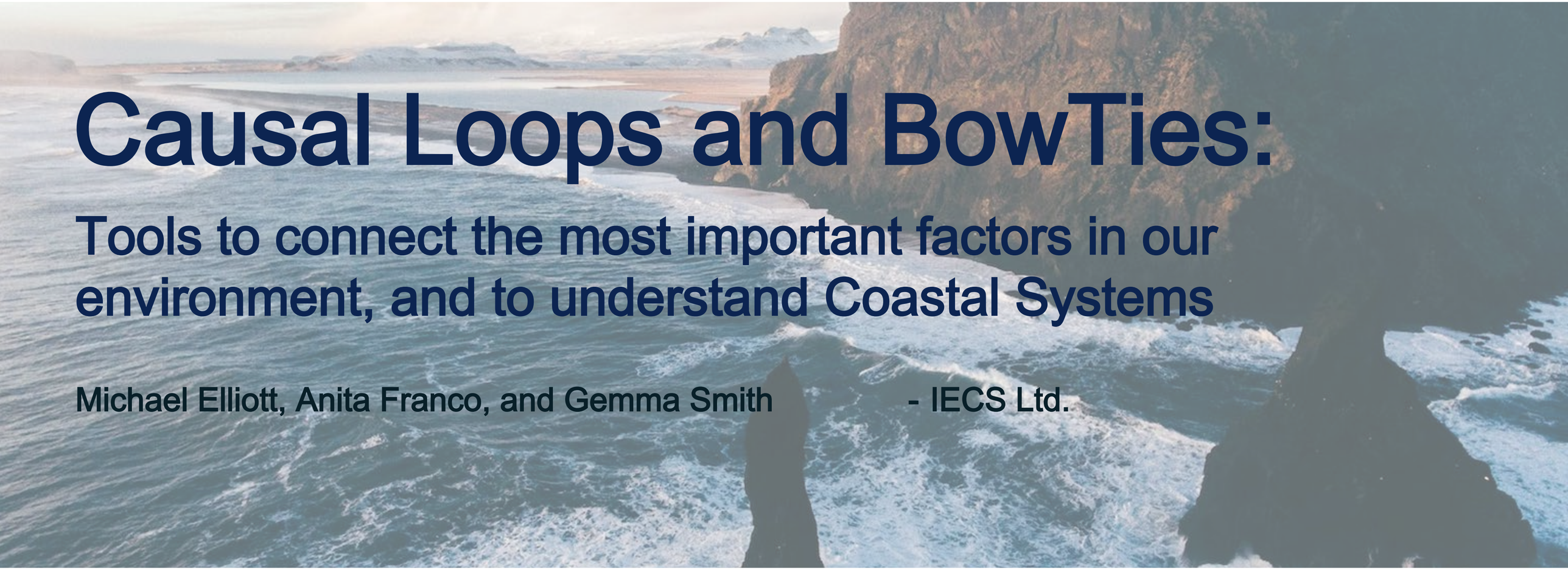

# Causal Loops and BowTies:

## Tools to connect the most important factors in our environment, and to understand Coastal Systems

Michael Elliott, Anita Franco, and Gemma Smith - IECS Ltd.

Funded by the European Union

# Objectives of the Session

1. Provide an overview of the Simple SES and Bow-Tie tools.
2. Explain how these may aid users in understanding a problem
3. Gain feedback and input from you as Stakeholder!

# Management Questions:

- Where are the problems & What changes do they cause?
- What is the impact of these on ecosystem structure and functioning?
- What are the repercussions for ecosystem valuation based on economy-ecology interactions?
- What are the future environmental changes and economic futures?
- What governance framework is there, what do stakeholders need?
- What can we do about the problems?
- Where are the risks and how to address them now and in the future?
- What are the governance successes, failures and implications?
- How ‘good’ is the decision-making?
- What are the bottlenecks, showstoppers and train-wrecks?

# Hazard & Risk Typology:

| Hazard leading to Risk (depending on assets) |
|---|
| A) Surface hydrological hazards |
| B) Surface physiographic removal by natural processes - chronic/long-term |
| C) Surface physiographic removal by human actions - chronic/long-term |
| D) Surface physiographic removal - acute/short-term |
| E) Climatological hazards - acute/short term |
| F) Climatological hazards - chronic/long term |
| G) Tectonic hazards - acute/short term |
| H) Tectonic hazards - chronic/ long term |
| I) Anthropogenic microbial biohazards |
| J) Anthropogenic macrobial biohazards |
| K) Anthropogenic introduced technological hazards |
| L) Anthropogenic extractive technological hazards |
| M) Anthropogenic acute chemical hazards |
| N) Anthropogenic chronic chemical hazards |
| O) Anthropogenic acute geopolitical hazards |
| P) Anthropogenic chronic geopolitical hazards |

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journal homepage: www.elsevier.com/locate/ocecoaman

Review

A typology of marine and estuarine hazards and risks as vectors of change: A review for vulnerable coasts and their management

Michael Elliott [a,*], Nicholas D. Cutts [a], Anna Trono [b]

Chapter 1

A Synthesis: What Is the Future for Coasts, Estuaries, Deltas and Other Transitional Habitats in 2050 and Beyond?

Michael Elliott*, John W. Day†, Ramesh Ramachandran‡, Eric Wolanski§

(NB. All hazards and risks exacerbated by climate change)

# Challenges for management (RA&RM; OA&OM):

***Risk Assessment:***

- Where are the problems and what changes do they cause? (ExUP & EnMP)
- What is their impact on ecosystem structure and functioning?
- What are the repercussions for ecosystem valuation based on economy-ecology interactions?
- What are the future environmental changes and economic futures?

***Risk Management:***

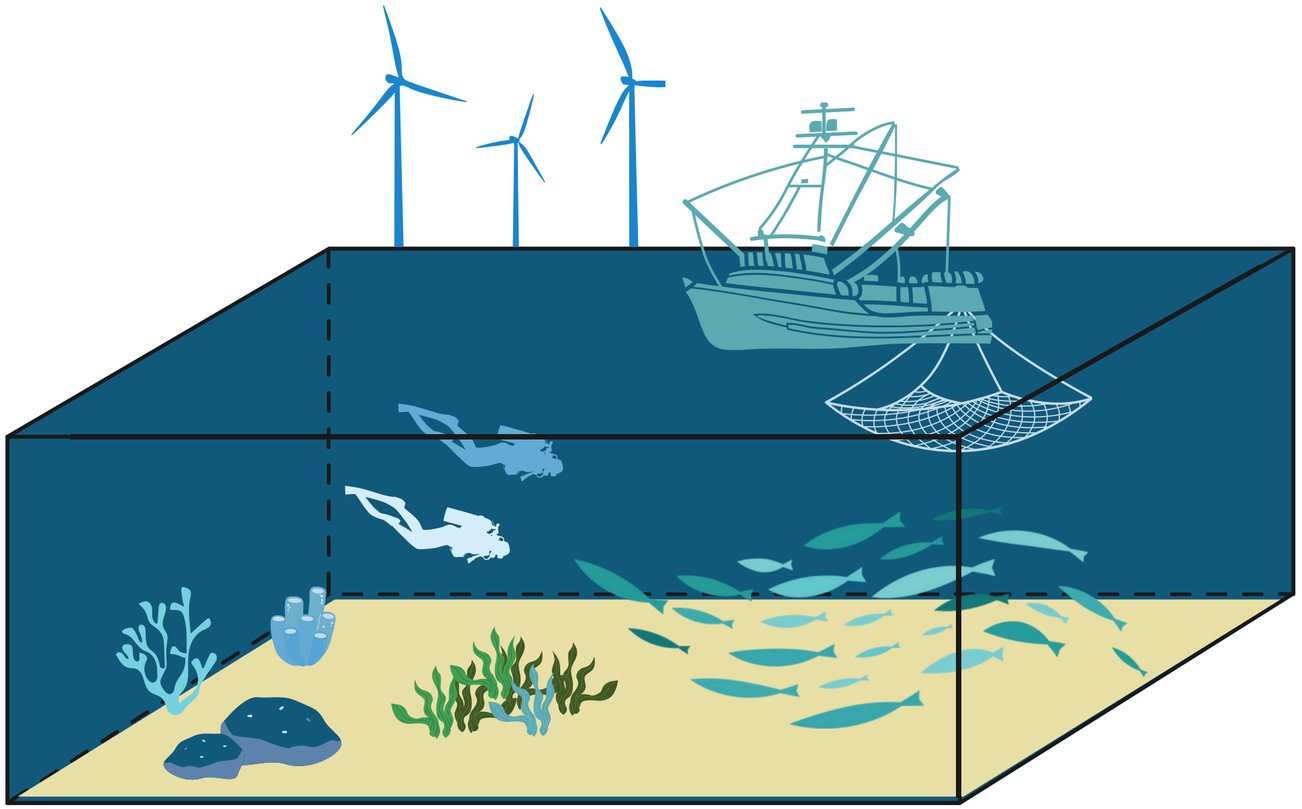
- What governance framework is there, what do stakeholders need & what are successes & failures?
- What can we do about the problems, hazards & risks and how to address them now and in the future?
- How 'good' is the decision-making?

***And the corollary: Opportunity Assessment and Management***

(Elliott, 2014 Mar. Poll. Bull.; Cormier et al 2019 OCMA, and others)

# What is a Marine Social -Ecological System?

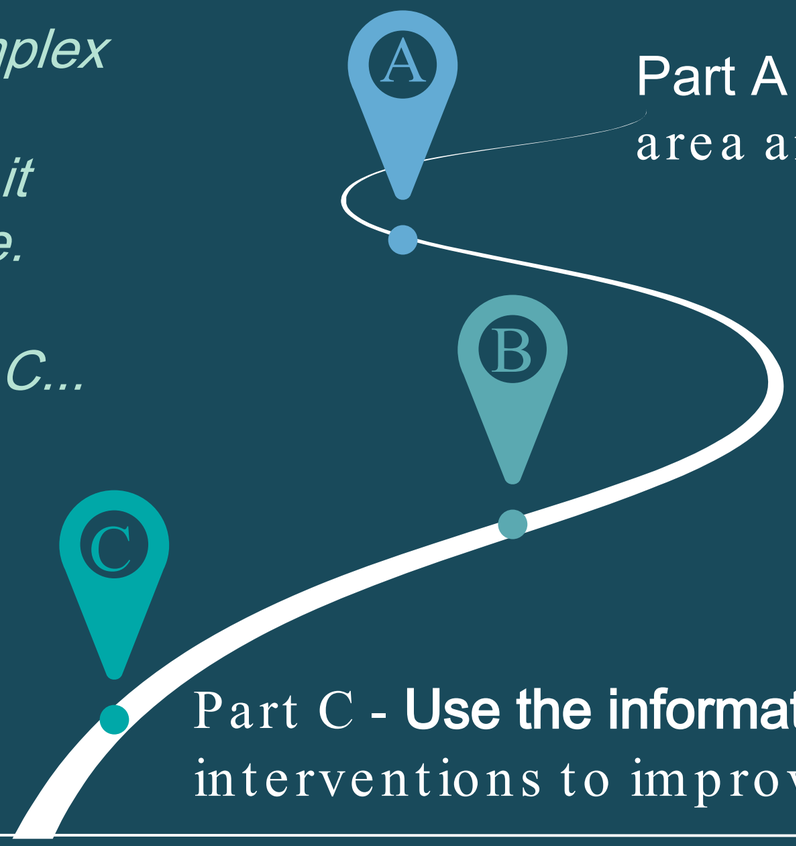
- A marine area where human and natural elements exist together and impact each other .



