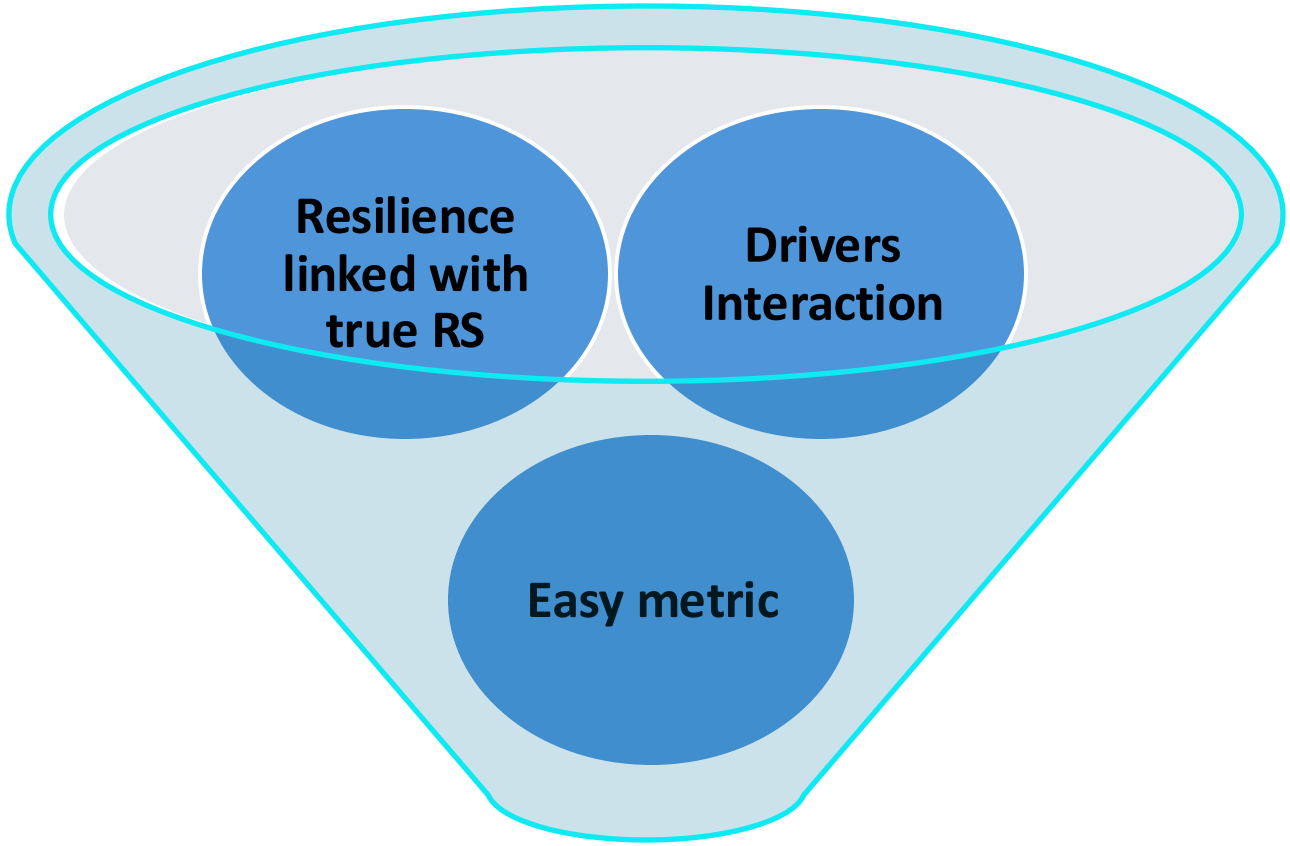
cuspRA = (scaled(horD+verD))

