MODULE 3 - RESILIENCE IN MARINE SYSTEMS: CONCEPTS AND PRACTICE

Susa Niiranen

susa.niiranen@su.se

STOCKHOLM UNIVERSITY (SU)

BRIDGE-BS

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No:101000240.

1. WHY TO CARE ABOUT RESILIENCE?

Why is understanding resilience important?

- **In ecosystems**, resilience refers to the ability to **retain essential functions, structures and feedbacks** when faced with external stress (Folke 2006, also used in BRIDGE-BS)
- Resilience implies a degree of predictable behavior making it **a key characteristic often valued by managers.**
- In the context of ecosystem services, resilience supports ecological stability and often ensures the sustained delivery of benefits to people.
- Mapping current resilience and discovering/measuring resilience promoting properties contributes towards assessing the **safe operating space (SOS) of social-ecological systems (SES).**

Ecosystem Services (ES) = benefits that people derive from ecosystems, such as oceans (MEA, 2005).

Safe Operating Space (SOS) = the environmental conditions within which humanity can develop and thrive for generations without causing unacceptable, potentially irreversible earth system changes (Rockström *et al.* 2009)

Resilience in marine systems and BRIDGE-BS project

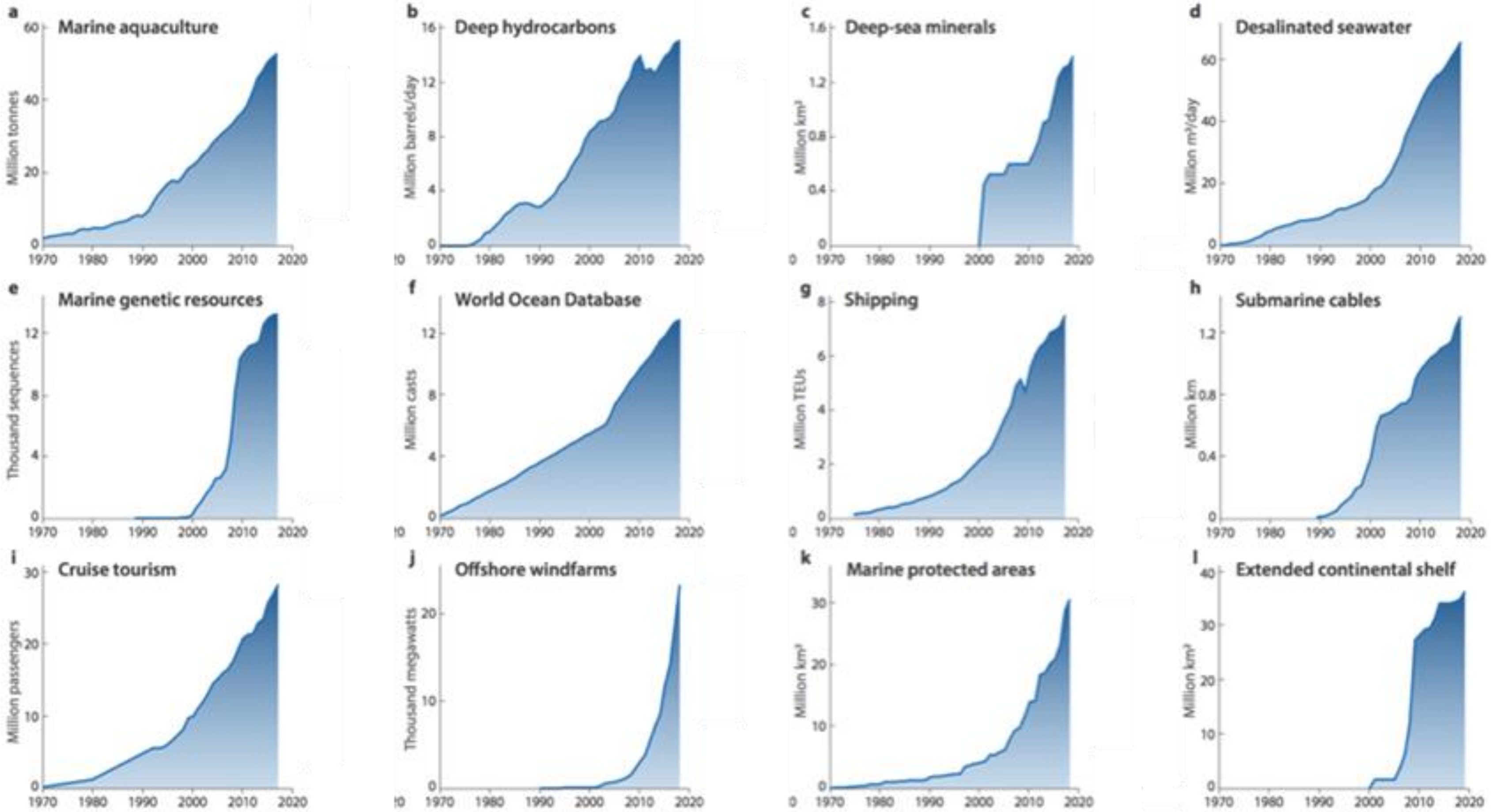
Regime shifts and loss of resilience has been observed and studied in several marine and ocean systems during the past decades (e.g. Pacific, Baltic Sea, NE Atlantic)

In BRIDGE-BS project we assess the resilience of the Black Sea ecosystems and SES, and identify the key functions that provide for sustainable ecosystem service (ES) production under different social-ecological (SES) conditions by:

- Identifying key state variables (indicators), drivers and their relationships
- Analysing past tipping points, as well as the current state of (S)ES resilience
- Studying ecosystem tipping points and ES resilience in future scenarios using modelled data

Both quantitative and more qualitative resilience assessment methods are used in BRIDGE-BS.

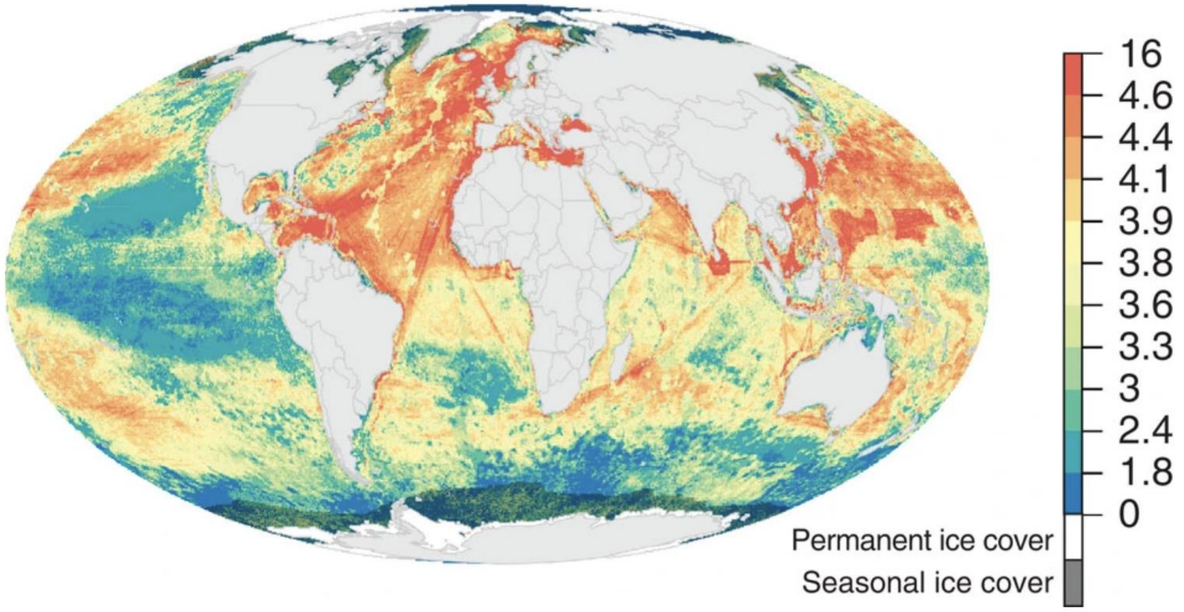
Why is resilience so important? The *blue acceleration*