# The Simple SES Approach

*Helps managing a complex marine system by understanding how it behaves as a whole.*

*It is as 'simple' as A, B, C...*




Part A - **Understand the Priorities** in the area and what we are intending to improve.

Part B - **Gather information** on the system to inform upon how it works.

Part C - **Use the information** to design management interventions to improve the situation.

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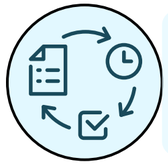
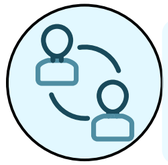
# **Part A -** Understand the Priorities in the area and what we are intending to improve.



Project Management

Risk Assessment



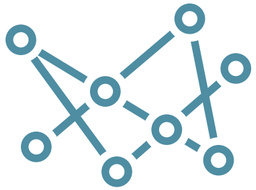
Stakeholder engagement and communication

The rules are in place (Policy) and who is responsible for management (Administration)

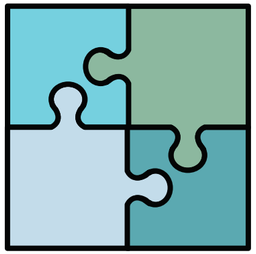
Define challenges, Priorities, and Scope of the approach with stakeholders

# **Part B** - Gather information on the system to inform upon how it works.

Identify indicators for Social and Ecological elements in the system.

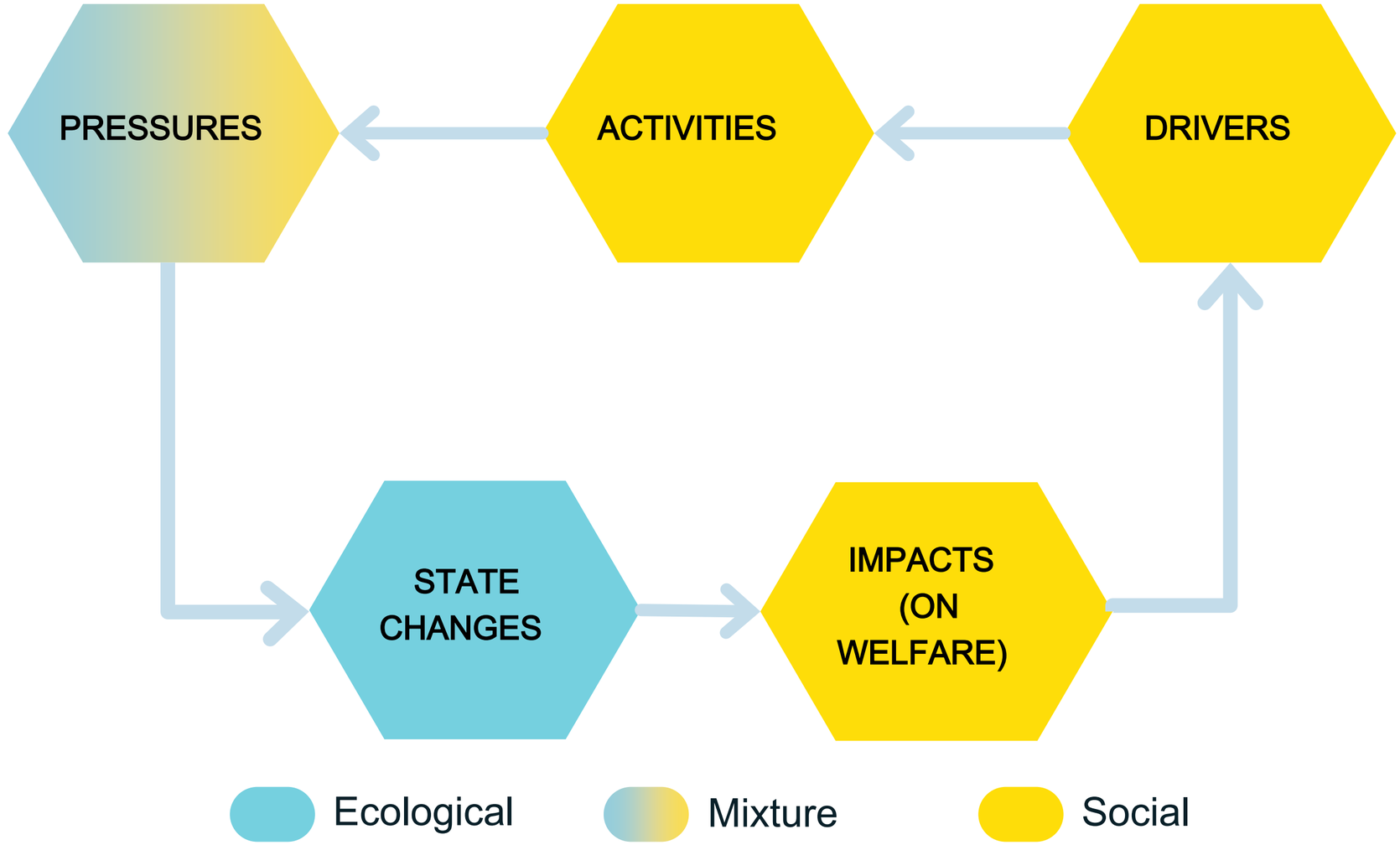


Using data, expert opinion, and stakeholder knowledge assess the connections between indicators.

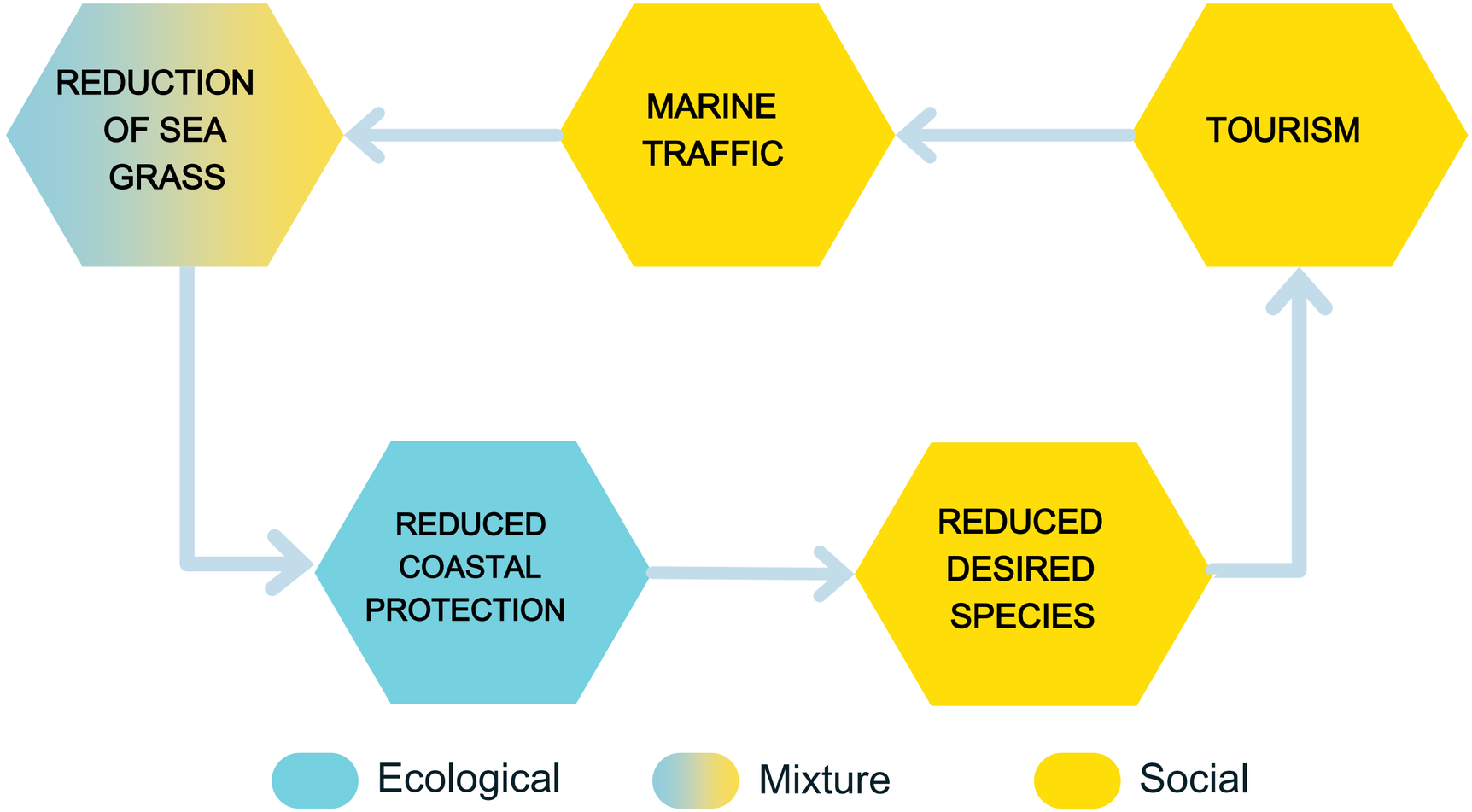


View the system in focus as a whole.