Methodological framework: CUSPRA

Vasilakopoulous & Marshall, 2015; Sguotti et al., 2024

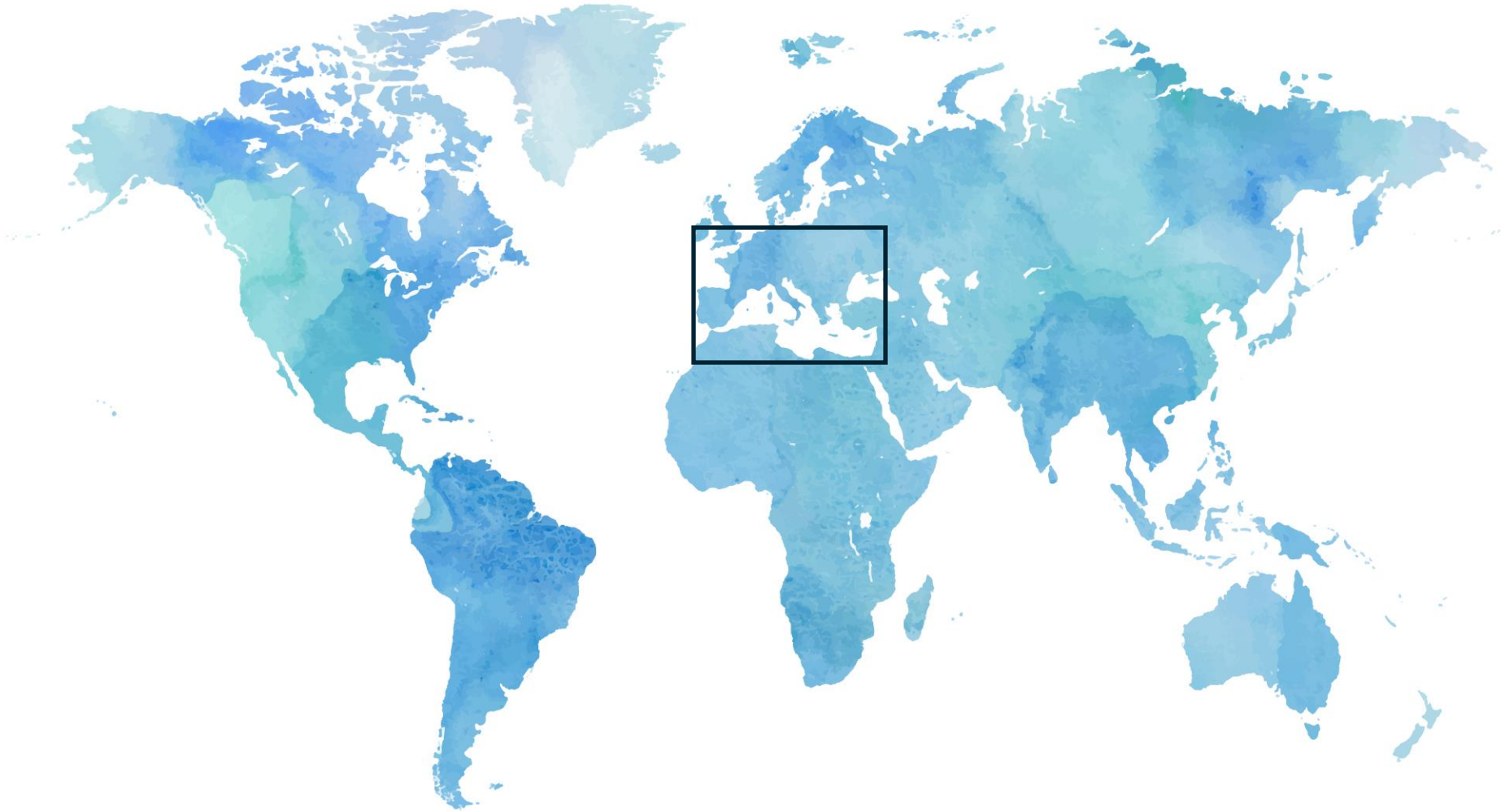
The new index and how to apply it





Real-time resilience indicator

Estimating resilience of the Northern Adriatic Sea

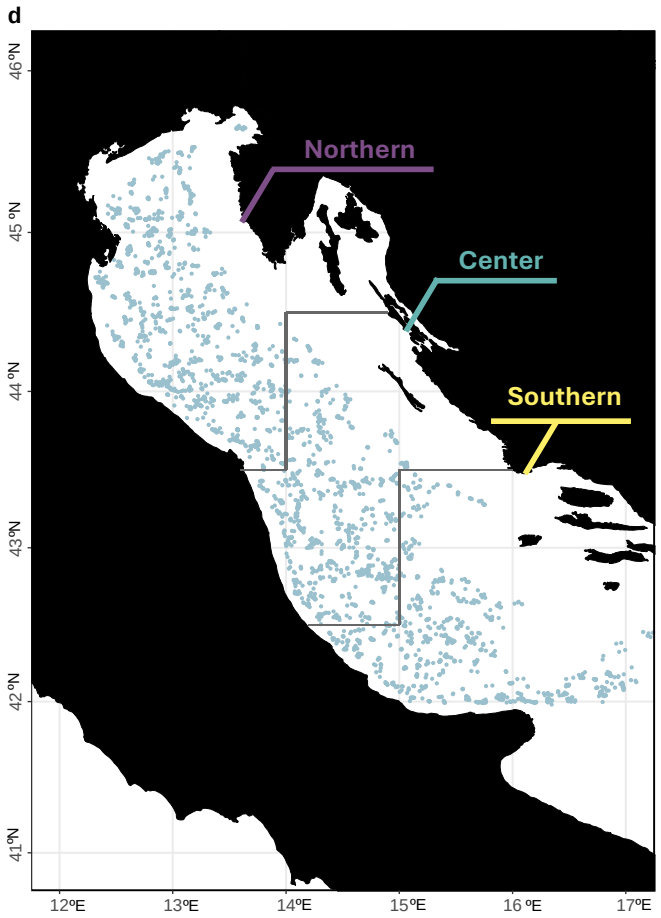


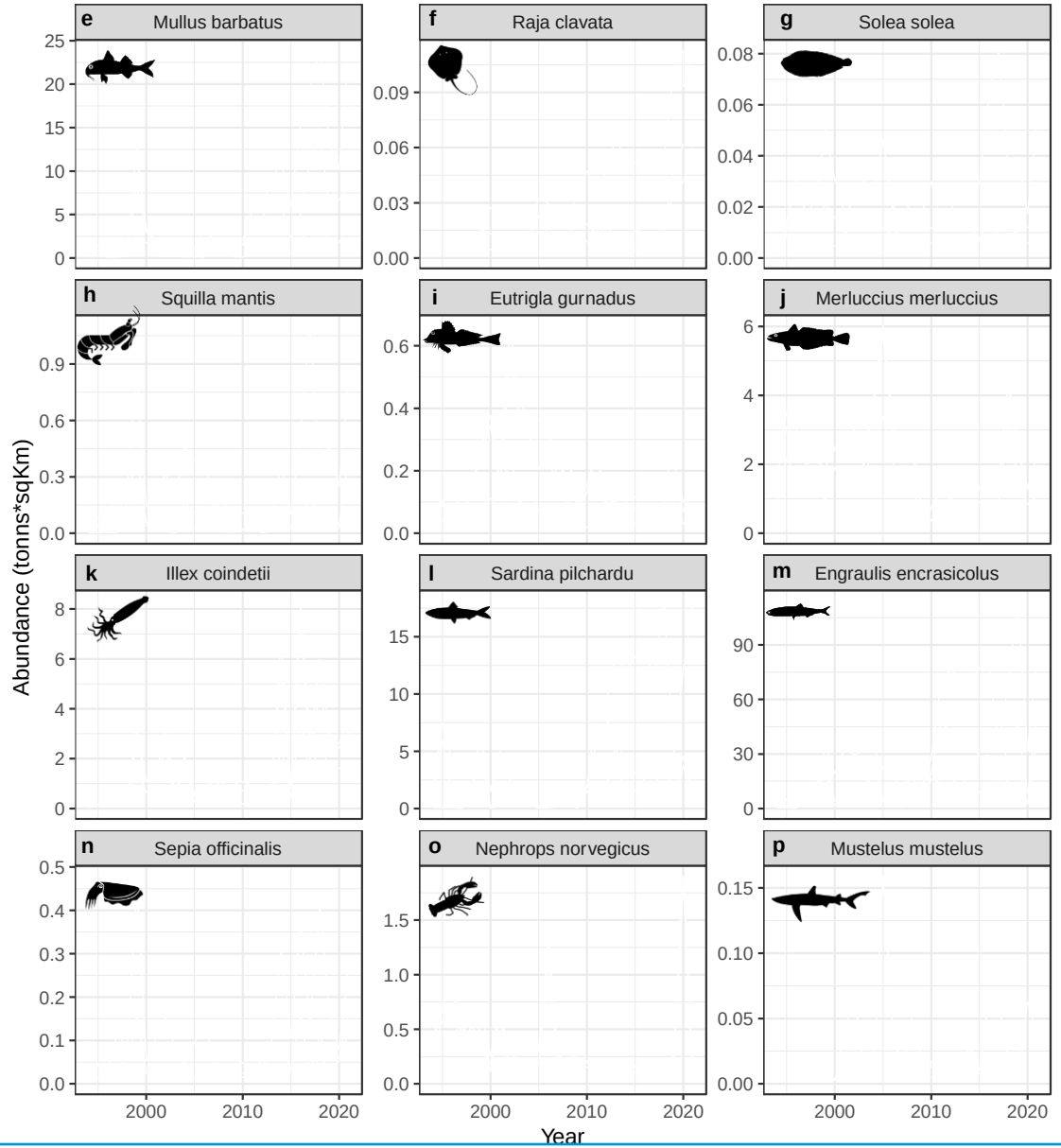
Sguotti et al in prep

Estimating resilience of the Northern Adriatic Sea

Trawl survey data 1995-2024

117 species
81 fish
9 elasmo