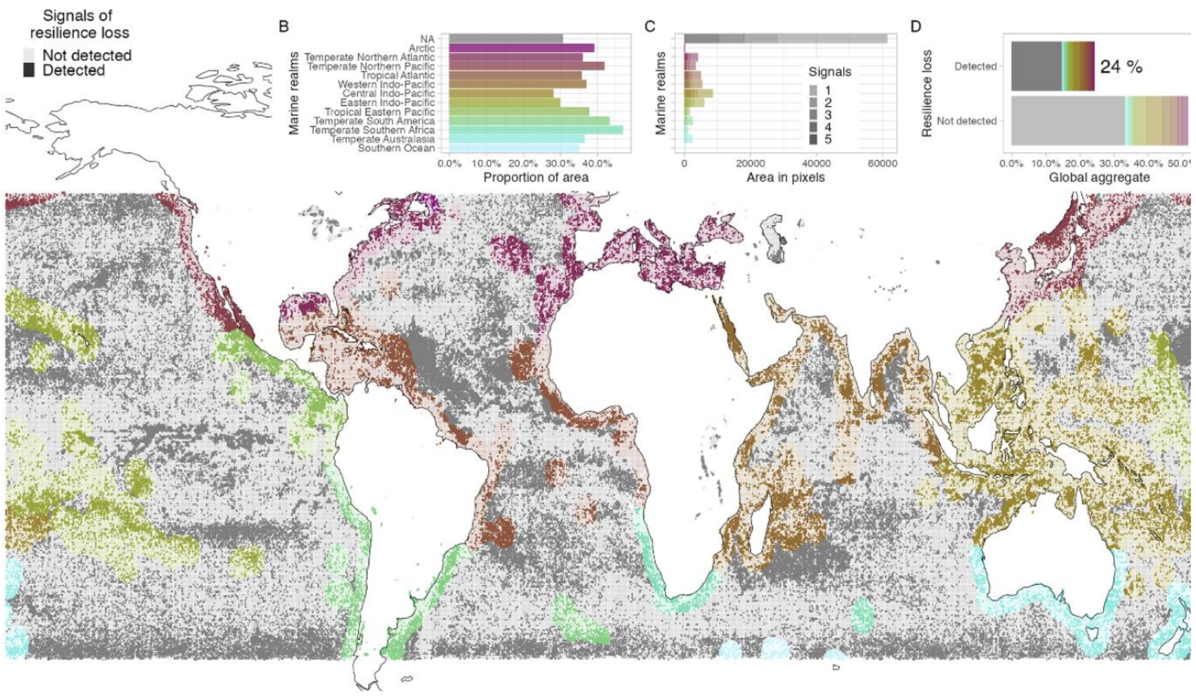
Jouffray et al. 2020
One Earth

Why is resilience so important? *Global loss of ecological resilience*

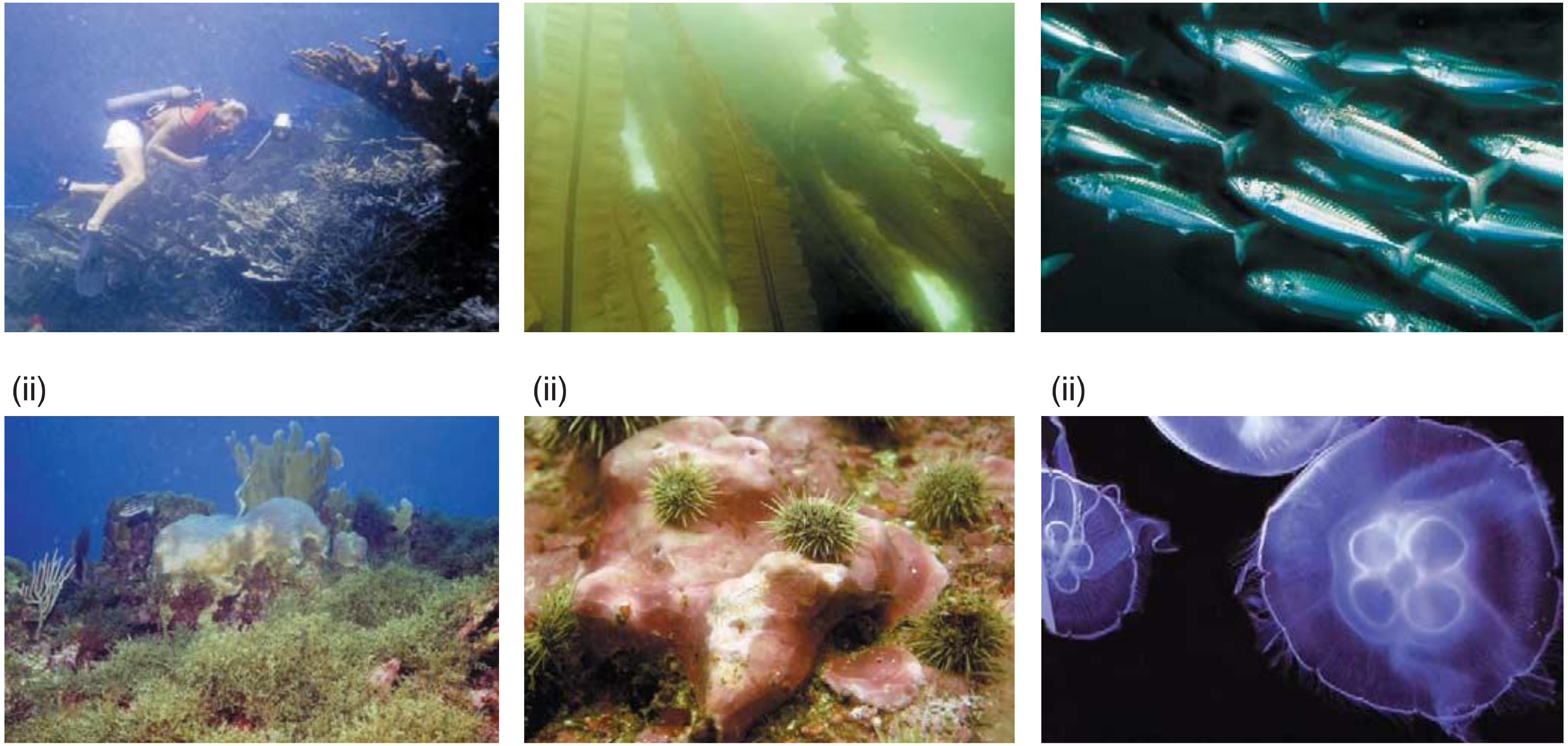
Cumulative impacts on oceans (Halpern *et al.* 2015)



24% of ocean ecosystems show resilience loss (Rocha 2022)



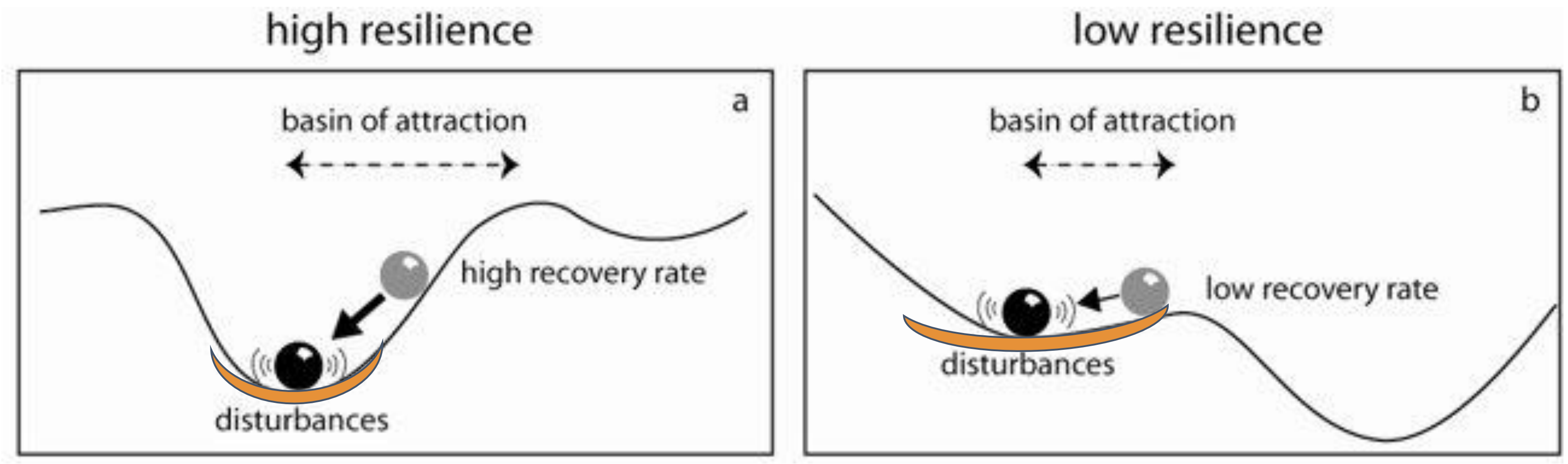
Regime shifts are a result of perturbation exceeding the system-specific resilience (resulting in changes in system identity, i.e. structure, function and feedbacks)



(Hughes et al. 2005)

2.DEFINITIONS OF ECOLOGICAL AND ENGINEERING RESILIENCE

Resilience loss and tipping points

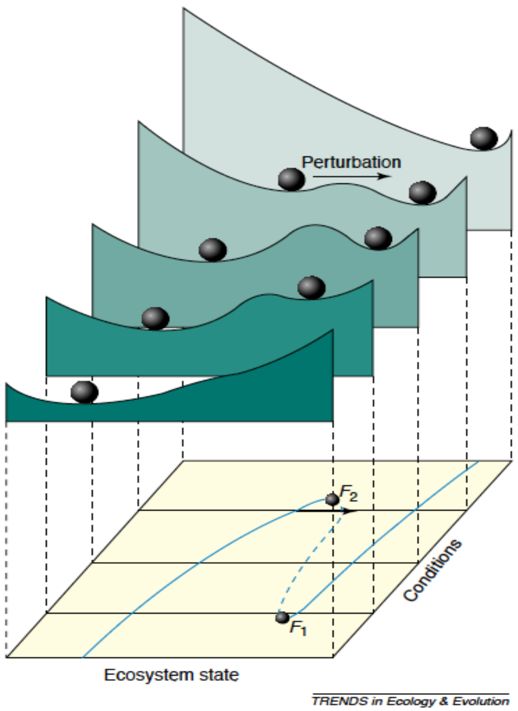


(Van Nes & Scheffer, American Naturalist 2007)

Ecosystem properties have an important role in defining the size of the "basin of attraction" and how resilient the ecosystem is towards different stressors.

Ecosystem vs. Engineering resilience?