# Indicators

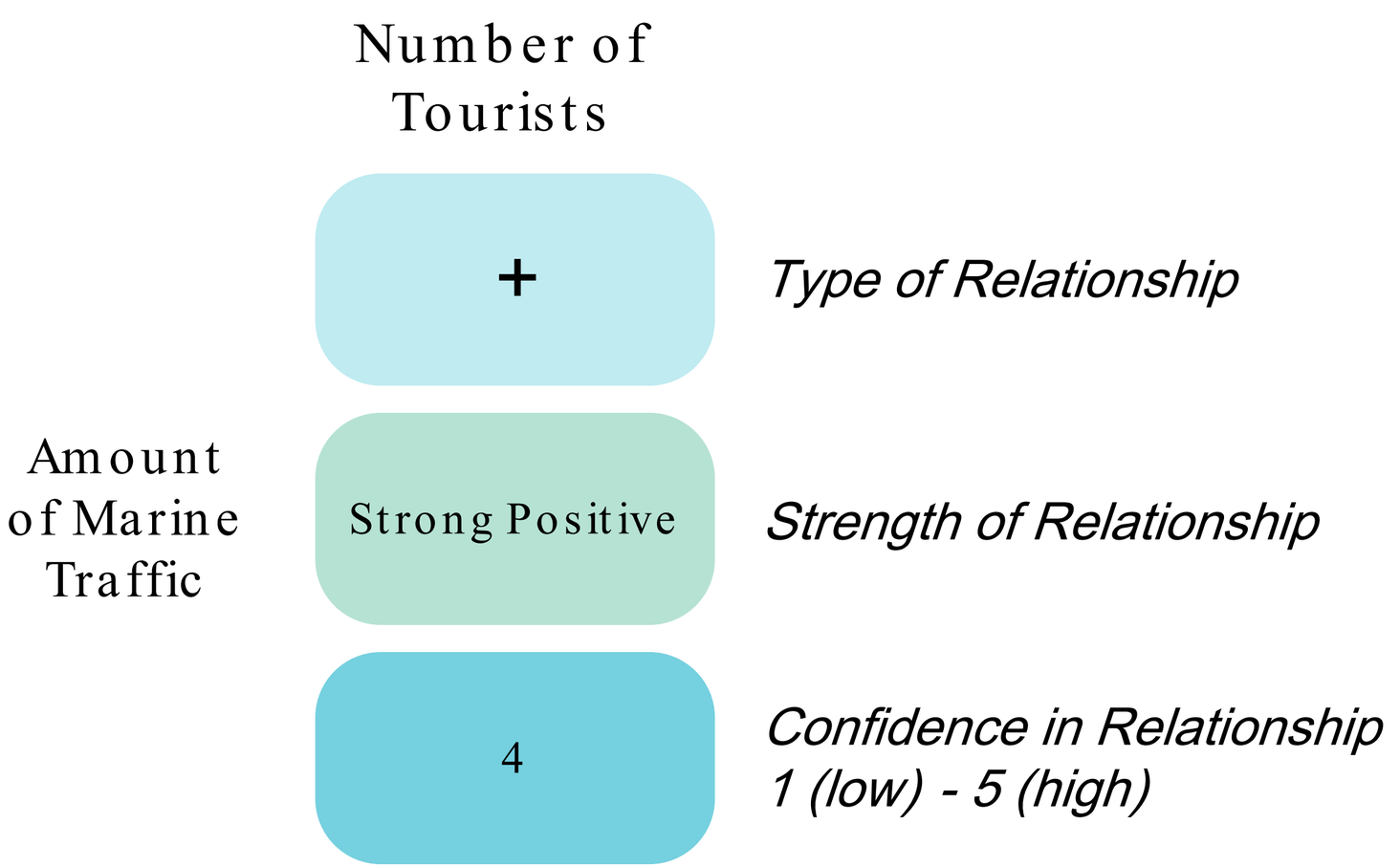

PRESSURES
ACTIVITIES
DRIVERS
STATE CHANGES
IMPACTS (ON WELFARE)
Ecological
Mixture
Social

# Indicators


REDUCTION OF SEA GRASS
MARINE TRAFFIC
TOURISM
REDUCED COASTAL PROTECTION
REDUCED DESIRED SPECIES
Ecological
Mixture
Social

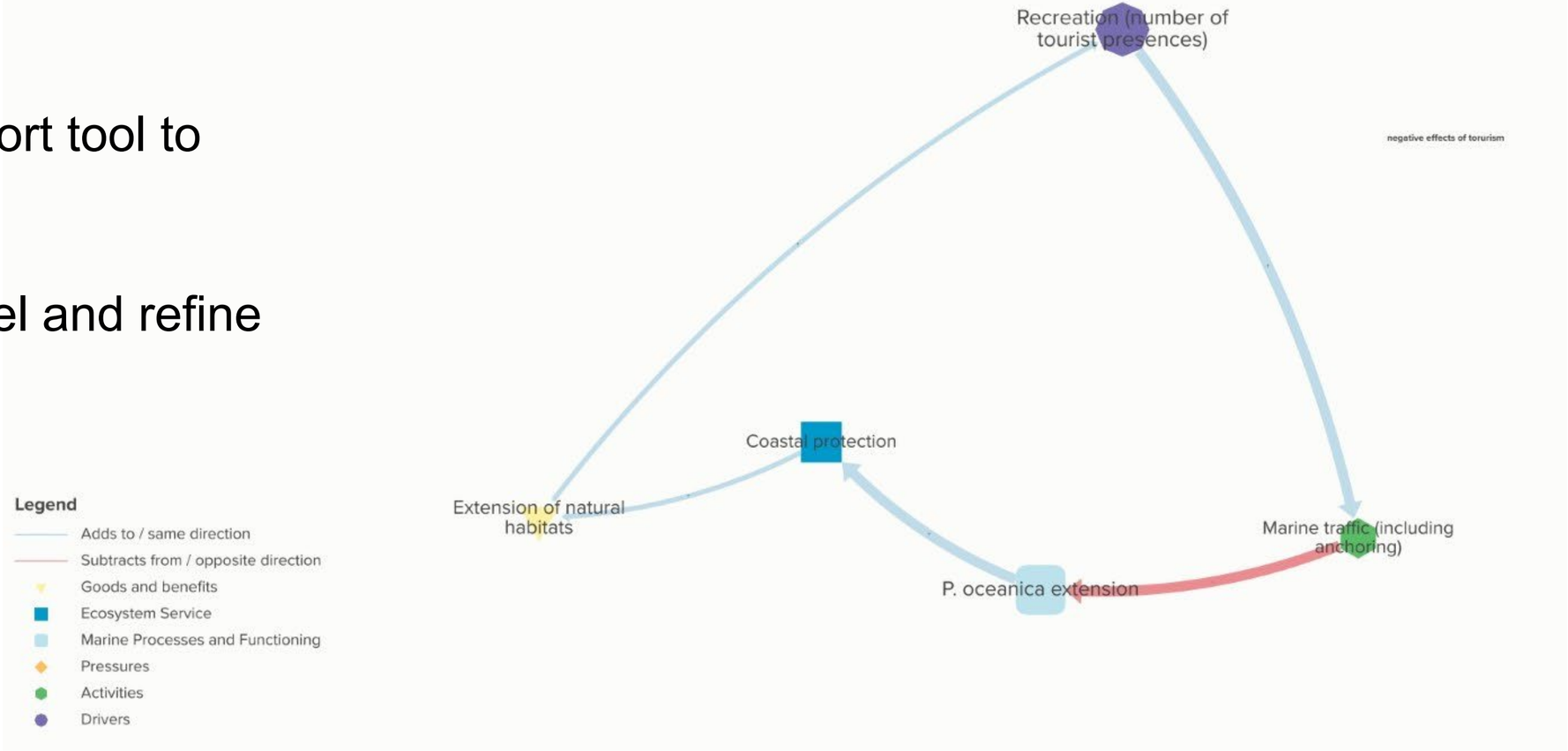
# Assessment

- **Assess the related indicators**

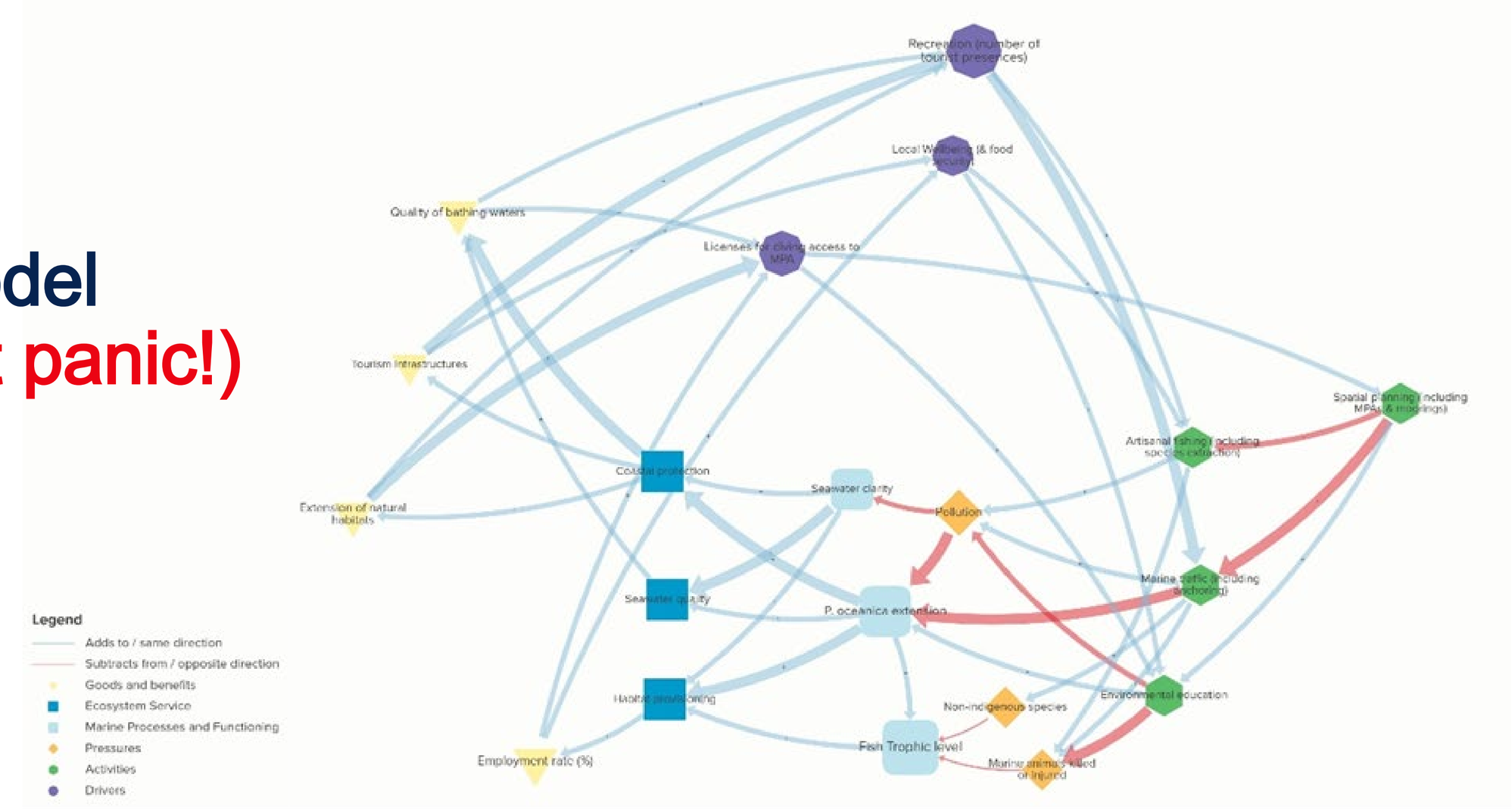


# Single loop model

- Use Decision Support tool to generate the model
- Reflect on the model and refine with stakeholders



# Full Model
# (Do not panic!)

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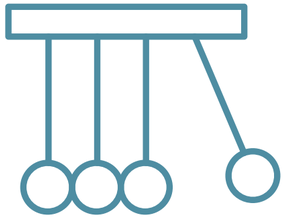
# **Part C -** Use the information to design management interventions to improve the situation.