18 mollusks
9 crustaceans





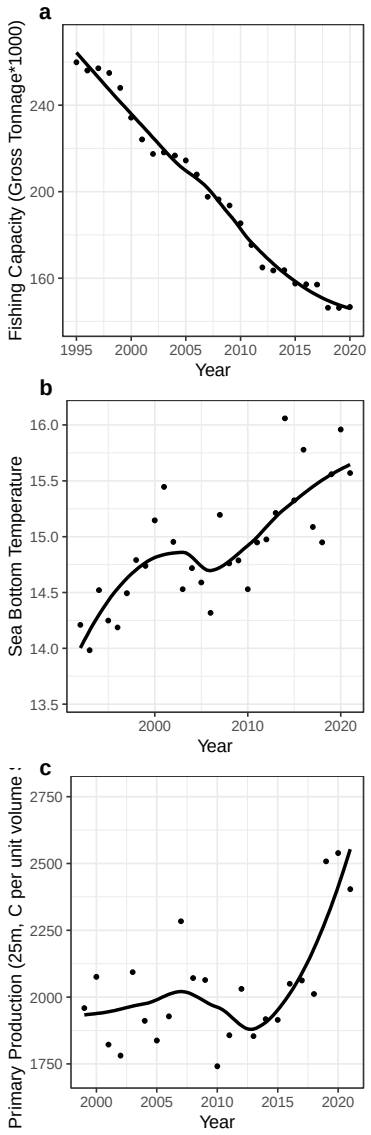
Sguotti et al in prep

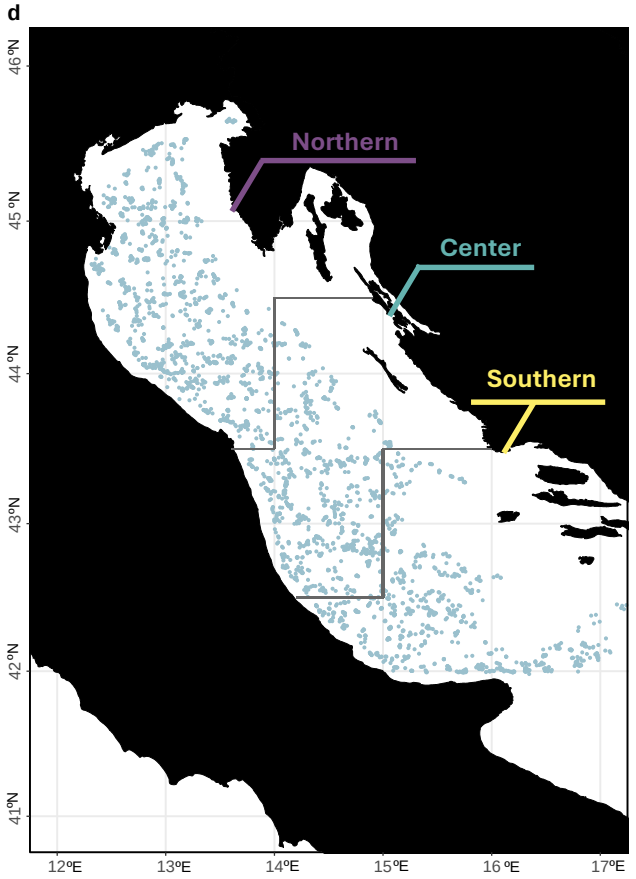
The Pressures

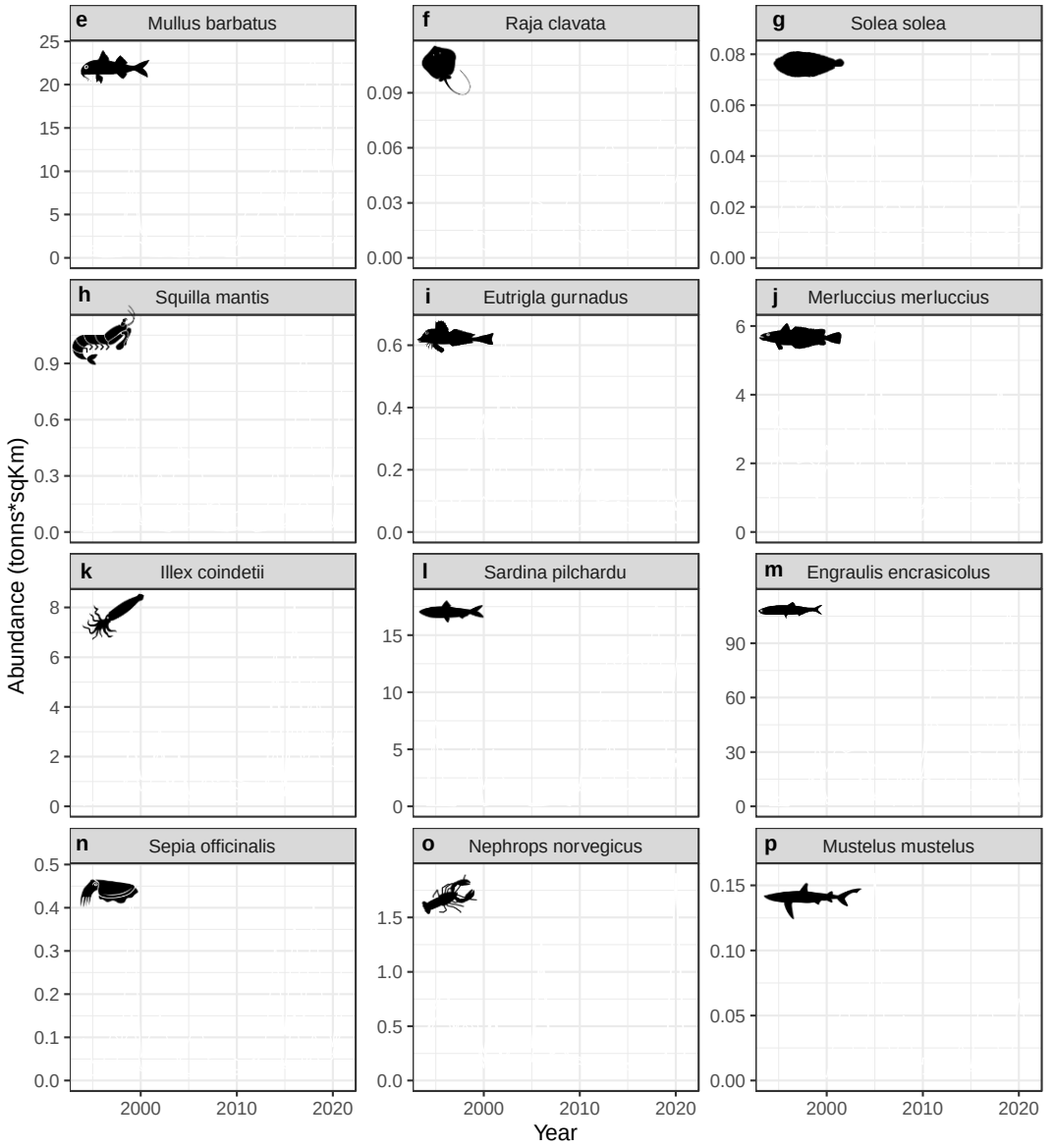
Fishing Capacity (STEFC)

SBT (Copernicus)

PP (Copernicus)







Sguotti et al in prep

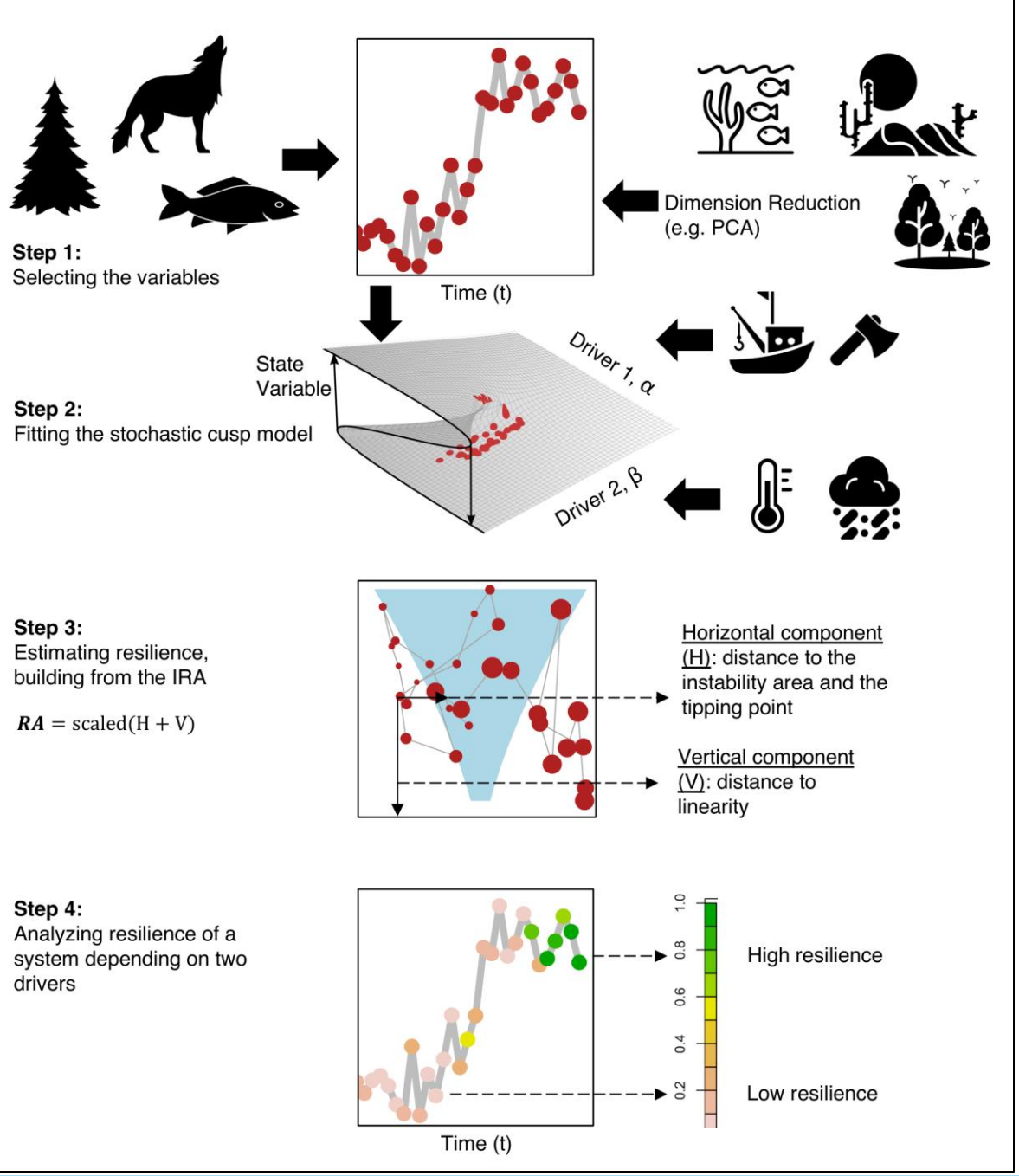
The Methodology

Perform a PCA to reduce dimensionality and select **PC1** and **PC2**

Fit cusp model with F as alpha and SBT and PP as beta and validate it.