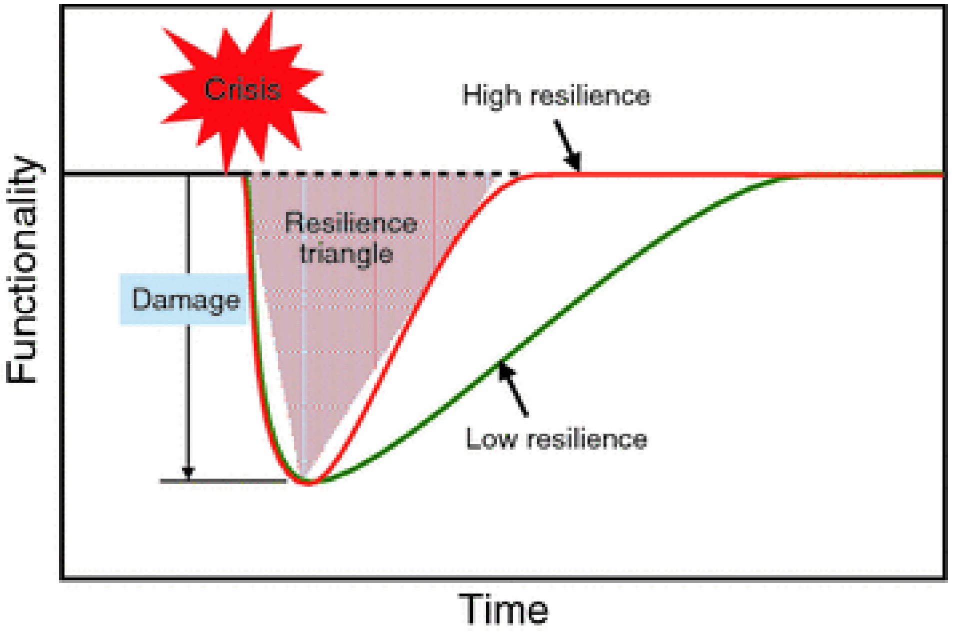
ECOSYSTEM RESILIENCE



The capacity of a system to absorb shocks and perturbations and **retain structure, functioning and feed-backs**
(e.g., Scheffer et al. 2003 (fig.), Walker et al. 2004)

ENGINEERING RESILIENCE

time

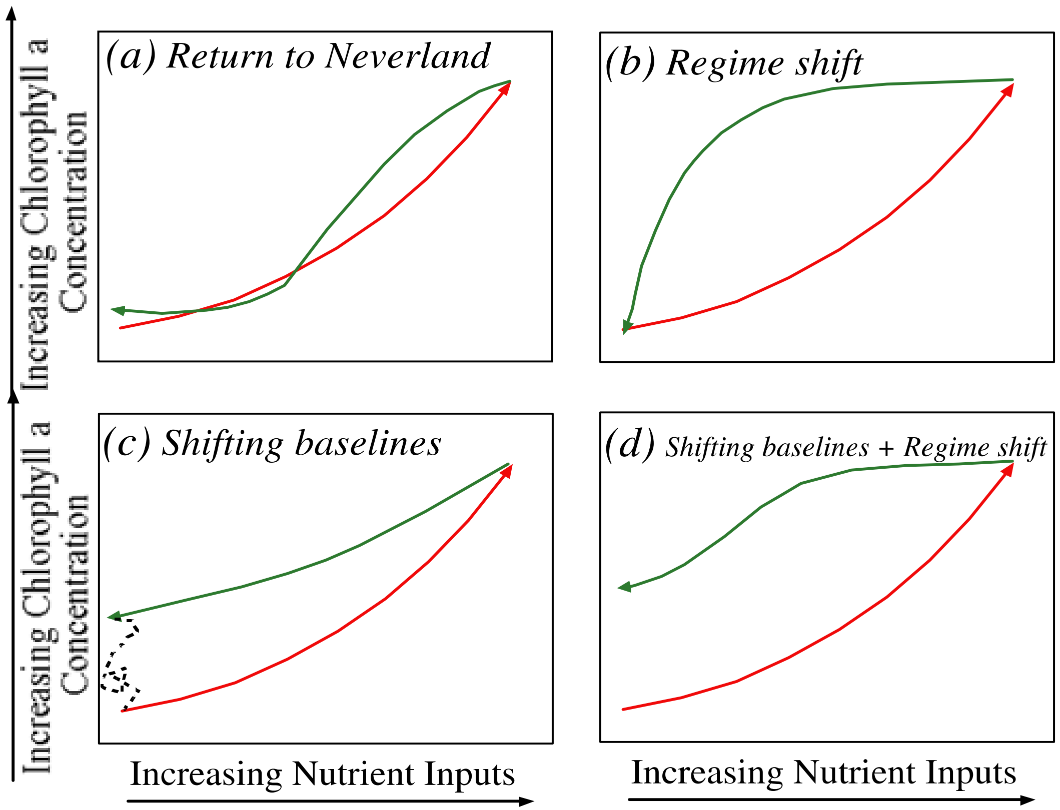


The **time** it takes for a system to **regain its original level of functionality** after a perturbation or shock.
(e.g., Furuta 2014 (fig))

Ecological vs. Engineering resilience?

- **Engineering resilience** is quite a popular concept as it is directly linked to recovery and is as such intuitive for managers
- **But it may be a bit too simple:**
  - after a disturbance the system recovery can be quite unique as it depends on system complexity and multiple driver interactions
  - After recovery the system may look similar, but it is often not the same as before (i.e. functions differently) → significance for management