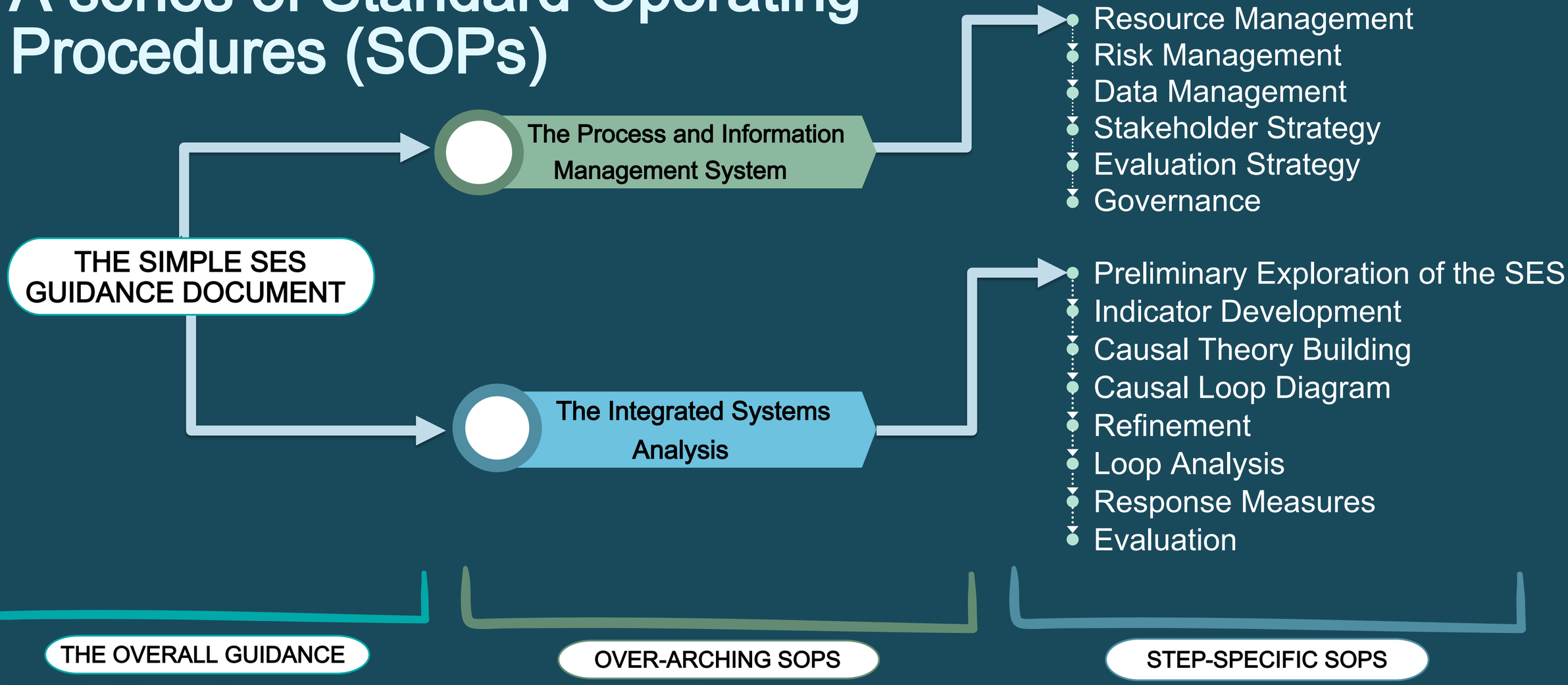
Identify influential points for intervention



Explore unintended consequences

Design Management Response Measures

# A series of Standard Operating Procedures (SOPs)

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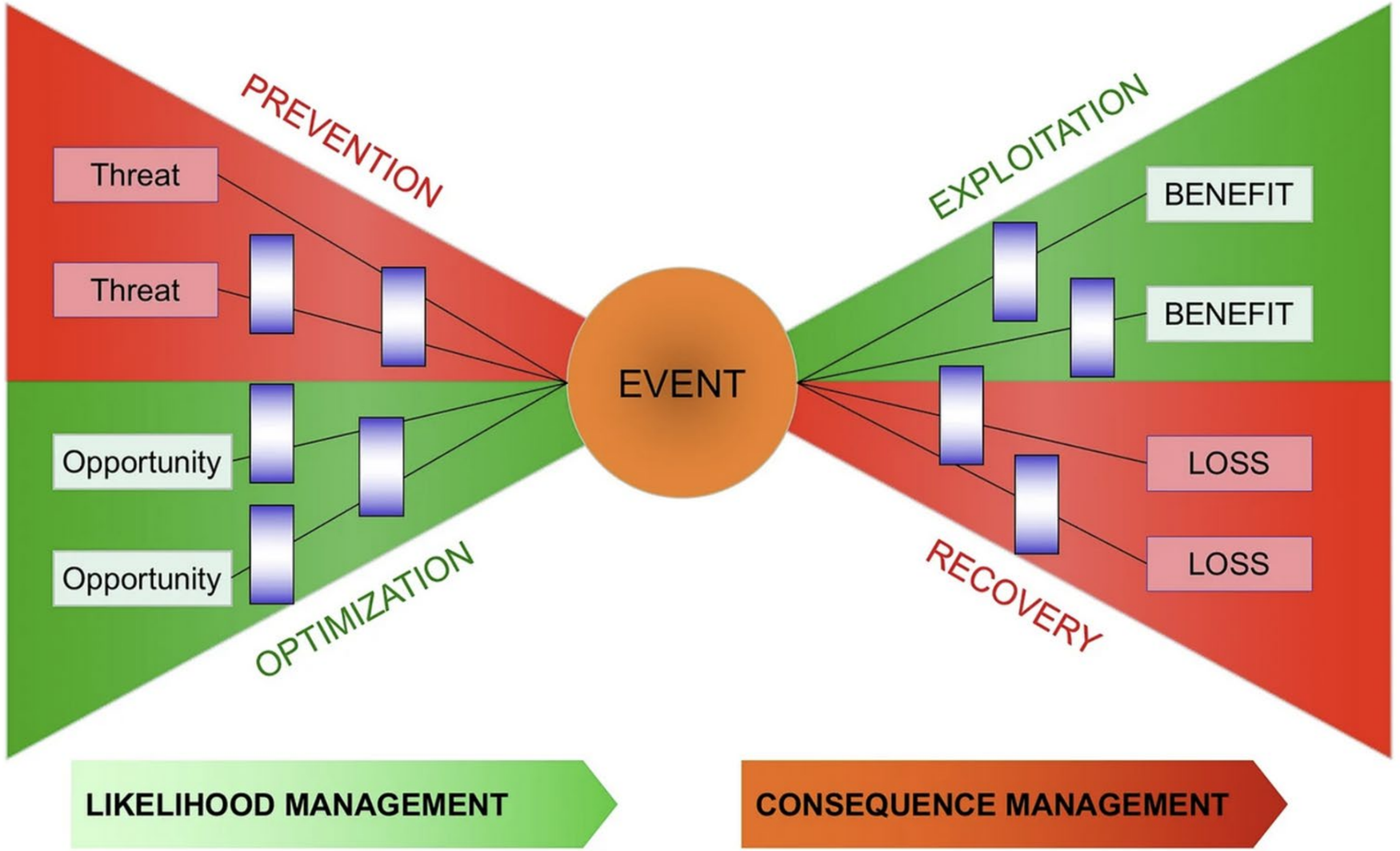
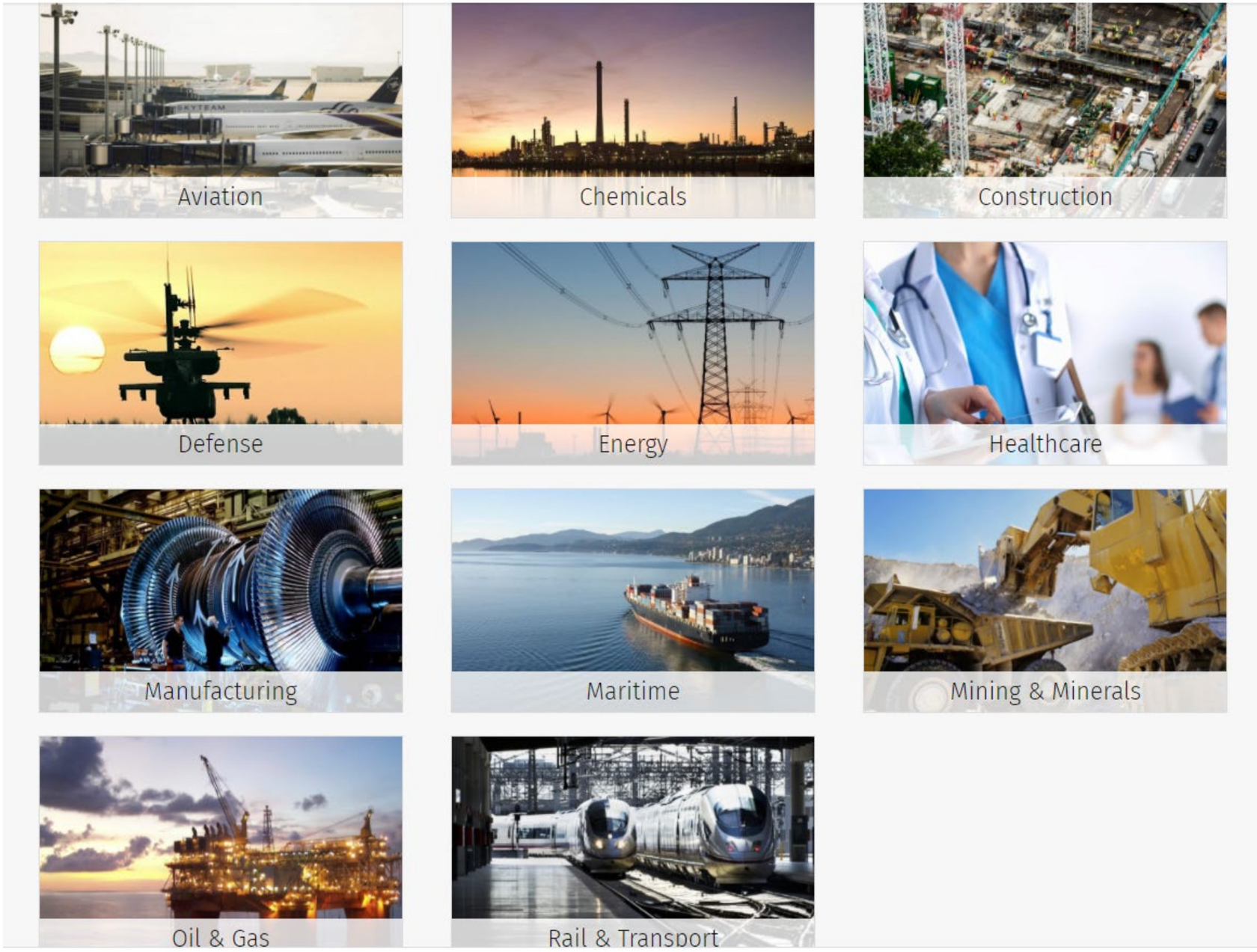
# What is a Bow -Tie?