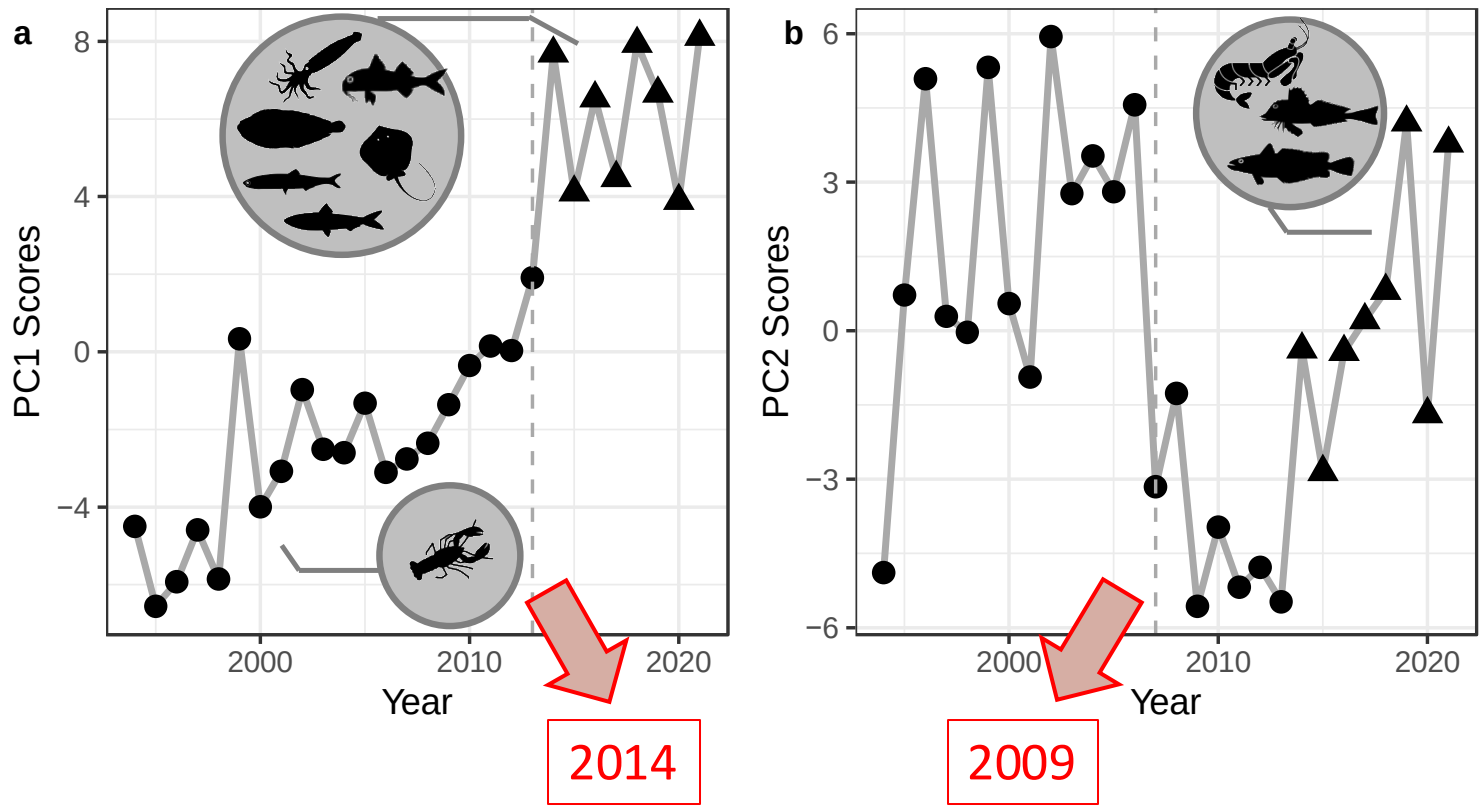
If model pass evaluation criteria, **present cusp bifurcation…**

Estimate resilience



A tipping point occurred in 2014

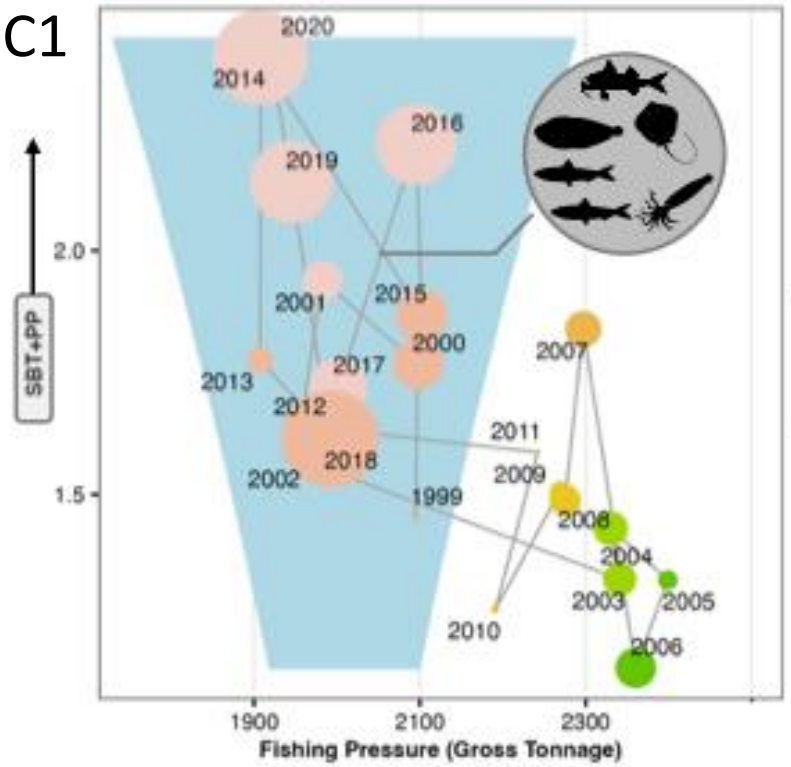
PCA:
PC1+PC2 = 30%



Tipping point of all community in 2014
More species become dominant after 2014

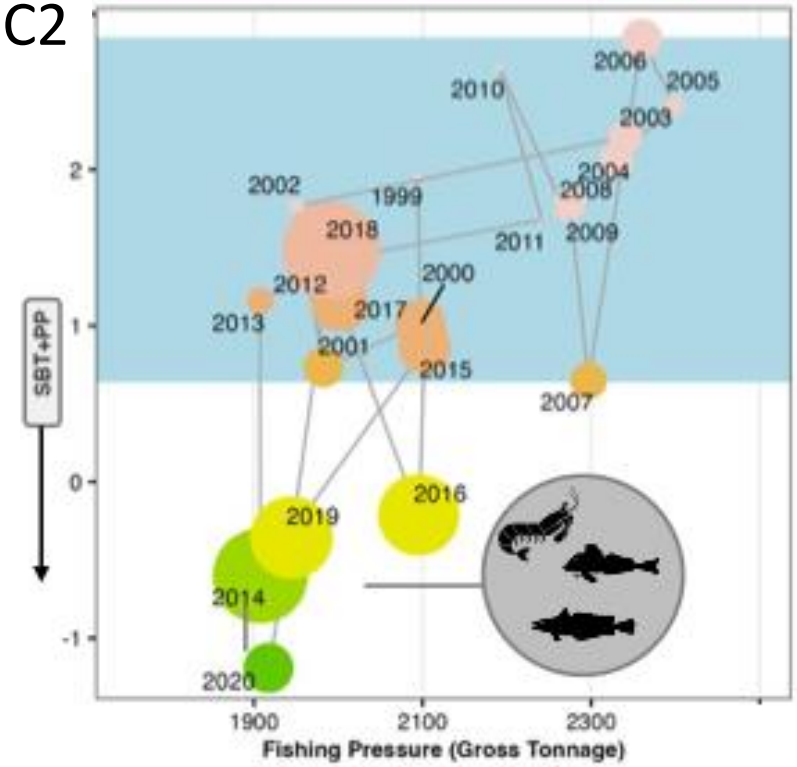
The total community of GSA 17 present catastrophic shifts