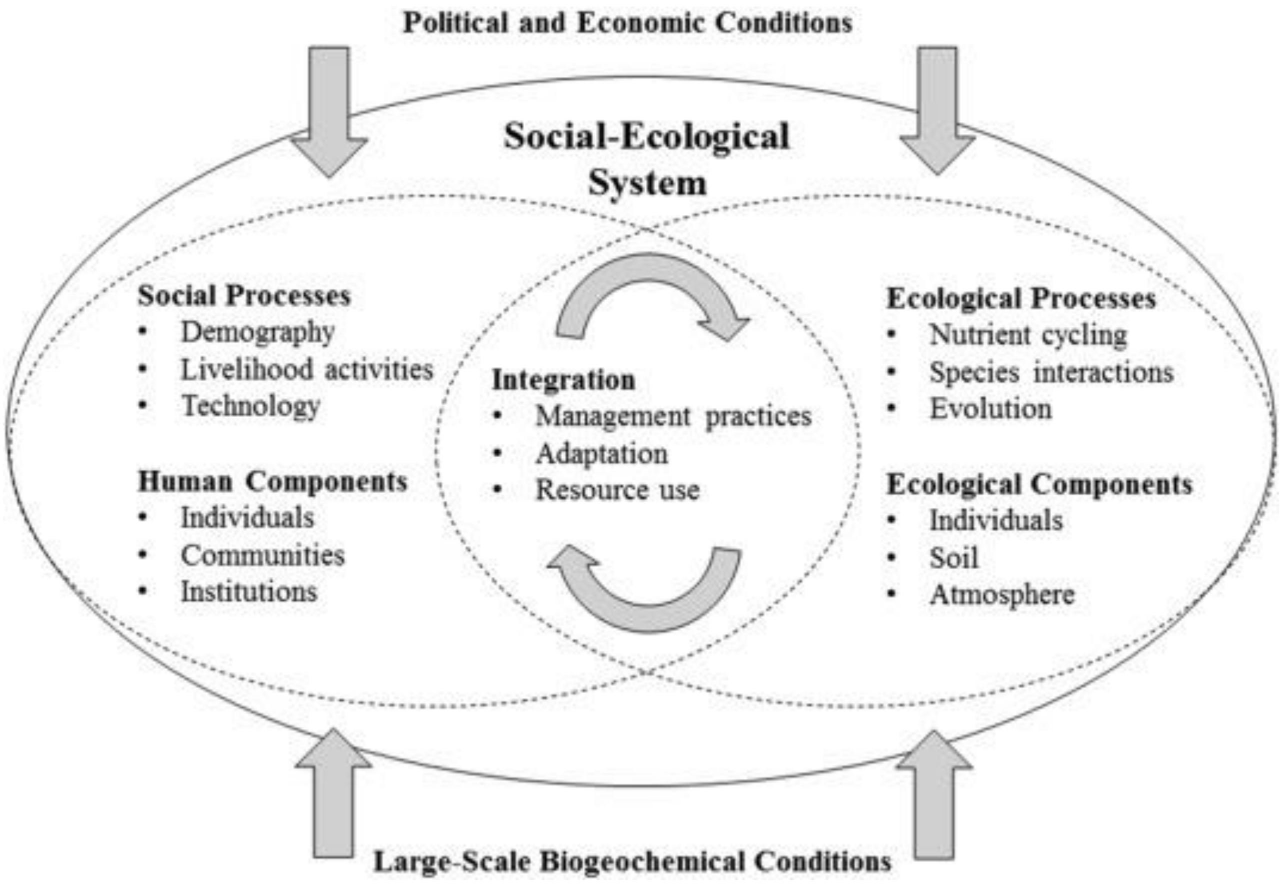
Recovery and shifting baselines



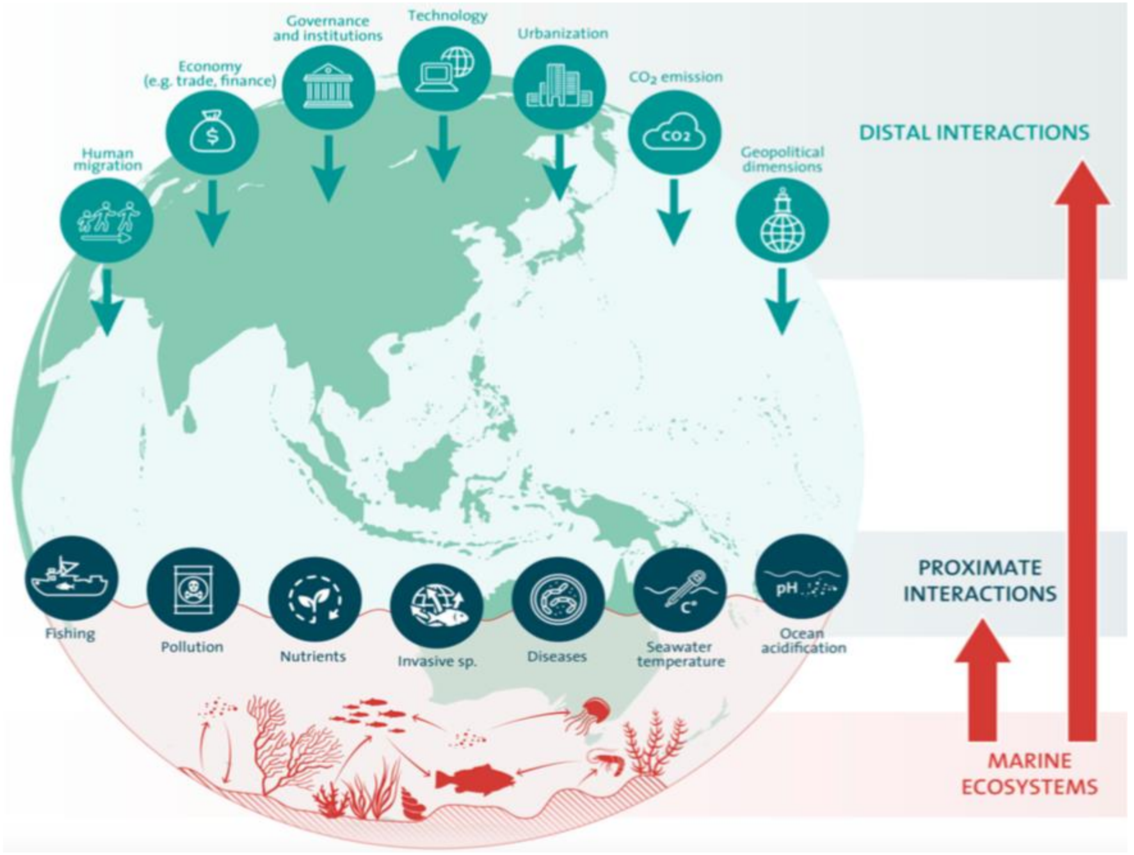
(Duarte et al 2009)

3. DEFINITION OF SOCIAL-ECOLOGICAL (SES) RESILIENCE

Oceans as complex social-ecological systems



(Virapongse *et al.* 2016)



Cross-scale interactions (Österblom *et al.* 2017)

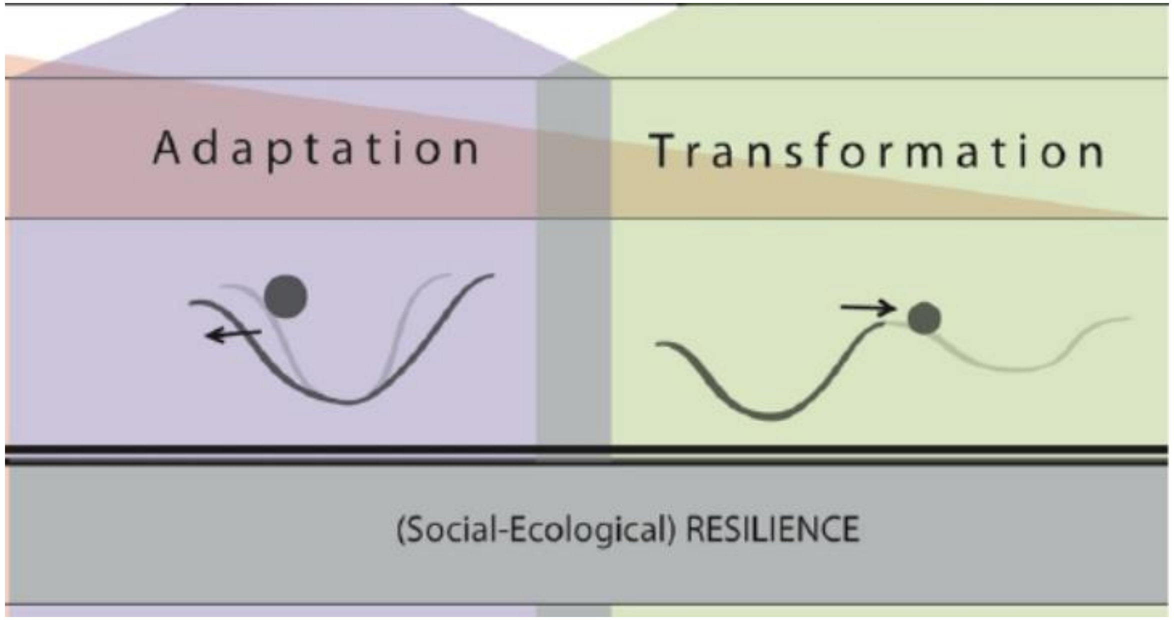
Social-ecological (SES) resilience

SES resilience = The capacity to sustain human well-being in the face of change, both by **buffering** shocks and through **adapting** and **transforming (**e.g., Folke *et al.* 2016**)**.

Resilient SESs:

- persist
- **adapt** (a process that enables a system to maintain its identity, so that it is better able to cope with trends and shocks, or to reduce vulnerability to disturbance)
- **transform** (a shift in a current system to a substantial new and different one)

Adaptation vs. transformation:



(Adapted from Chelleri and Olazabai 2012)

Persistence in resilience: Is it always good?

- For a long-time resilience has focused on absorbing shocks and maintaining function → beneficial for predictability
- However, there are other aspects: e.g. capacity for renewal, re-organisation, and development that are likely to be more relevant for e.g. sustainability
- In a resilient SES, disturbance has the potential to create opportunities for innovations and potentially transformation

Enhancing Ecosystem Service (ES) resilience – the seven principles (Biggs et al. 2012)

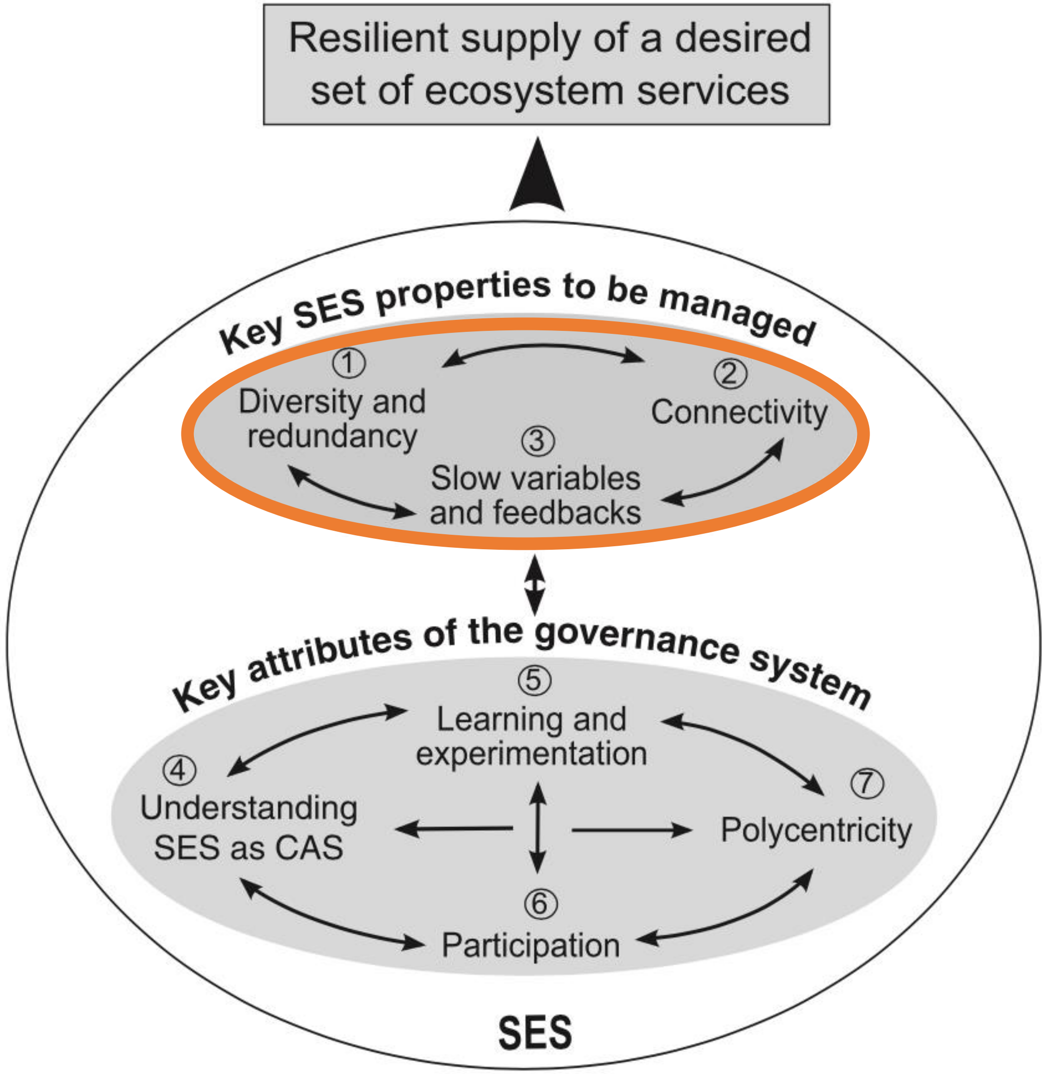


Figure 1

The seven principles reviewed in this paper, grouped into those that relate to generic social-ecological system (SES) properties to be managed and those that relate to key properties of SES governance. Abbreviation: CAS, complex adaptive systems.