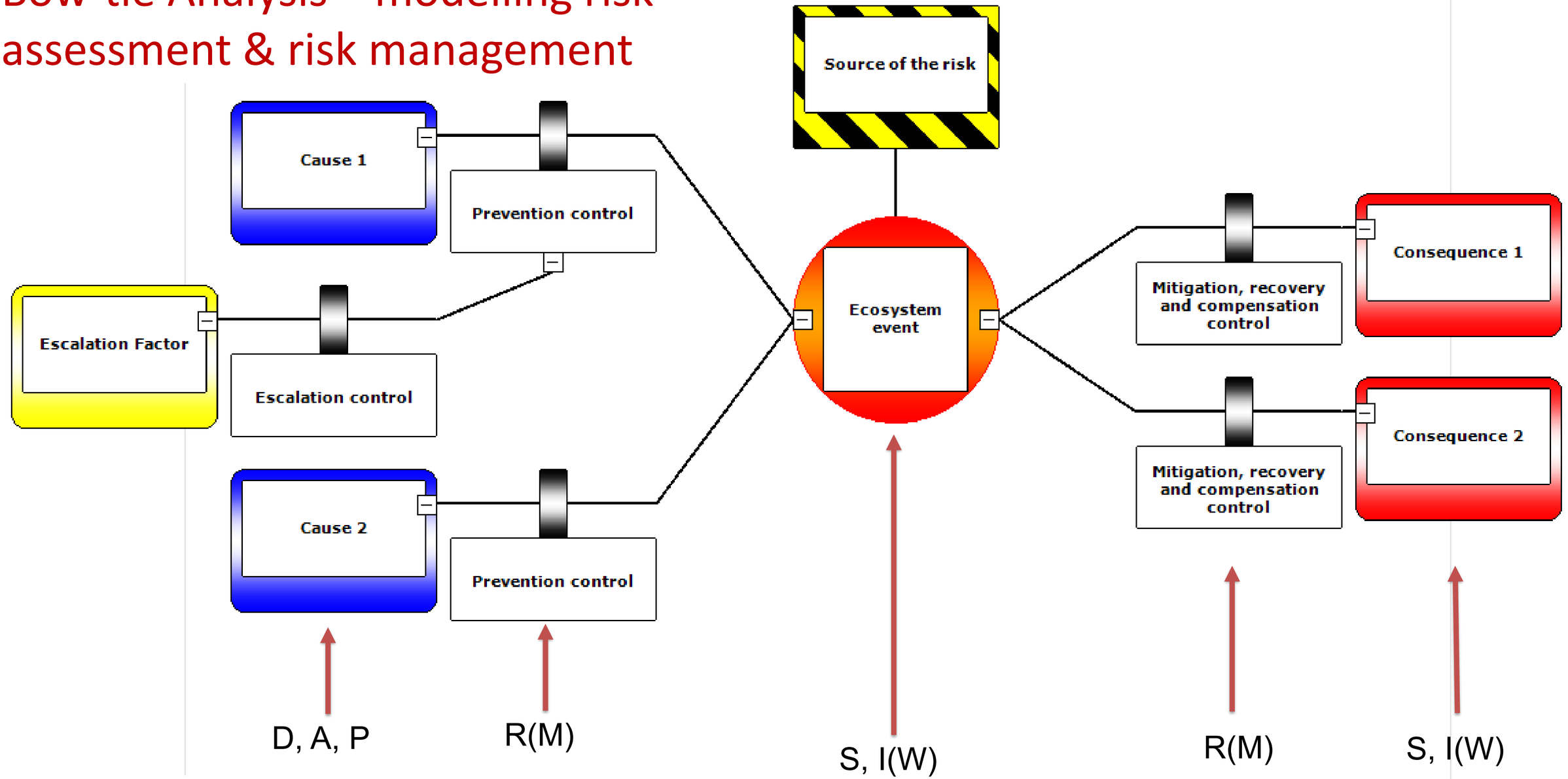



https://www.cgerisk.com/industries/

Proprietary Bow-tie analysis has been used by many industries (ISO accredited ISO 2018; IEC/ISO 2019) -

And:
Commercial Businesses
Consulting
Educational
Finance
Food & Agriculture
Fire & Rescue Services
Government
Tank Storage & Pipelines
Water

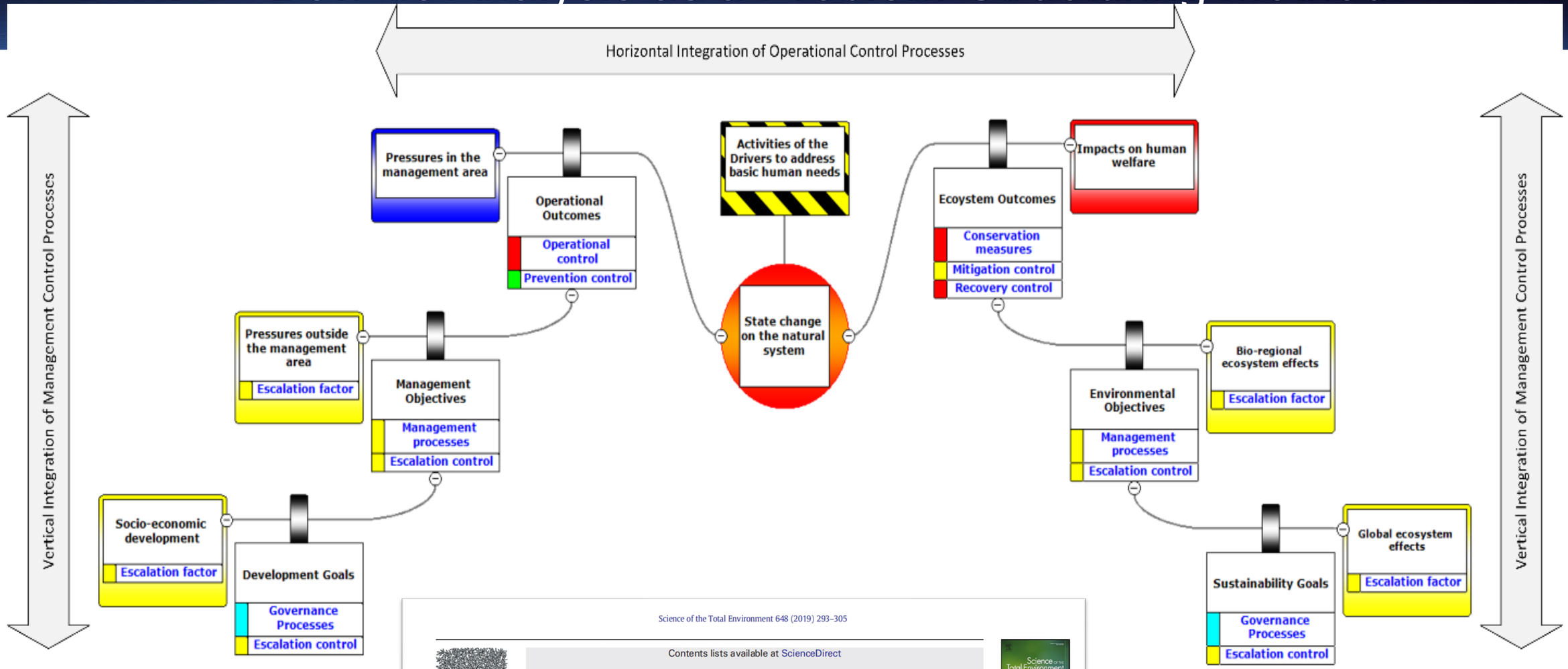
# Bow-tie Analysis – modelling risk assessment & risk management




(Cormier et al., 2019, Sci. Tot. Env.)