PC1



Cusp model pass validation → **cusp bifurcation**

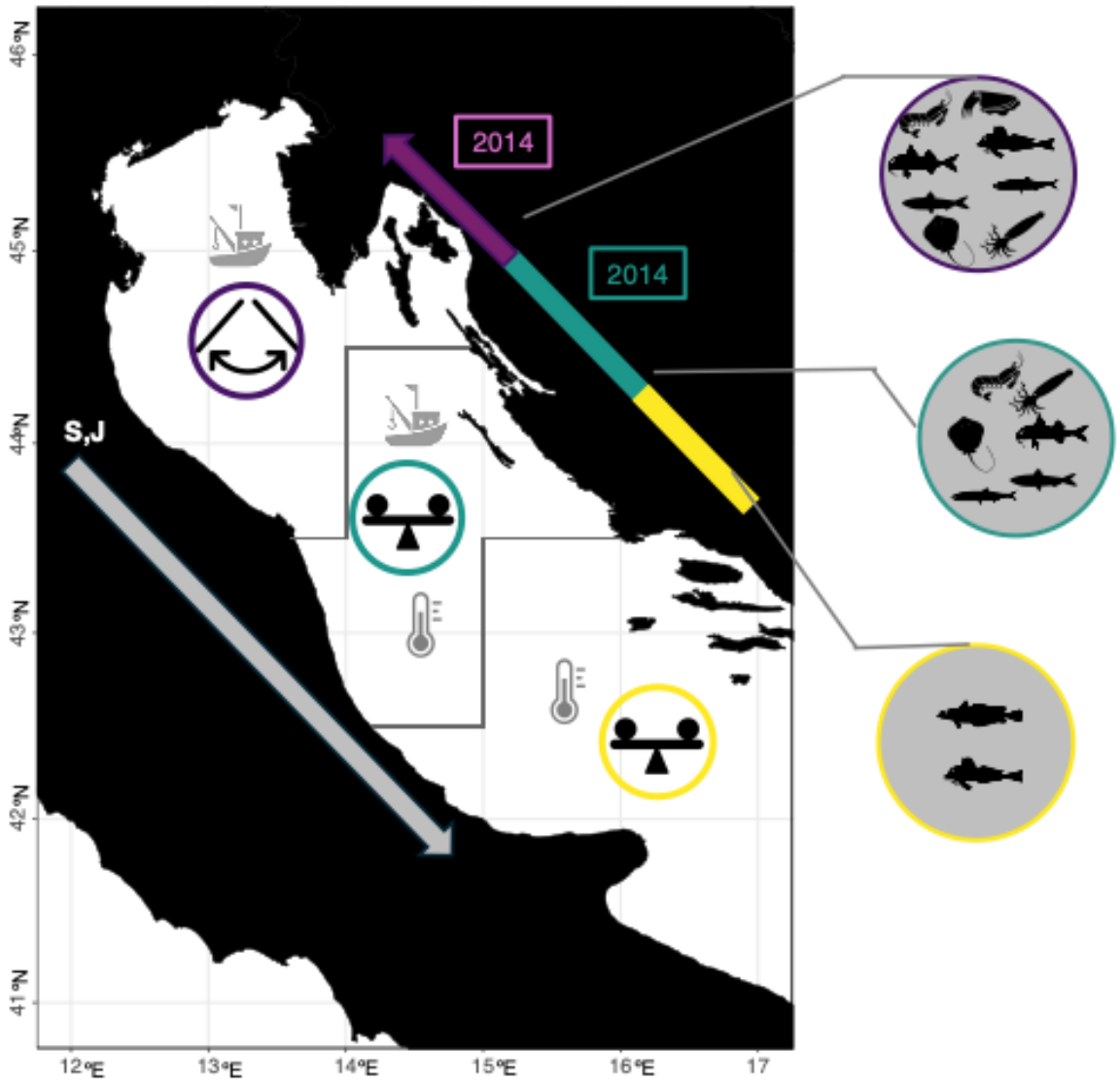
PC2



Positive Tipping point in 2014 due to decline in F and SBT and PP increase.
PC1 at the moment highly unstable.

Tipping point also around 2010 due to SBT and PP increase.
PC2 is now in a stable state.

Different subareas present different dynamics



Regime shift on many species due to decline in Fishing and is now in an **unstable state.**

Regime shift that intereseted a good number of species due to decline in **Fishing** and increase of **SBT.** It is now in a **stable state**

Regime shift on just few species due to increase of **SBT.** It is now in a **stable state**

Sguotti et al in prep

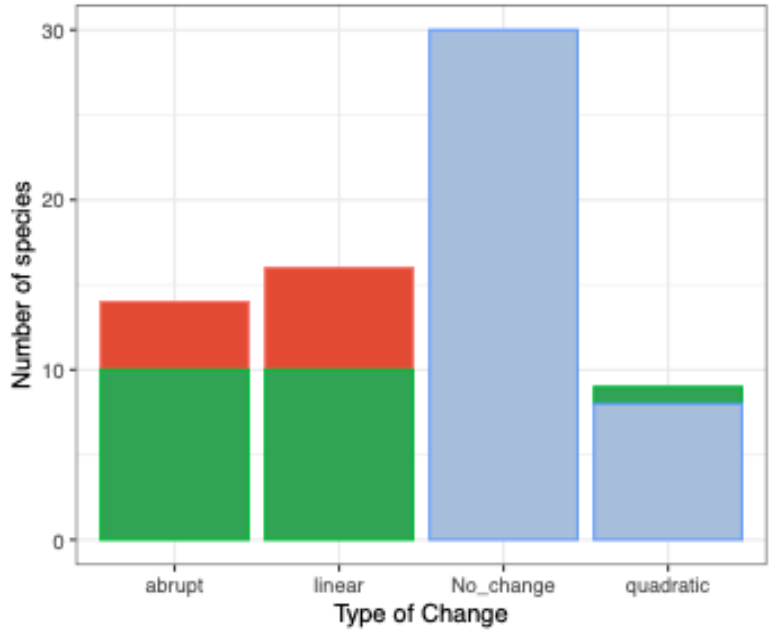
Species show a variety of trends across the different areas

Biological Conservation
Volume 290, February 2024, 110429

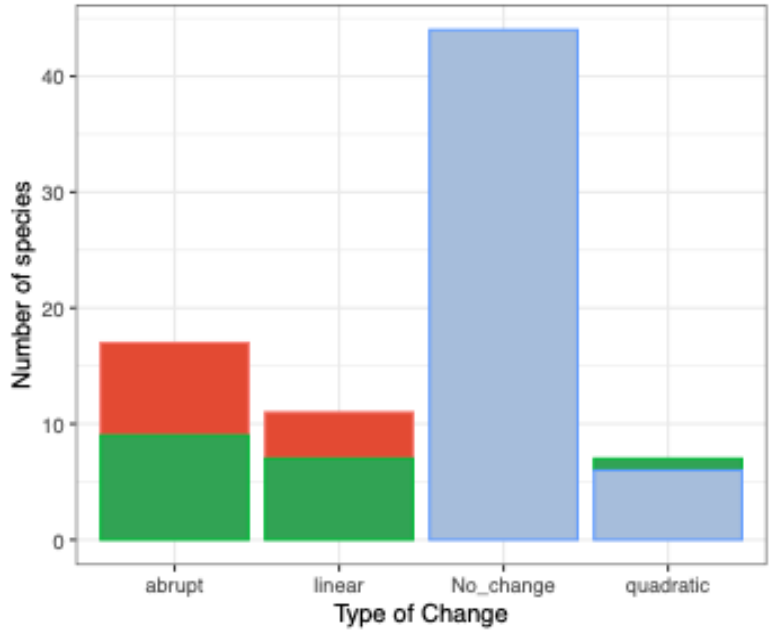
A systematic approach for detecting abrupt shifts in ecological timeseries

Mathieu Pélissié, Vincent Devictor, Vasilis Dakos

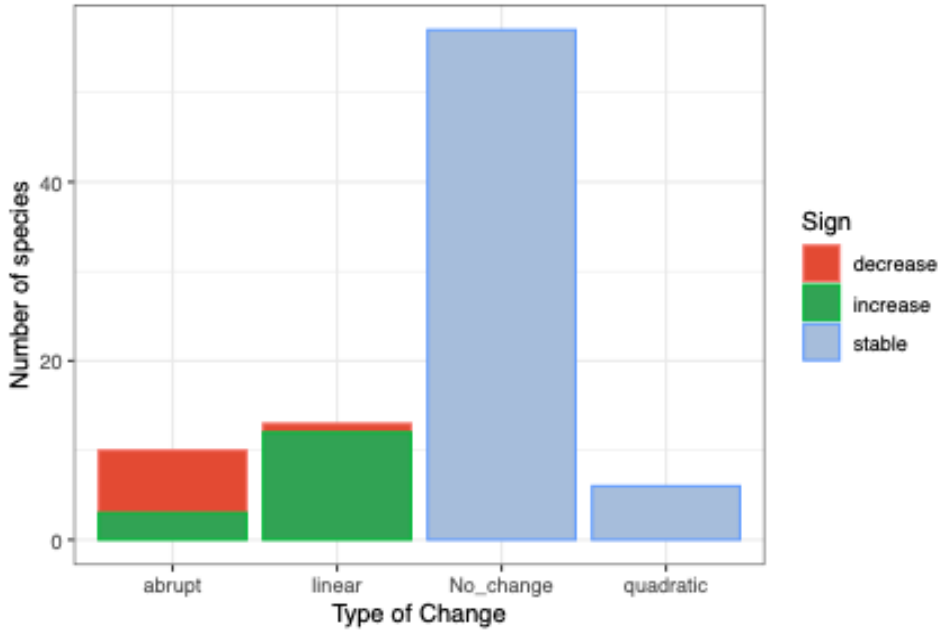
North



Center



South



In the North and center more species changed aruptly and increase compared to the south

What is the resilience of the Northern Adriatic Sea?

- **General increase of species** after 2014 (in some cases linear in some non-linear), especially in the Northern and southern areas.

- **Tipping point due to a decline of fishing and temperature increase happened in 2014 at the total Adriatic community level.** Interestingly from other studies also using different data or at single species (SOLEMON, Landings) we find the same results.

- **Different dynamics** can be found across the different regions, with the northern and central areas presenting more species showing abrupt changes and tipping point compared to the southern area.

- **Fishing pressure** seems more relevant in driving the Northern part of the Adriatic Sea.