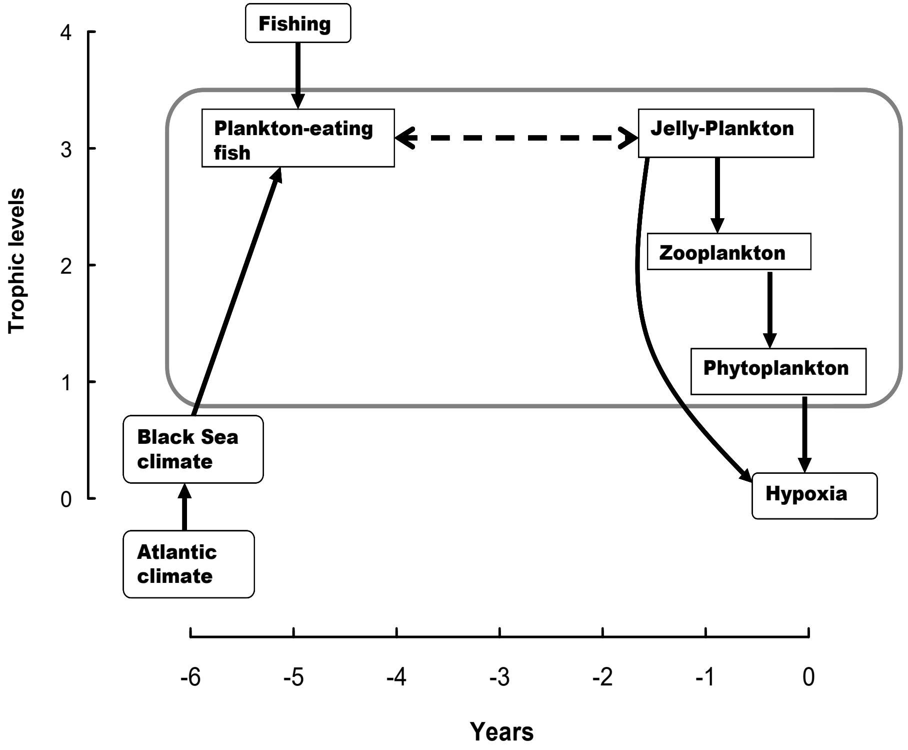
4. RESILIENCE ASSESSMENTS WITHIN THE BLACK SEA CONTEXT (BRIDGE-BS PROJECT)

Examples of resilience loss: Black Sea regime shift

Black Sea is one of the marine ecosystems that has historically undergone a clear change (i.e. regime shift) in ecosystem state.

(ii)

(fig. from Hughes *et al.* 2006)

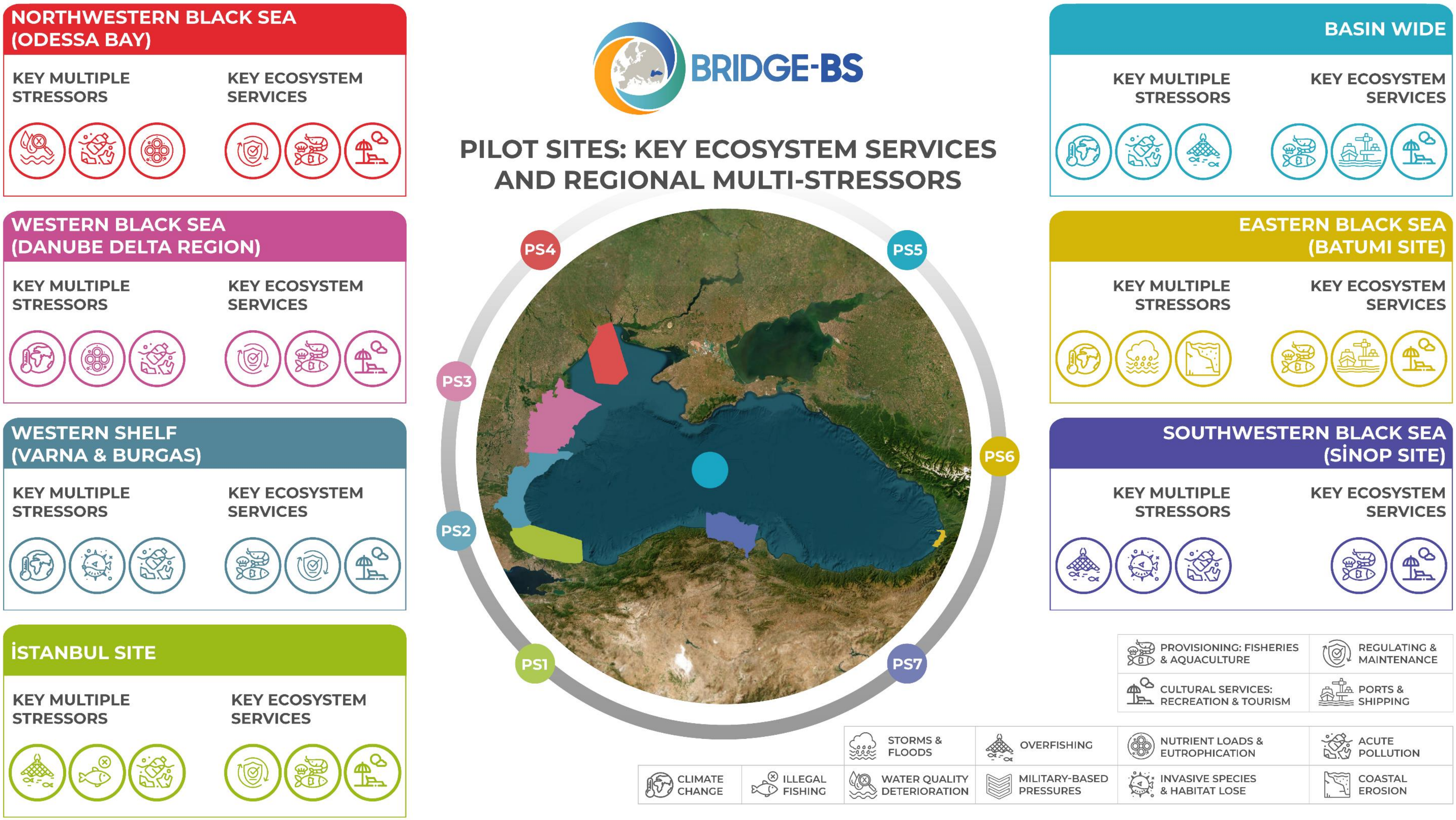


(Daskalov *et al.* 2017)

Resilience assessments using time-series data

In BRIDGE-BS we explored the **dynamics of Black Sea Ecosystem and SES resilience** using available time series and modelled data to…

1. Study different ecosystem and SES states (in fisheries) and how they respond to drivers
2. Identify tipping points
3. Assess the distance of the system to these tipping points


BRIDGE-BS
PILOT SITES: KEY ECOSYSTEM SERVICES AND REGIONAL MULTI-STRESSORS
NORTHWESTERN BLACK SEA (ODESSA BAY)
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
WESTERN BLACK SEA (DANUBE DELTA REGION)
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
WESTERN SHELF (VARNA & BURGAS)
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
İSTANBUL SITE
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
BASIN WIDE
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
EASTERN BLACK SEA (BATUMI SITE)
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
SOUTHWESTERN BLACK SEA (SİNOP SITE)
KEY MULTIPLE STRESSORS
KEY ECOSYSTEM SERVICES
PS4
PS5
PS3
PS6
PS2
PS1
PS7
PROVISIONING: FISHERIES & AQUACULTURE
REGULATING & MAINTENANCE
CULTURAL SERVICES: RECREATION & TOURISM
PORTS & SHIPPING
STORMS & FLOODS
OVERFISHING
NUTRIENT LOADS & EUTROPHICATION
ACUTE POLLUTION
CLIMATE CHANGE
ILLEGAL FISHING
WATER QUALITY DETERIORATION
MILITARY-BASED PRESSURES
INVASIVE SPECIES & HABITAT LOSE
COASTAL EROSION

Integrated Resilience Assessment

(Vasilakopoulos and Marshall 2015, Vasilakopoulos *et al.* 2017)

STEP1. COMPLEXITY REDUCTION

- Identifying key variables (indicators) of change

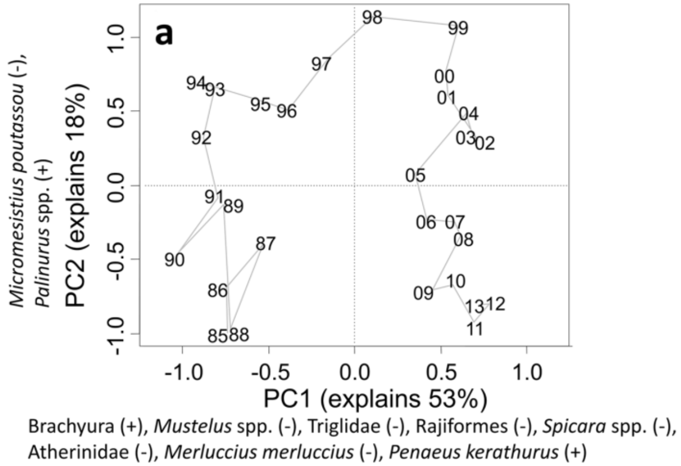
STEP2. EXPLORING THE DRIVER-STATE RELATIONSHIPS AND POTENTIAL TIPPING POINTS (GAMs/TGAMs)

- Identifying what is the type of response of (eco)system state to change in key drivers

STEP3. RESILIENCE ASSESSMENT

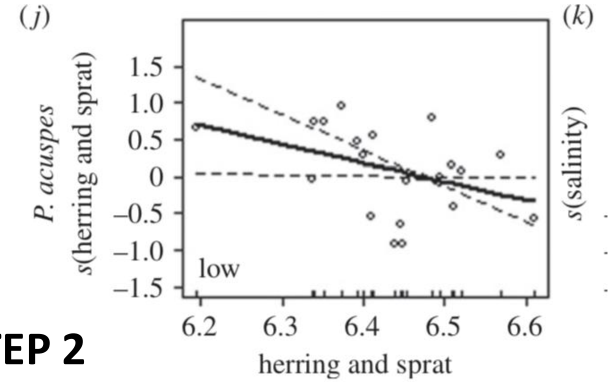
- Exploring relative resilience in time
- Drawing resilience landscapes