*Stakeholder consultation – to determine causes and consequences and to agree the responses throughout the sequence*

# Bow-tie Analysis as a Problem-Structuring Method

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ELSEVIER

Putting on a bow-tie to sort out who does what and why in the complex arena of marine policy and management

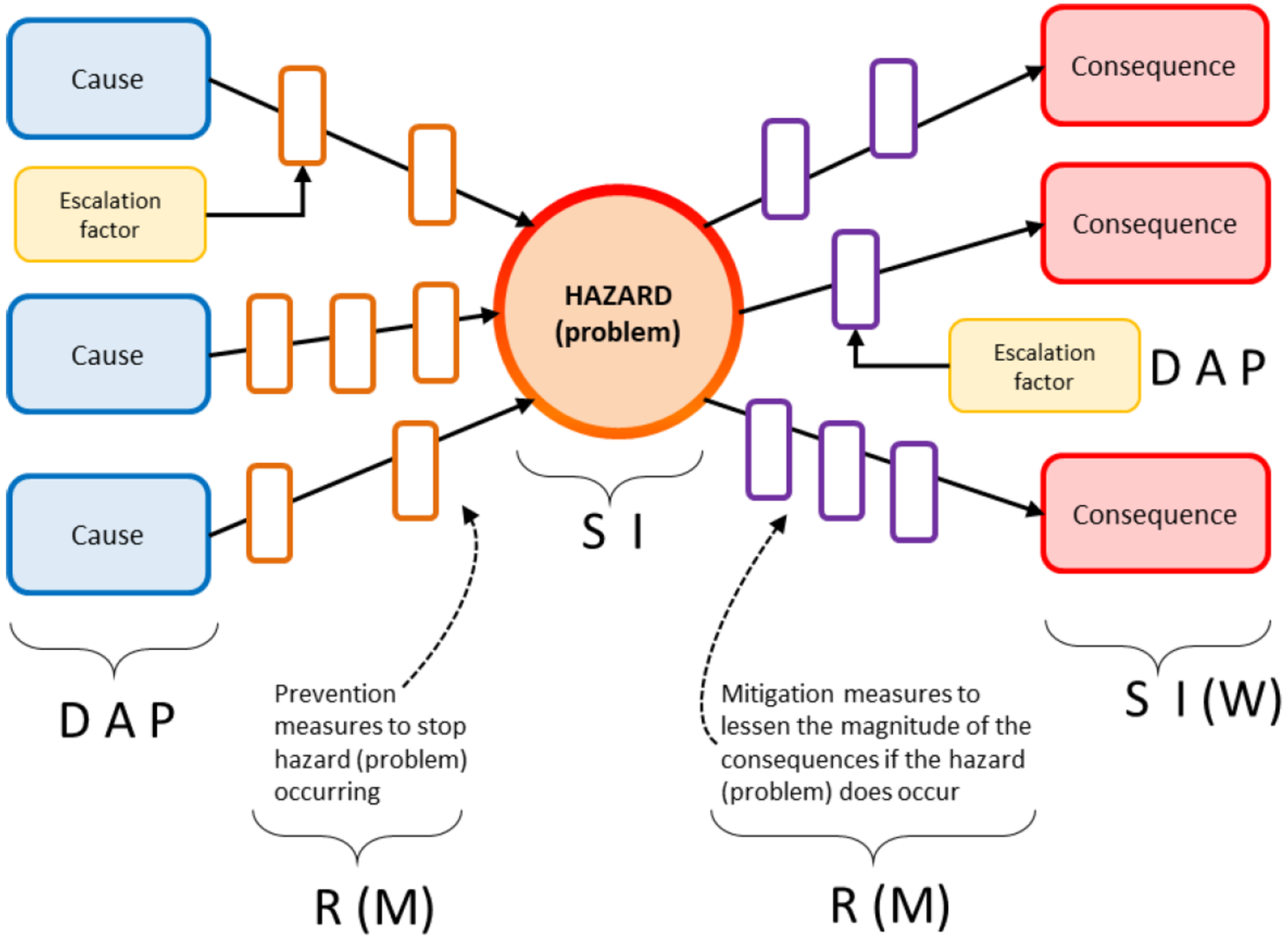
Roland Cormier [a,*], Michael Elliott [b], Jake Rice [c]

CERES was the first attempt to use BT analysis for climate change repercussions for fisheries and aquaculture

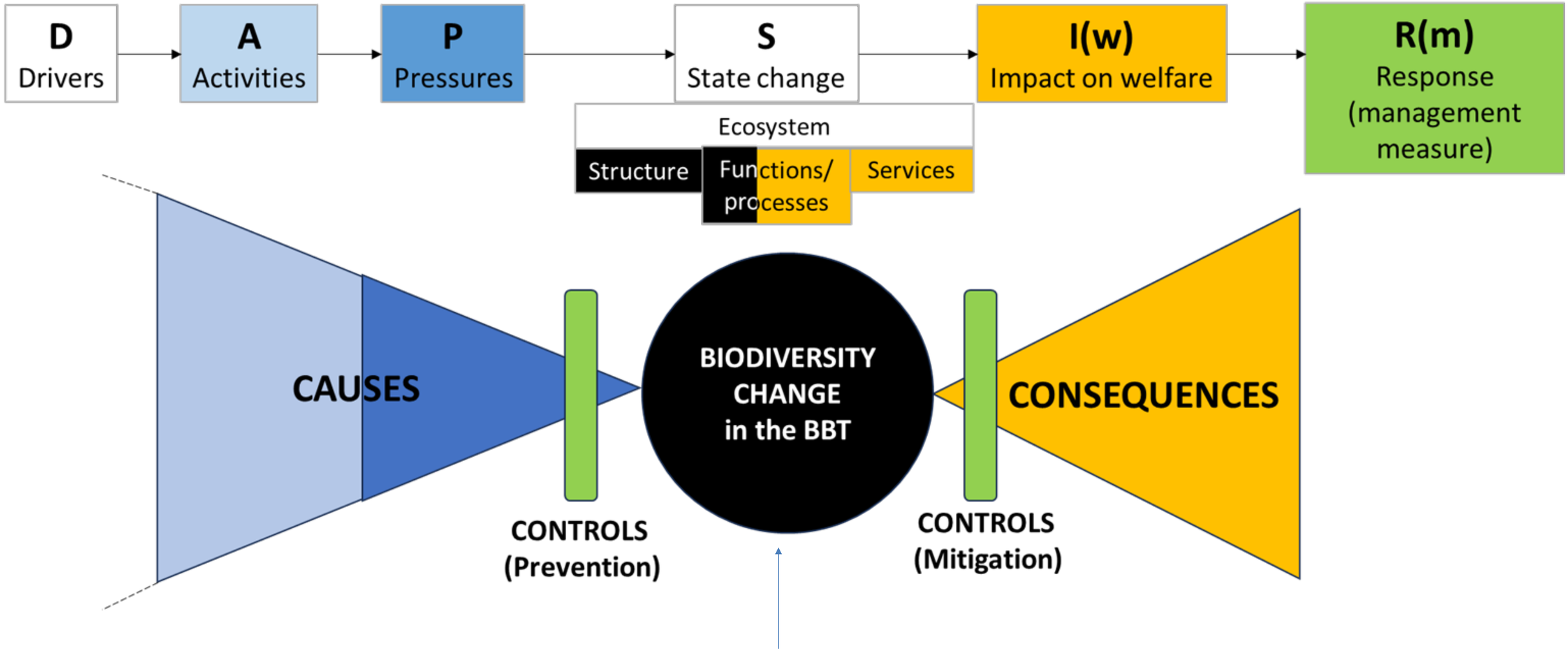
# BowTies to connect important factors

- What is an/some issue(s) of concern in managing your area?
- Do you need a rigorous, ISO-standard method to tackle the issue(s)?
- What are the causes of the concern(s)?
- Can you rigorously determine prevention controls to remove the concern and mitigation controls to lessen the consequences?
- Can you determine the consequences (positive and negative) from the concern?
- If the consequences are not prevented or mitigated then do they lead to further chains of management?
- Do you need to carry out scenario analysis using a Bow-tie structure?

# What is a Bow -Tie?



# Operationalising Bow-tie generic structure in MARBEFES




Central event in MARBEFES Bow-tie is split into multiple central nodes depending on the different ways the biodiversity change manifests in the specific case study/BBT