Sguotti et al in prep

General results

- **CUSPRA helped to better understand the dynamics of the systems and could potentially help to inform management, if integrated with other indicators.**

- **Problem of the scales:**

  Different spatial patterns of tipping points and stability

  Different transmission **from organisms to the community**

- **Crucial to better understand what scales might be more meaningful to investigate for management.**

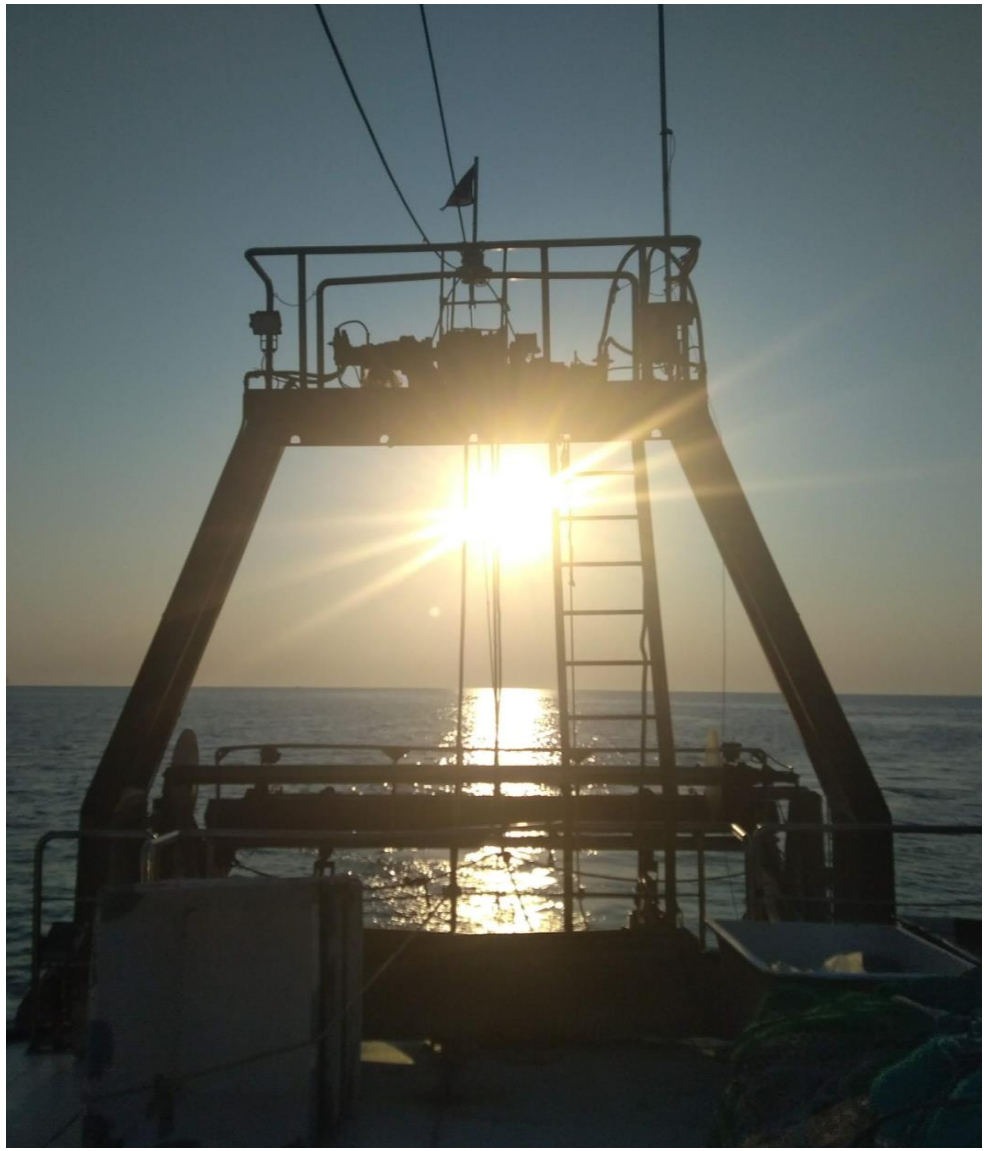
HIGH SEMPLIFICATION

DATA AND METHODS DEMANDING

Other approaches????

Sguotti et al in prep

Local Ecological Knowledge: a powerful tool



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+

Strong cooperation with fishers of Chioggia

Fishers experience the sea **everyday**

LEK have been proved useful to understand trends and patters of marine ecosystems

Could fishers be sentinels of the sea and anticipate tipping points?

Piccardi et al., 2023; Panozzo et al, in prep

Tipping points in landings of Chioggia harbour

Received: 18 March 2022 | Accepted: 23 September 2022
DOI: 10.1111/1365-2656.13831

Journal of Animal Ecology | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

Stable landings mask irreversible community reorganizations in an overexploited Mediterranean ecosystem

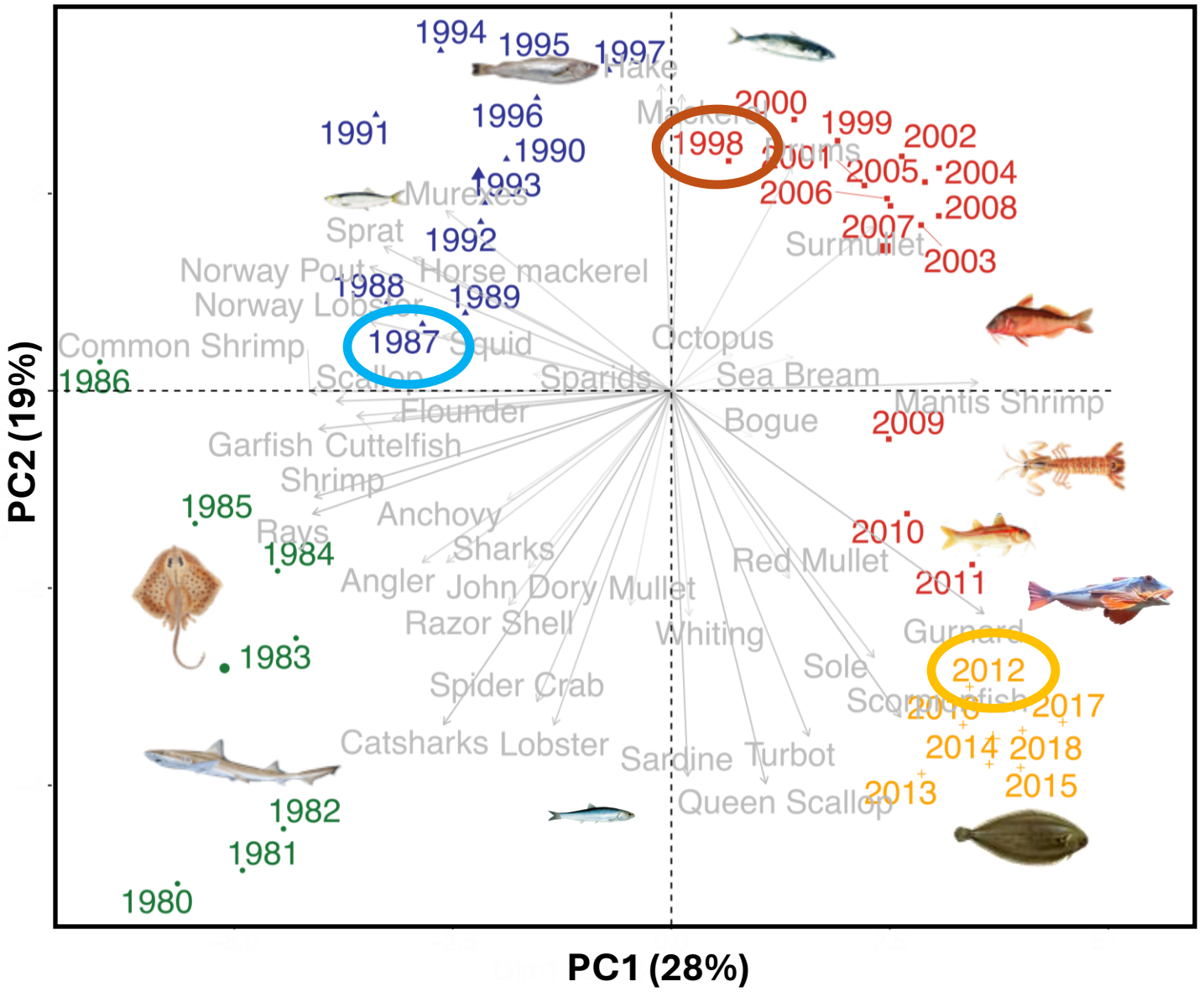
Camilla Sguotti[1,2] | Aurelia Bischoff[1] | Alessandra Conversi[3] | Carlotta Mazzoldi[2,4] | Christian Möllmann[1] | Alberto Barausse[2,4]