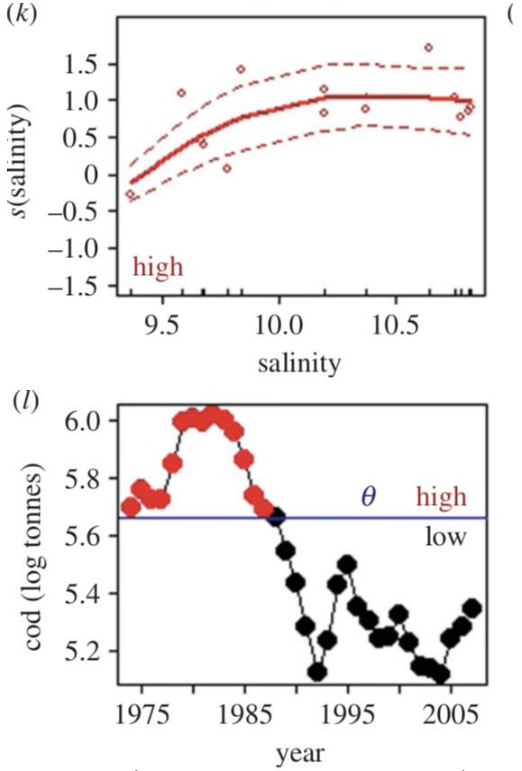
STEP 1



Vasilakopoulos *et al.* 2017)

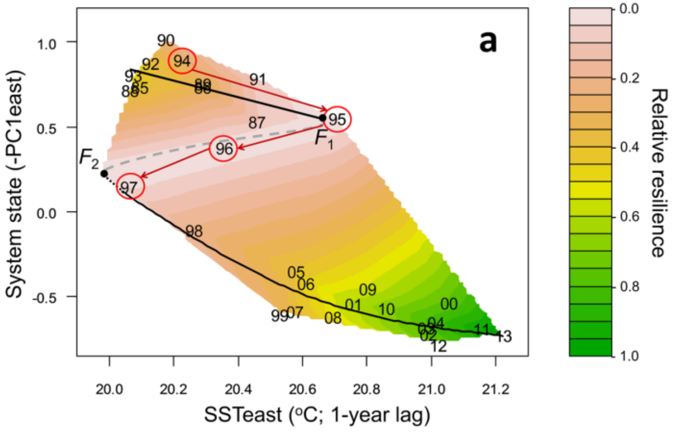
STEP 2





(Blenckner *et al.* 2015)

STEP 3

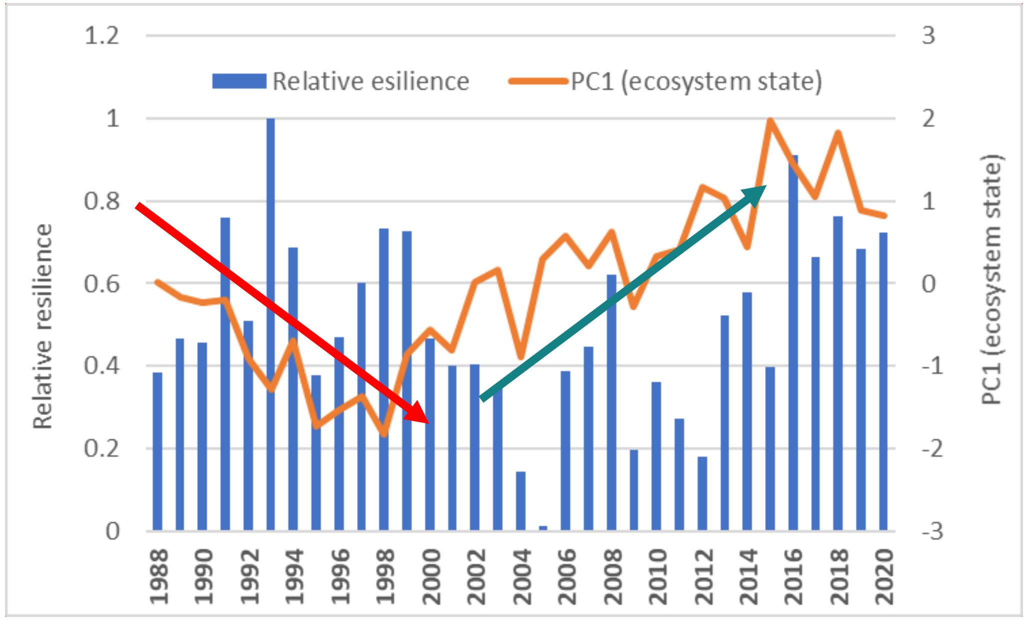


Vasilakopoulos *et al.* 2017)

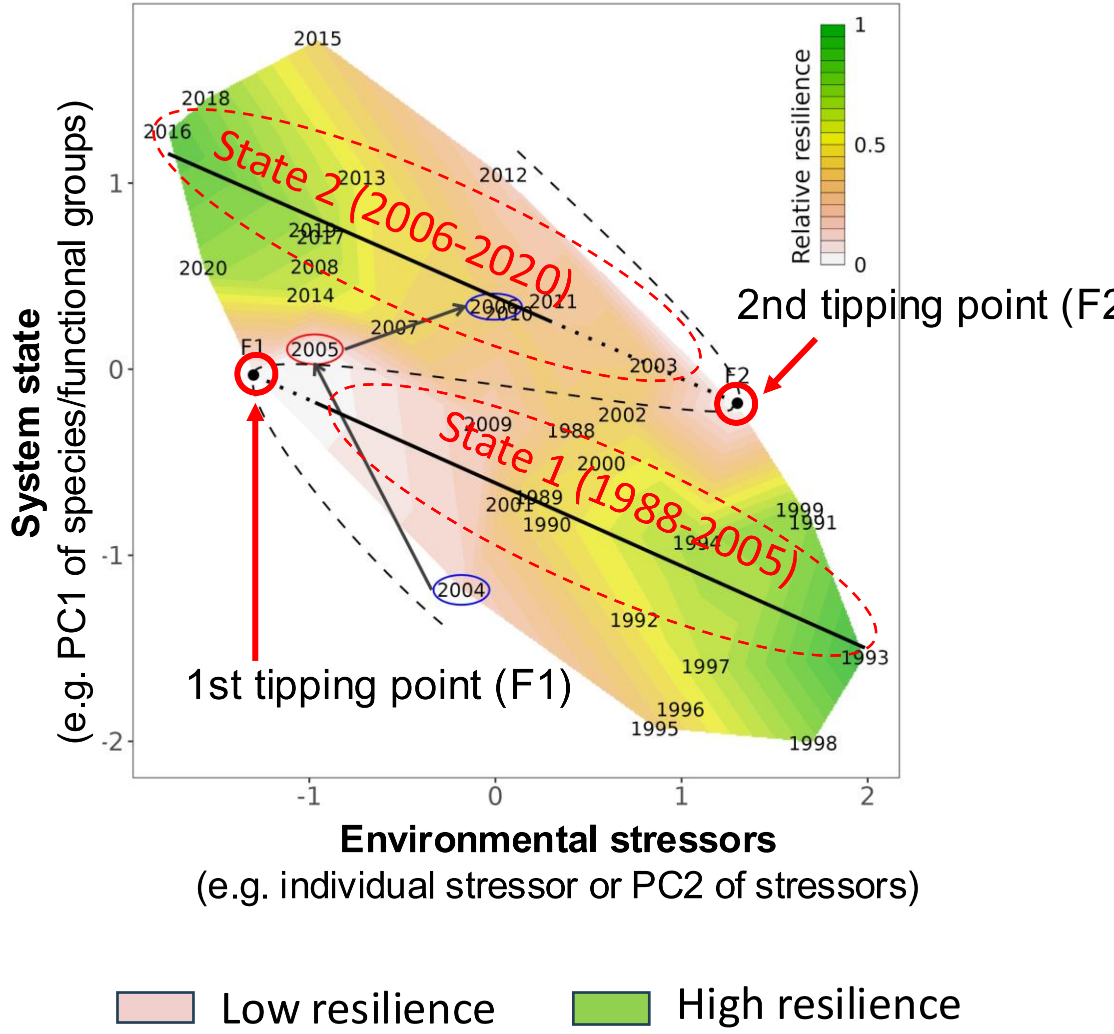
Resilience landscapes (basin-scale analysis, Daskalov *et al.* In prep)

- A full integrated resilience assessment (IRA) on ecosystem data across 4 TLs (phytopl, zoopl, jellyfish, planktivores) for 1988-2020.