# The central event of Bow-tie in MARBEFES

**In MARBEFES**

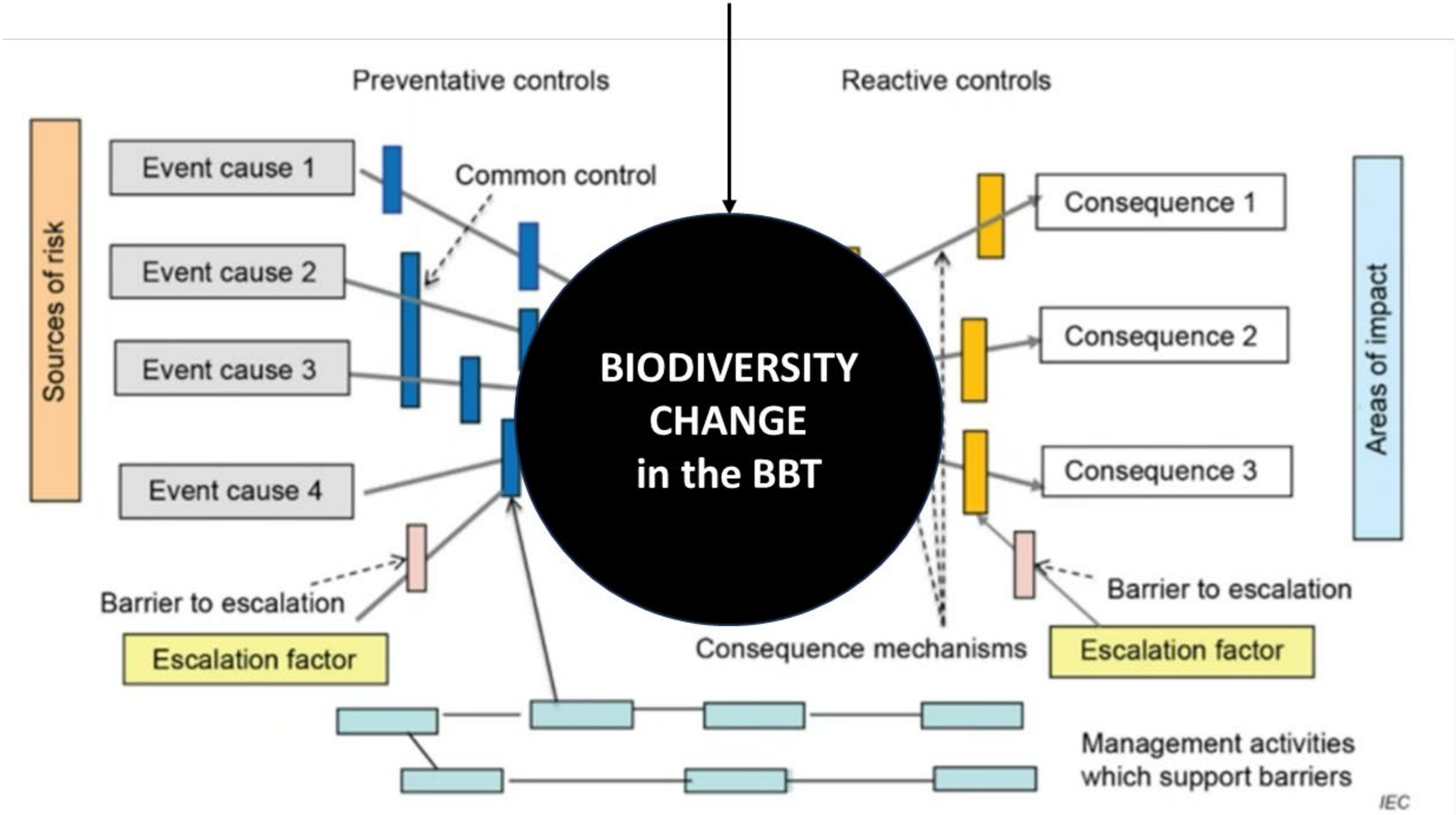


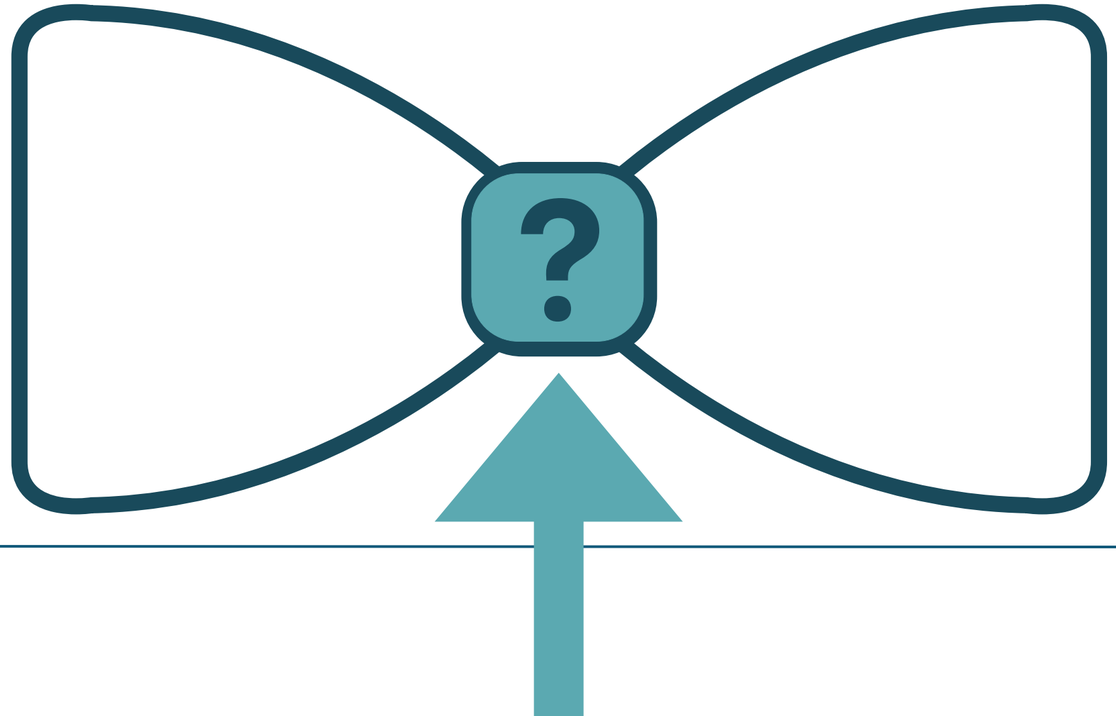

**Figure B.2 – Example of Bowtie**

*Source: ECS/ISO (2019)*

# How to form a bowtie

## Step 1: The central event

- Also known as the knot, the problem or the issue, this is key to forming the Bow-Tie or what is the problem I am worrying about?



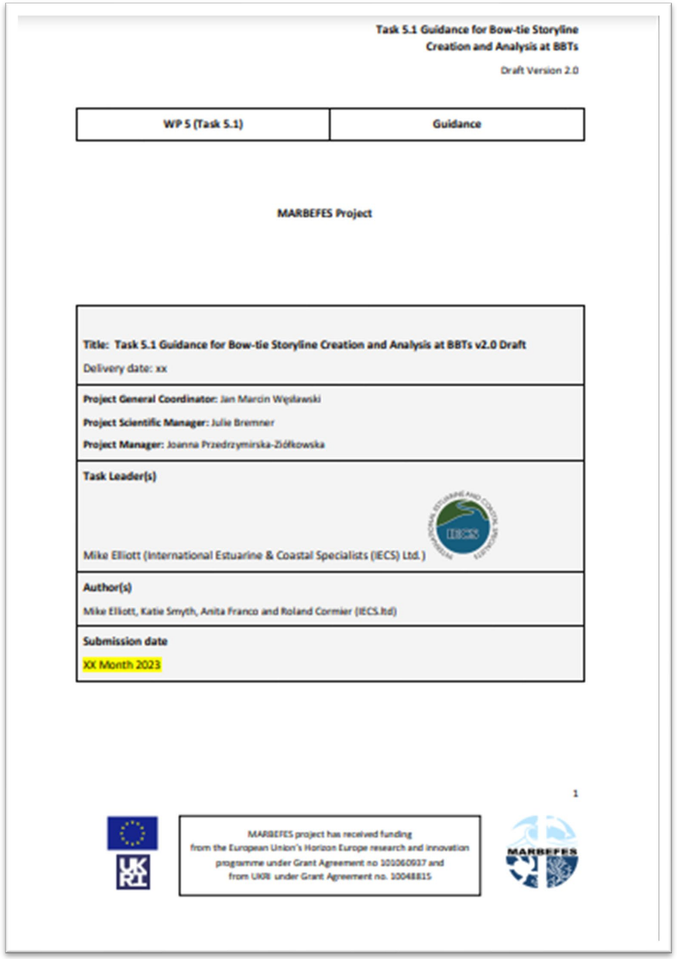
# MARBEFES – ‘the big idea’ – the ‘central knot of the BT’

*“What natural conditions and human activities (both local and global) are now reducing the value (in ecological and socio-economic terms) of biodiversity at your BBT or will reduce that in the future and what can/will marine management and governance do about it?”*

Fulfilling this requires you to know:

- the type and value the biodiversity in its various forms,
- the endogenic and exogenic causes of changes to it,
- the consequences of those changes in ecological, socio-economic and socio-cultural terms,
- the types of solutions possible including governance and management, and
- the desires of stakeholders and their advisors.

To do all of that requires clear guidance for effective an efficient use



Task 5.1 Guidance for Bow-tie Storyline Creation and Analysis at BBTs

Draft Version 2.0

| WP 5 (Task 5.1) | Guidance |
|---|---|

MARBEFES Project

**Title: Task 5.1 Guidance for Bow-tie Storyline Creation and Analysis at BBTs v2.0 Draft**

Delivery date: xx

**Project General Coordinator:** Jan Marcin Węsławski

**Project Scientific Manager:** Julie Bremner

**Project Manager:** Joanna Przedrzymirska-Ziółkowska

**Task Leader(s)**

Mike Elliott (International Estuarine & Coastal Specialists (IECS) Ltd.)

**Author(s)**

Mike Elliott, Katie Smyth, Anita Franco and Roland Cormier (IECS ltd)

**Submission date**

XX Month 2023

1

MARBEFES project has received funding from the European Union's Horizon Europe research and innovation progamme under Grant Agreement no 101060937 and from UKRI under Grant Agreement no. 10048815

# Central Event

The Central event in a MARBEFES Bow-tie includes multiple central nodes depending on the different ways the biodiversity change manifests in the specific case study/BBT

These are site-specific (e.g. may be a loss of a particular habitat important in the area, a change in the distribution or condition of the population of a particular species in the area) and therefore are defined by the user (BBT)

**No standardised list for these central event nodes has been created**, but rather the nodes have been identified by the BBT for their specific Bow-tie

# How to form a bowtie

## Step 2: Causes

- What are the causes of the central event/problem?
- What mechanisms can be used to prevent these causes from leading to the central event?
- What management measures that can be applied to reduce the magnitude of or likelihood of the central event happening due to the causes? (e.g. to adapt, control, mitigate or compen -sate?)
- What factors can enhance the management measures and what factors can cause them to fail?

# Standardised lists for Bow-tie elements in MARBEFES

## Causes (Activities & Pressures)

| CAUSES of Biodiversity change: 1. | Standardised vocabulary for ACTIVITIES |
|---|---|
| Hierarchy | New ID# | Causes_1.Activities_name |
| Level 1 | A1 | PHYSICAL RESTRUCTURING OF RIVERS, COASTLINE OR SEABED (WATER MANAGEMENT) |
| Level 1 | A2 | EXTRACTION OF NON-LIVING RESOURCES |
| Level 1 | A3 | PRODUCTION OF ENERGY |
| Level 1 | A4 | EXTRACTION LIVING RESOURCES |
| Level 1 | A5 | CULTIVATION OF LIVING RESOURCES |
| Level 1 | A6 | TRANSPORT |
| Level 1 | A7 | URBAN AND INDUSTRIAL USES |
| Level 1 | A8 | TOURISM AND LEISURE |
| Level 1 | A9 | SECURITY/DEFENCE |