Alberto Barausse

Carlotta Mazzoldi

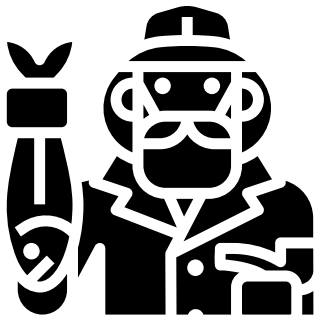
Christian Möllmann

Alessandra Conversi

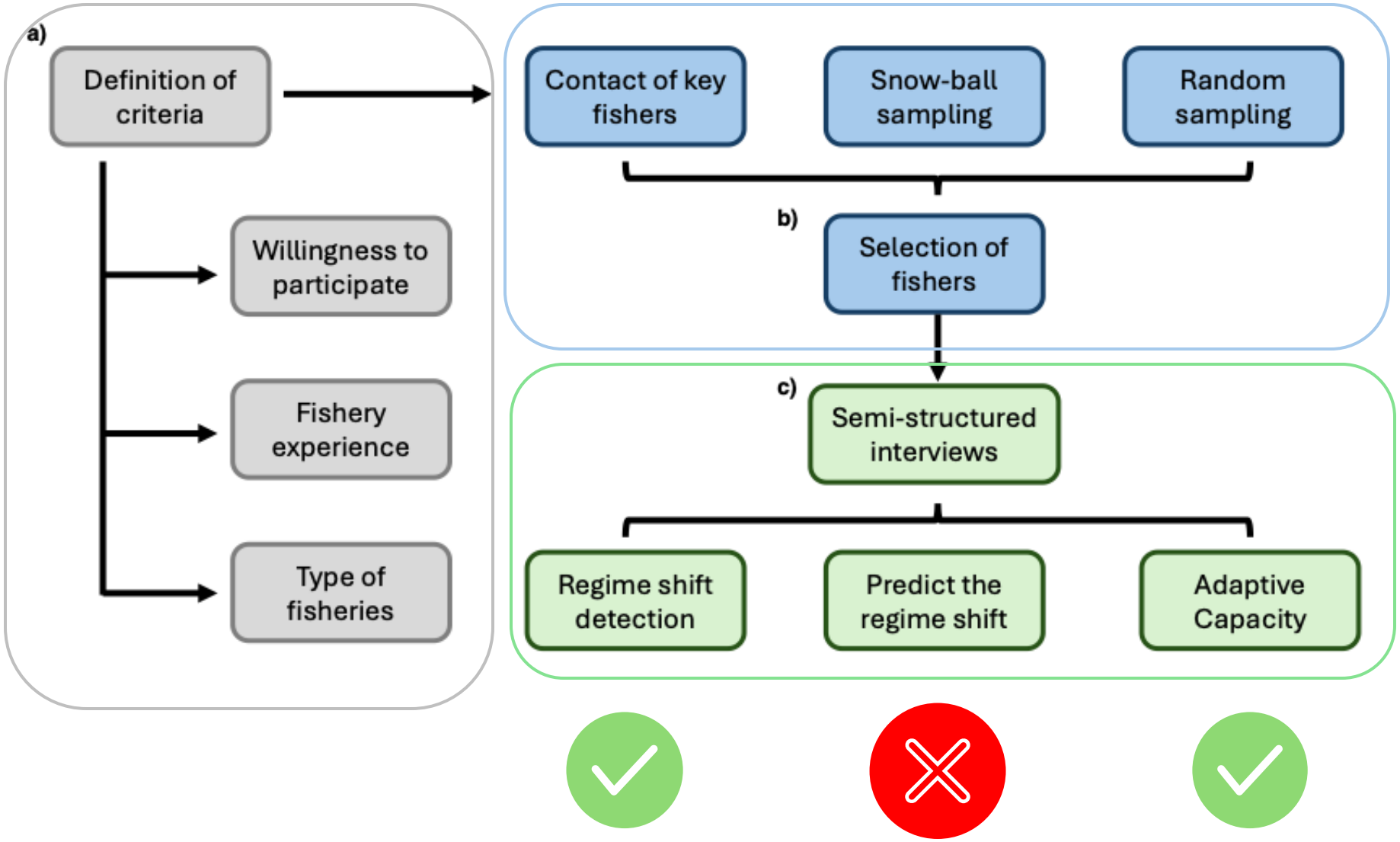


Can Local Ecological Knowledge anticipate tipping points?

Federica Panozzo



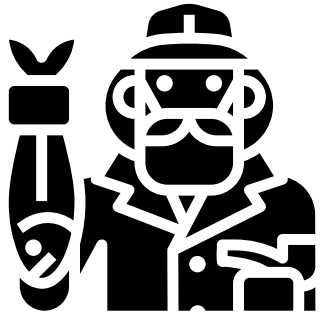
24 fishers interviewed



Panozzo et al in prep

Local Ecological Knowledge can provide information to monitor system

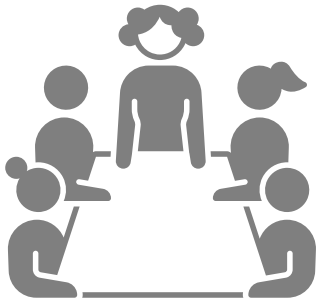
- The fishers **remembered the changes** that occurred in the three years identified as tipping points.
- They remembered **how** the catches changed but also they were able to reconsturct **causes** of the shifts.
- **They were not able to anticipate the shifts, but, retrospectively, they suggest potential indicators to monitor to antcipate tipping points**
- **Adaptive Capacity of the fishery was high**



Panozzo et al in prep

How to include regime shifts into policy? ReMSES

Participants ReMSES workshop, Chioggia, November 2023



24 scientists

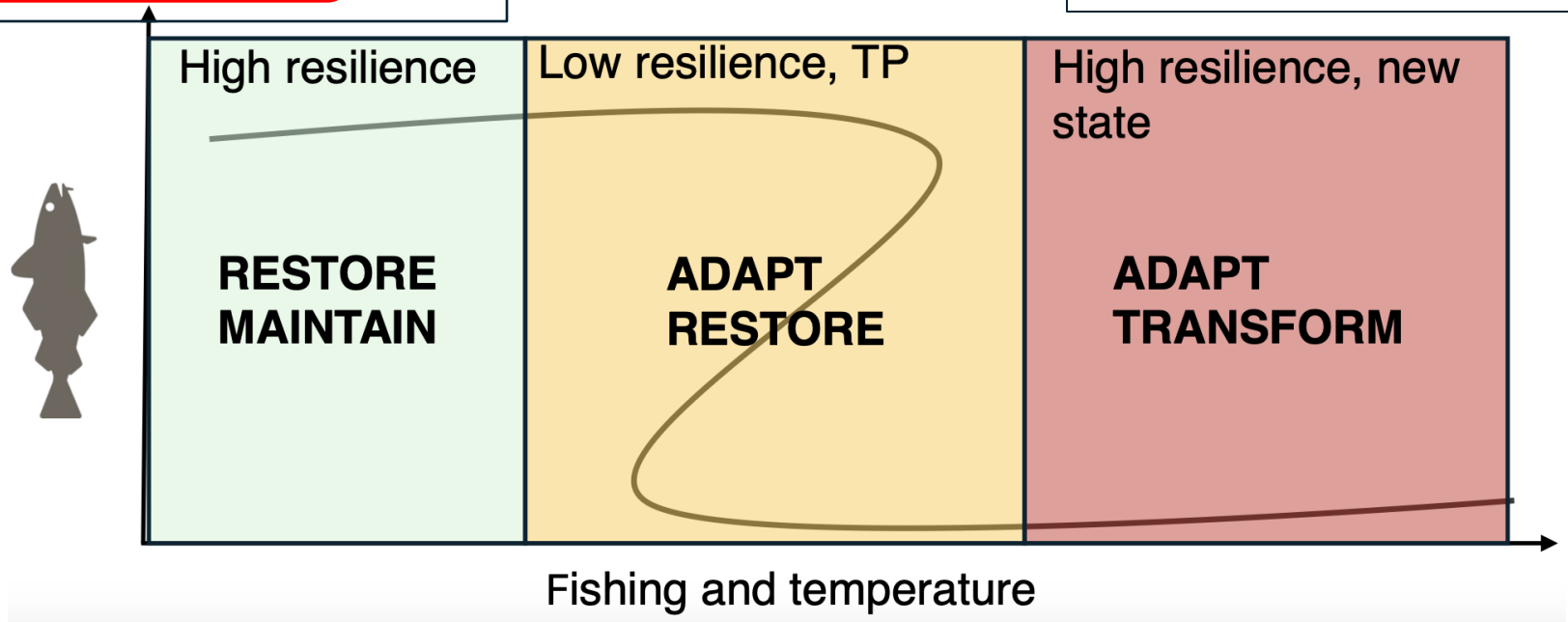
6 countries

Modellers
Social scientists
Experimental scientists

How to include regime shifts into policy? ReMSES

- **Integrate** different types of methods and data
- Understand **mechanisms and feedbacks**

- We might **not be able to cross** Tipping Point again

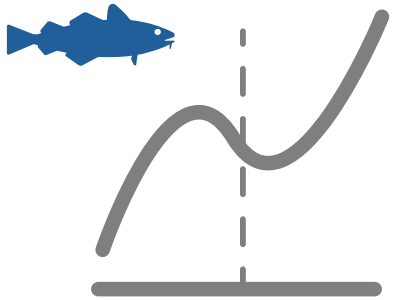


- Adopt an **operational** definition of resilience and tipping points
  - **Change societal and policy thinking**→ moving targets