- A shift was indicated at around 2005, when the system was shown to change state (possibly towards previous conditions)

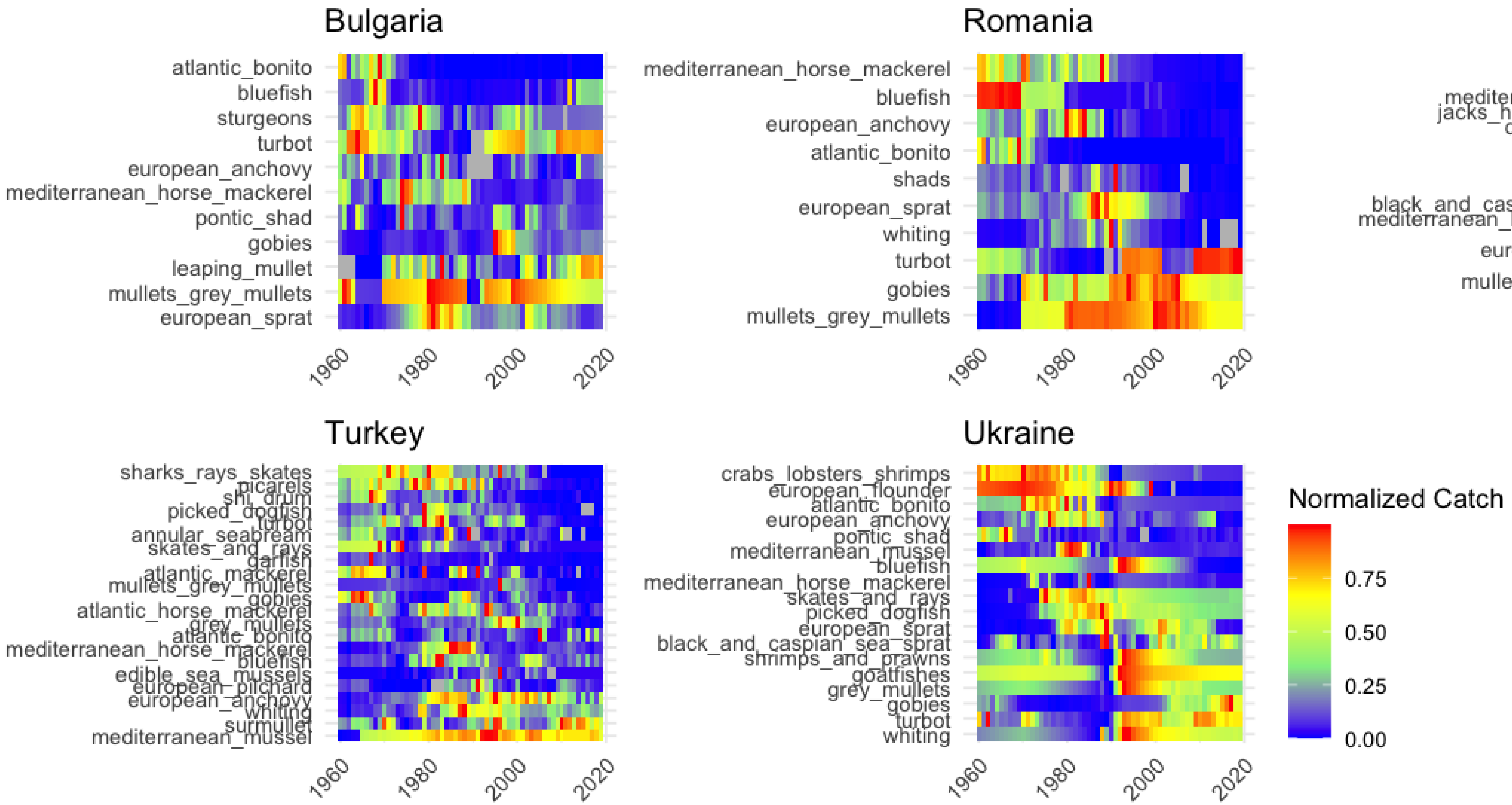


Example on Black Sea data (Daskalov et al., in prep):



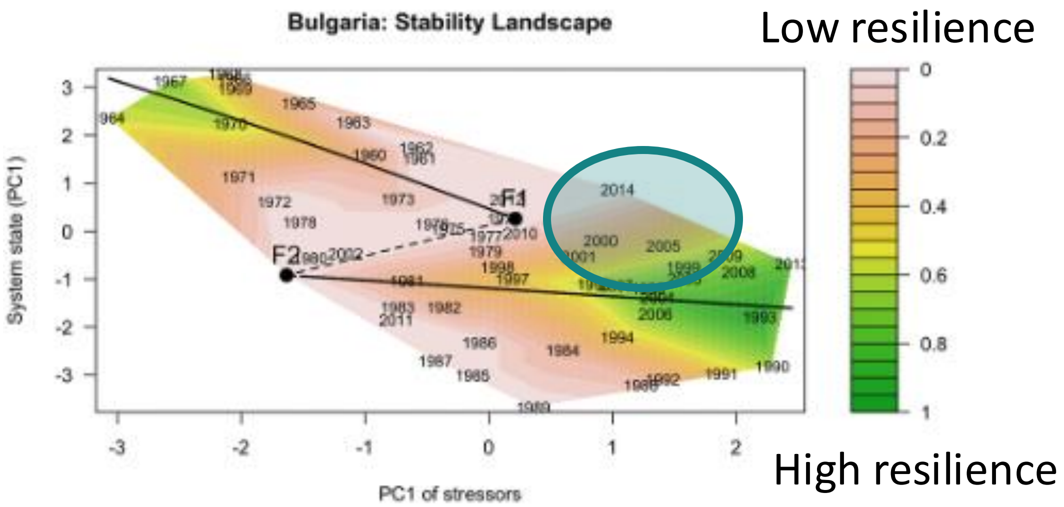
Resilience landscapes (EEZ-scale, Laznya *et al.* In prep)

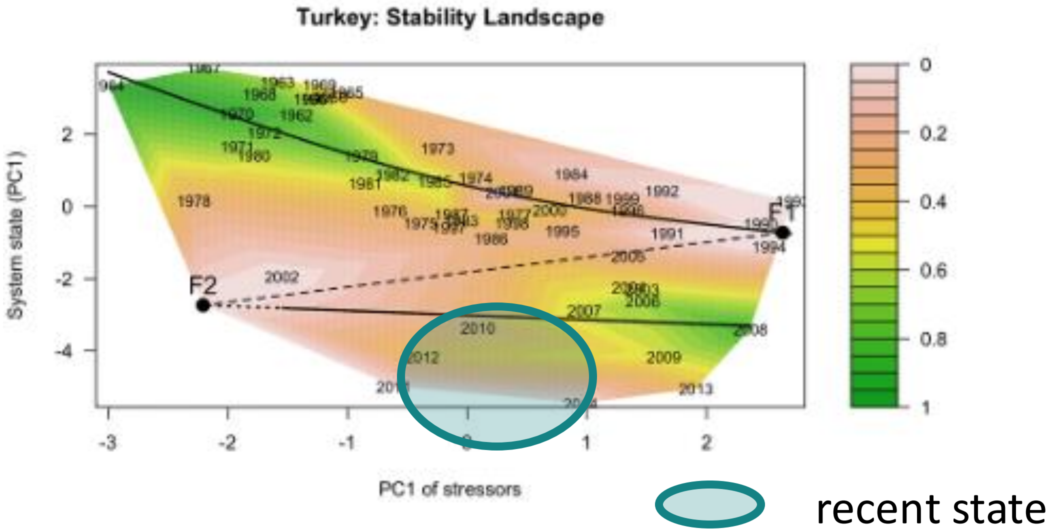
Fish landings data at EEZ level used from the Sea Around Us data base (1960-2020)



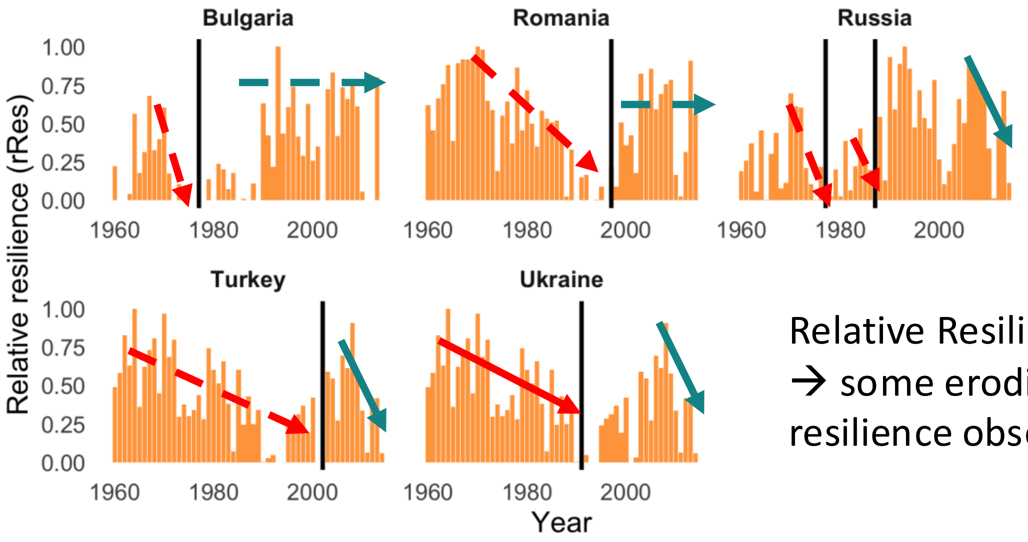
Heatmaps describing the change in landings composition caught at different BS EEZs

Resilience landscapes (SES landings – EEZ-scale, Laznya *et al.* In prep)