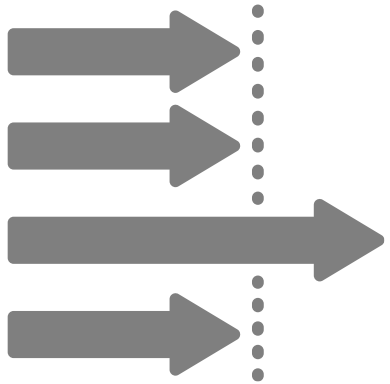
Sguotti et al in prep

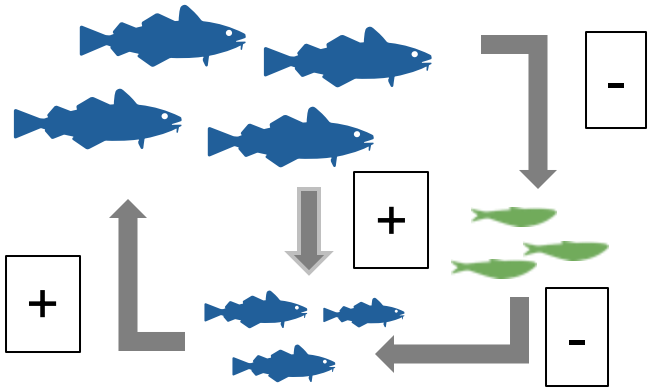
Moving towards feedbacks mechanisms…

Understanding the **feedbacks** is the key!



Analyses of the **state of the system**





Process-based approach to understand feedbacks

European Research Council

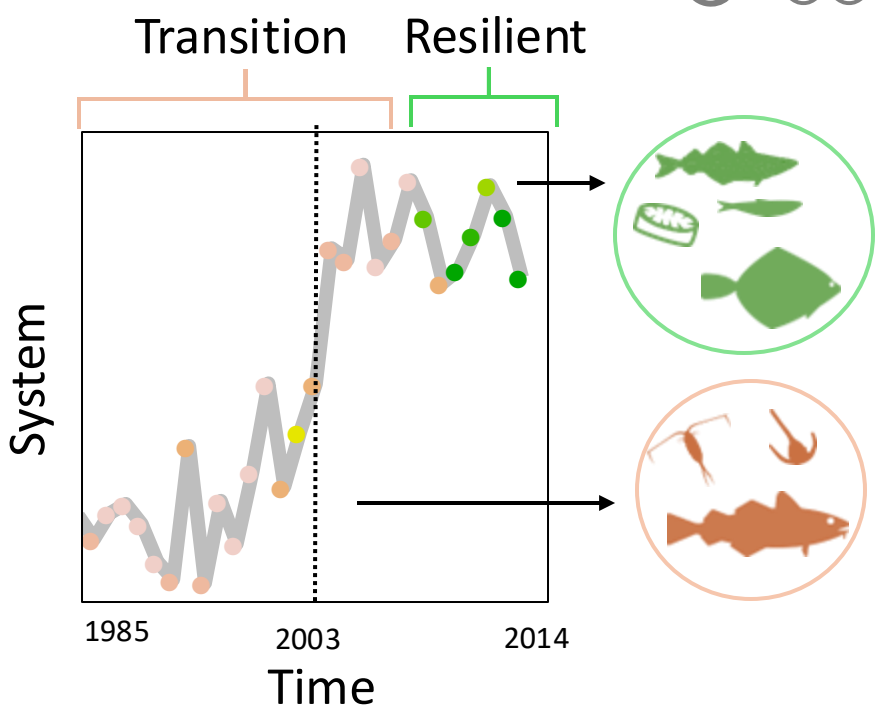
Established by the European Commission

FEEDRES will build an innovative framework based on process-informed **statistical modelling** to reach an **understanding of mechanisms of regime shifts.**

FEEDRES Basic Methods

Characterize elements and interconnections of systems during the different regime shift phases

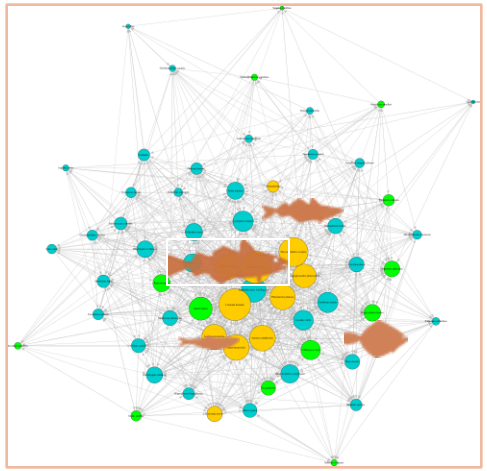
Apply CUSPRA

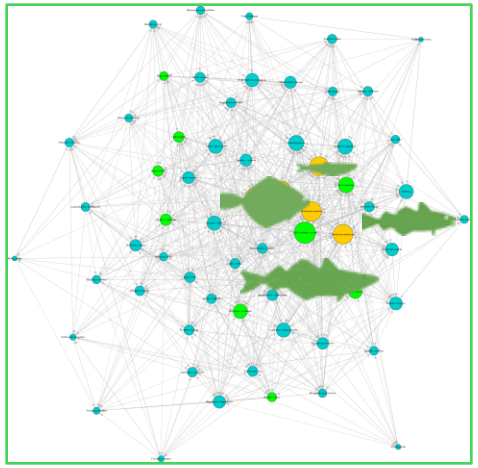


Sguotti et al., 2024

Detect structural links

Convergent Cross Mapping
Body Size Network
Matrix Community model

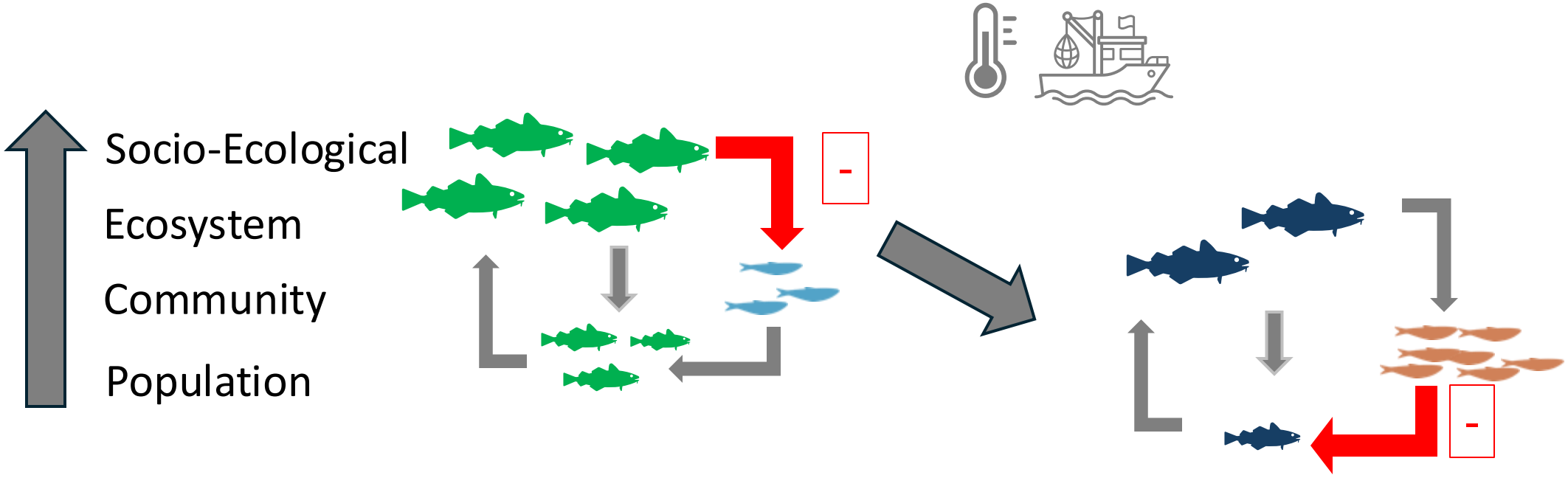




Gravel et al., 2013; Sugihara et al., 2014; Lytle & Tokin 2023

WP3: Detect feedbacks of regime shifts

1. Feedbacks models with Stella Architect



Mechanisms

Detect feedbacks and estimate their relative importance

Conclusions

- **Understanding and anticipating** tipping points is fundamental in an epoch of global changes
- **Multiple methods** need to be adopted in order to have more confidence that a tipping point occurred or will occurr in a system
- While **estimating resilience** and modelling tipping point is **crucial**, a step forward needs to be made to **identify feedback mechanisms** in complex systems

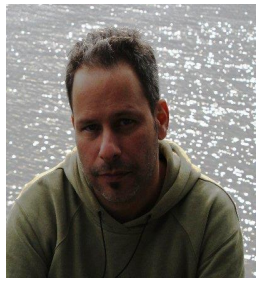
Integrate resilience and tipping points into management approaches in order to manage systems under global changes!!

Thank you for the attention!!










Questions?
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