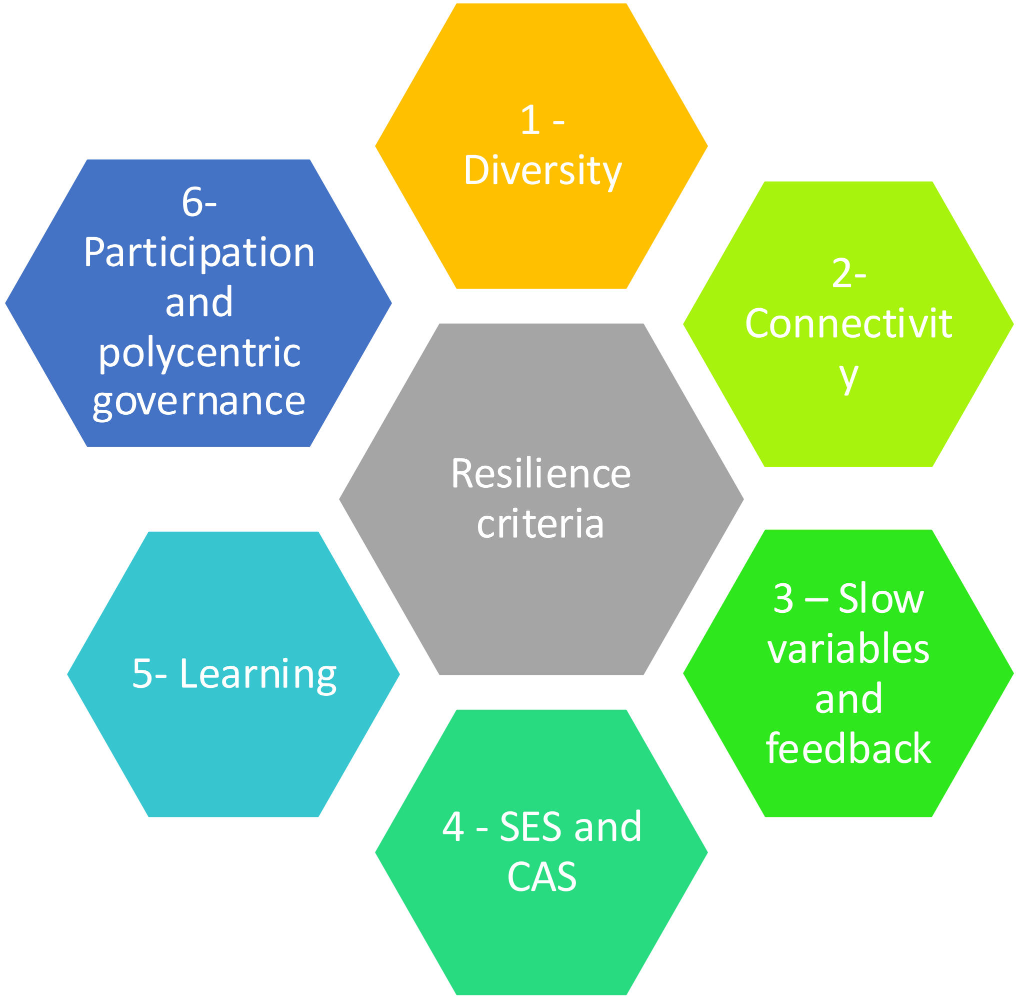
- A full SES IRA on EEZ-specific fish landings (PC1 of species landed)
- Stressors included: SST (winter), NAO, EAWR and fishing effort
- $PC1_{stressors}$ explained most variation in relation to $PC1_{landings}$ and was used for analysis: effort explained most variation in $PC1_{stressors}$



Relative Resilience Index
→ some eroding resilience observed

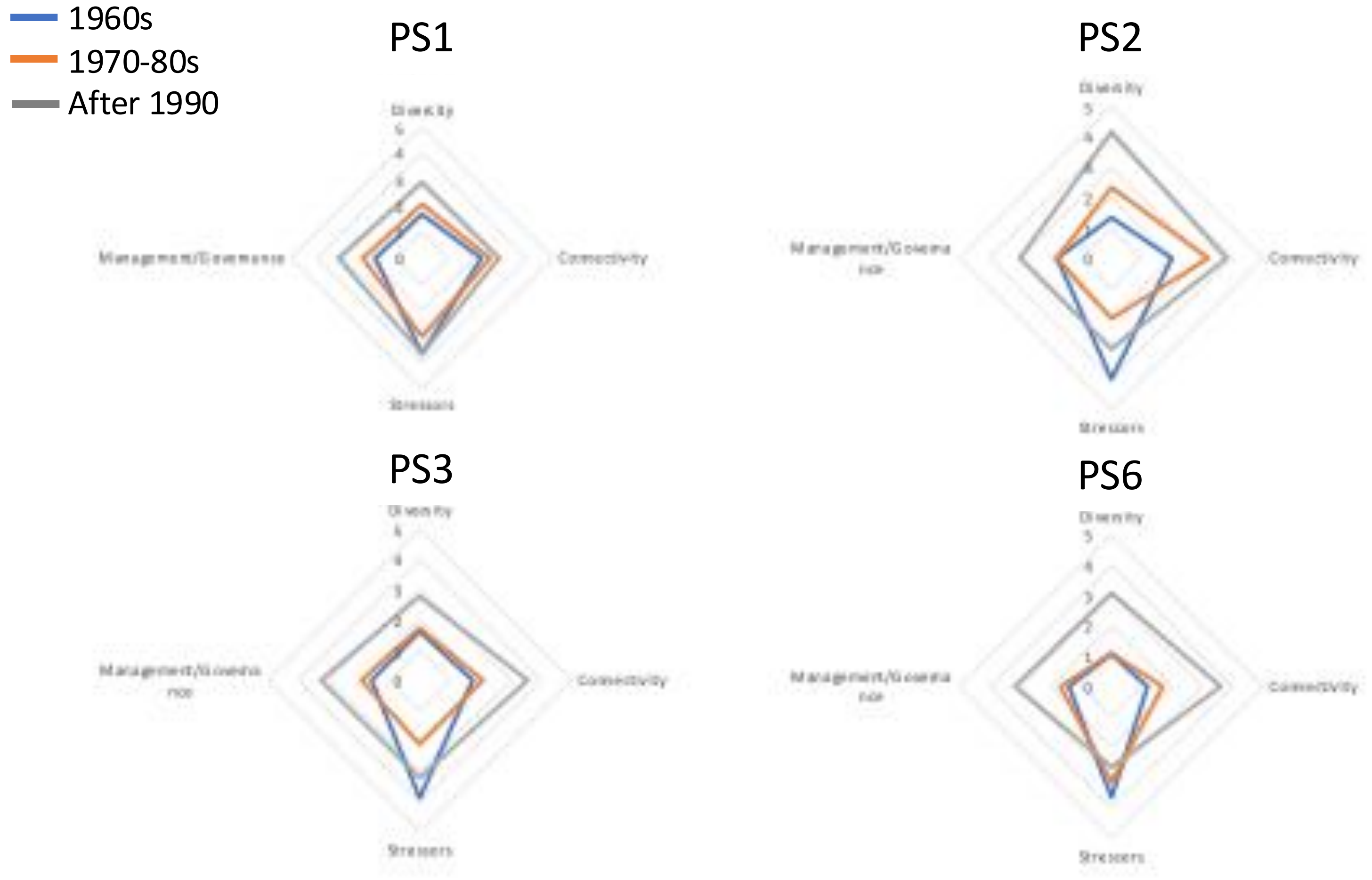
ES resilience (qualitative assessment – Bridge-BS Pilot site-scale, Laznya *et al.* in prep)

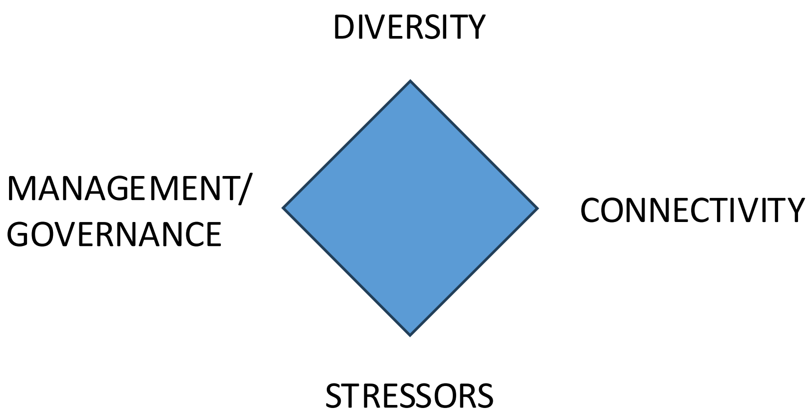
- ES resilience principles were used to identify the state of resilience promoting/eroding features across PSs in selected **regulating, cultural and provisional ESs**
- A questionnaire was issued to regional/local experts containing ES-specific questions relevant to the seven ES resilience principles (Biggs et al. 2012)
- In this questionnaire the respondents were asked to provide their answers on a Likert (1-5) scale for three different time-periods.
- A similar method has been presented in Salomon *et al*. 2019.



ES resilience (qualitative assessment – Pilot site-scale, Laznya *et al.* In prep)

Cultural ES example





- Diversity, management/ governance related and connectivity res. properties increased in time everywhere

Take home messages

- Resilience is a system property that is often seeked after by managers due to its connection to predictability
- **There are many definitions for resilience. The key is to be clear about what one is referring to!**
- There are important differences between Engineering, Ecological and SES resilience
- Measuring resilience is challenging, particularly prior to regime shifts taking place.
- IRA requires long time series of data across different ecosystem components and drivers. However, resilience assessments can also be carried out using more qualitative methods and expert knowledge
- Due to the historical shifts in ecosystem state, Black Sea is one of the systems, where carrying out resilience assessment is of particular interest

Key References

- Biggs, R., et al. (2012) Toward Principles for Enhancing the Resilience of Ecosystem Services. Annual Review of Environment and Resources, 37, 421-448.
- Daskalov, G.M., Boicenco, L., Grishin, A.N., Lazar, L., Mihneva, V., Shlyakhov, V.A. and Zengin, M. (2017), Architecture of collapse: regime shift and recovery in an hierarchically structured marine ecosystem. Glob Change Biol, 23: 1486-1498.
- Folke (2006). Resilience: The emergence of a perspective for social-ecological systems analysis. Global Environmental Change 16:253-267.
- Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, *21*(3).
- Vasilakopoulos, P. and Marshall, C.T. (2015), Resilience and tipping points of an exploited fish population over six decades. Glob Change Biol, 21: 1834-1847.
- Vasilakopoulos, P., Raitsos, D.E., Tzanatos, E. *et al.* (2017). Resilience and regime shifts in a marine biodiversity hotspot. *Sci Rep* 7, 13647.
- Salomon et al. (2019). Measuring social-ecological resilience reveals opportunities for transforming environmental governance. Ecology and Society, 24:3.

THANK YOU!

STAY TUNED!

bridgeblacksea.org

BRIDGE-BS

@BRIDGE_BlackSea

@BRIDGEBlackSea

BRIDGE Black Sea

BRIDGE Black Sea