*From MSFD lists (Levels 1&2)*

| | A | B | C | | | |
|---|---|---|---|---|---|---|
| 1 | CAUSES of Biodiversity change: 1. Standardised vocabulary for ACTIVITIES | | | | | |
| 2 | Hierarchy | New ID# | Causes_1.Activities_name | | | |
| 3 | Level 1 | A1 | PHYSICAL RESTRUCTURING OF RIVERS, COASTLINE OR SEABED (WA | | | |
| 4 | Level 2 | A1.1 | Land claim | | | |
| 5 | Level 2 | A1.2 | Canalisation and other watercourse modifications | | | |
| 6 | Level 2 | A1.3 | Coastal defence and flood protection | | | |
| 7 | Level 3 | A1.3.1 | Flood defence - hard engineering methods (e.g., seawalls) | Higher level scenarios (Land2Sea) | << MSFDa3 | |
| 8 | Level 3 | A1.3.2 | Flood defence - soft engineering methods (e.g., beach nourishment, managed realignment) | - | << MSFDa3 | |
| 9 | Level 2 | A1.4 | Offshore structures (other than for oil/gas/renewables) | MSFD list (amended EU 2017/845) | MSFDa4 (<< MSFDat1) | included in MSFDat1 |
| 10 | Level 2 | A1.5 | Restructuring of seabed morphology, including dredging and depositing of materials | MSFD list (amended EU 2017/845) | MSFDa5 (<< MSFDat1) | included in MSFDat1 |
| 11 | Level 1 | A2 | EXTRACTION OF NON-LIVING RESOURCES | MSFD list (amended EU 2017/845) | MSFDat2 | |
| 12 | Level 2 | A2.1 | Extraction of minerals (rock, metal ores, gravel, sand, shell) | MSFD list (amended EU 2017/845) | MSFDa6 (<< MSFDat2) | included in MSFDat2 |
| 13 | Level 3 | A2.1.1 | Coastal mining | Higher level scenarios (Land2Sea) | << MSFDa6 | subset because specified for coastal |
| 14 | Level 2 | A2.2 | Extraction of oil and gas, including infrastructure | MSFD list (amended EU 2017/845) | MSFDa7 (<< MSFDat2) | included in MSFDat2 |
| 15 | Level 2 | A2.3 | Extraction of salt | MSFD list (amended EU 2017/845) | MSFDa8 (<< MSFDat2) | included in MSFDat2 |
| 16 | Level 2 | A2.4 | Extraction of water | MSFD list (amended EU 2017/845) | MSFDa9 (<< MSFDat2) | included in MSFDat2 |
| 17 | Level 1 | A3 | PRODUCTION OF ENERGY | MSFD list (amended EU 2017/845) | MSFDat3 | |
| 18 | Level 2 | A3.1 | Renewable energy generation (wind, wave and tidal power), including infrastructure | MSFD list (amended EU 2017/845) + Highe | MSFDa10 (<< MSFDat3) | included in MSFDat3; has a correspon |
| 19 | Level 2 | A3.2 | Non-renewable energy generation | MSFD list (amended EU 2017/845) | MSFDa11 (<< MSFDat3) | included in MSFDat3 |
| 20 | Level 2 | A3.3 | Transmission of electricity and communications (cables) | MSFD list (amended EU 2017/845) | MSFDa12 (<< MSFDat3) | included in MSFDat3 |
| 21 | Level 1 | A4 | EXTRACTION LIVING RESOURCES | MSFD list (amended EU 2017/845) | MSFDat4 | |
| 22 | Level 2 | A4.1 | Fish and shellfish harvesting (professional, recreational) | MSFD list (amended EU 2017/845) | MSFDa13 (<< MSFDat4) | included in MSFDat4 |
| 23 | Level 2 | A4.2 | Fish and shellfish processing | MSFD list (amended EU 2017/845) | MSFDa14 (<< MSFDat4) | included in MSFDat4 |
| 24 | Level 2 | A4.3 | Marine plant harvesting | MSFD list (amended EU 2017/845) | MSFDa15 (<< MSFDat4) | included in MSFDat4 |
| 25 | Level 2 | A4.4 | Hunting and collecting for other purposes | MSFD list (amended EU 2017/845) | MSFDa16 (<< MSFDat4) | included in MSFDat4 |
| 26 | Level 1 | A5 | CULTIVATION OF LIVING RESOURCES | MSFD list (amended EU 2017/845) | MSFDat5 | |
| 27 | Level 2 | A5.1 | Aquaculture — marine, including infrastructure | MSFD list (amended EU 2017/845) | MSFDa17 (<< MSFDat5) | included in MSFDat5 |
| 28 | Level 2 | A5.2 | Aquaculture — freshwater | MSFD list (amended EU 2017/845) | MSFDa18 (<< MSFDat5) | included in MSFDat5 |
| 29 | Level 2 | A5.3 | Agriculture | MSFD list (amended EU 2017/845) | MSFDa19 (<< MSFDat5) | included in MSFDat5 |
| 30 | Level 3 | A5.3.1 | Use of biocides | Higher level scenarios (Land2Sea) | << MSFDa19 | |
| 31 | Level 3 | A5.3.2 | Use of N- fertilizers | Higher level scenarios (Land2Sea) | << MSFDa19 | |
| 32 | Level 3 | A5.3.3 | Use of P- fertilizers | Higher level scenarios (Land2Sea) | << MSFDa19 | |

metadata | CAUSES_Vocabulary1-Activities | CAUSES_Vocabulary2-Pressures | CAUSES from BBT Bow-ties

# Bow-tie analysis in MARBEFES - Standardised vocabularies

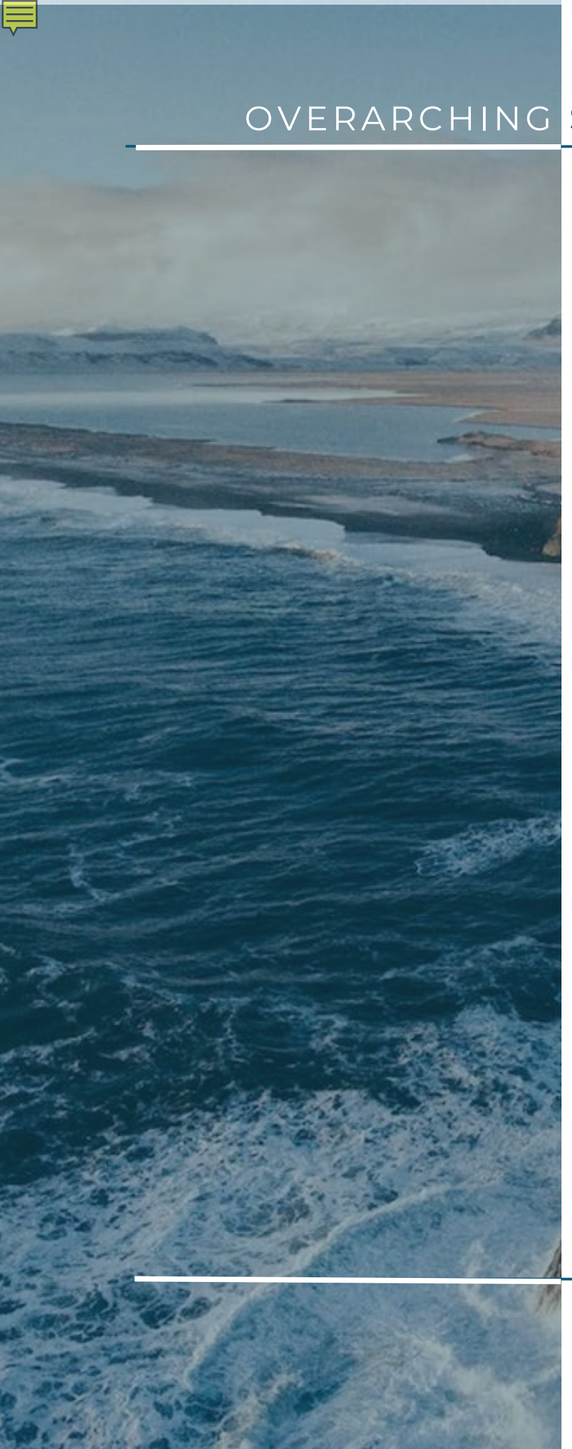
## Causes (Activities & Pressures)

| CAUSES of Biodiversity change: 2. Standardised vocabulary for PRESSURES | | |
|---|---|---|
| **Hierarchy** | **New ID#** | **Causes_2.Pressures_name** |
| Level 1 | P1 | **BIOLOGICAL PRESSURES** |
| Level 1 | P2 | **PHYSICAL PRESSURES** |
| Level 1 | P3 | **SUBSTANCES, LITTER AND ENERGY** |
| Level 1 | P4 | **CLIMATE CHANGE** |

*From MSFD lists (Levels 1&2)*

| | A | B | C | Source | ID# and relations | Remarks |
|---|---|---|---|---|---|---|
| 1 | CAUSES of Biodiversity change: 2. Standardised vocabulary for PRESSURES | | | | | |
| 2 | Hierarchy | New ID# | Causes_2.Pressures_name | Source | ID# and relations | Remarks |
| 3 | Level 1 | P1 | **BIOLOGICAL PRESSURES** | MSFD list (amended EU 2017/845) | MSFDpt1 | |
| 4 | Level 2 | P1.1 | Input or spread of non-indigenous species | MSFD list (amended EU 2017/845) + Higher lev | MSFDp1 (<< MAFDpt1) | included in MSFDpt1; |
| 5 | Level 2 | P1.2 | Input of microbial pathogens | MSFD list (amended EU 2017/845) | MSFDp2 (<< MAFDpt1) | included in MSFDpt1 |
| 6 | Level 2 | P1.3 | Input of genetically modified species and translocation of native species | MSFD list (amended EU 2017/845) | MSFDp3 (<< MAFDpt1) | included in MSFDpt1 |
| 7 | Level 2 | P1.4 | Loss of, or change to, natural biological communities due to cultivation of animal or | MSFD list (amended EU 2017/845) | MSFDp4 (<< MAFDpt1) | included in MSFDpt1 |
| 8 | Level 2 | P1.5 | Disturbance of species (e.g. where they breed, rest and feed) due to human presenc | MSFD list (amended EU 2017/845) | MSFDp5 (<< MAFDpt1) | included in MSFDpt1 |
| 9 | Level 2 | P1.6 | Extraction of, or mortality/injury to, wild species (by commercial and recreational fi | MSFD list (amended EU 2017/845) + Higher lev | MSFDp6 (<< MAFDpt1) | included in MSFDpt1; |
| 10 | Level 1 | P2 | **PHYSICAL PRESSURES** | MSFD list (amended EU 2017/845) | MSFDpt2 | |
| 11 | Level 2 | P2.1 | Physical disturbance to seabed (temporary or reversible) | MSFD list (amended EU 2017/845) | MSFDp7 (<< MAFDpt2) | included in MSFDpt2 |
| 12 | Level 2 | P2.2 | Physical loss (due to permanent change of seabed substrate or morphology and to e | MSFD list (amended EU 2017/845) + Higher lev | MSFDp8 (<< MAFDpt2) | included in MSFDpt2; |
| 13 | Level 2 | P2.3 | Changes to hydrological conditions | MSFD list (amended EU 2017/845) | MSFDp9 (<< MAFDpt2) | included in MSFDpt2 |
| 14 | Level 2 | P2.4 | New habitat creation | - | << MAFDpt2 | not included in MSFD |
| 15 | Level 1 | P3 | **SUBSTANCES, LITTER AND ENERGY** | MSFD list (amended EU 2017/845) | MSFDpt3 | |
| 16 | Level 2 | P3.1 | Input of nutrients — diffuse sources, point sources, atmospheric deposition | MSFD list (amended EU 2017/845) | MSFDp10 (<< MAFDpt3) | included in MSFDpt3 |
| 17 | Level 2 (indica | P3.1(indicator) | TN load (from agricultural land into rivers and coast) | Higher level scenarios (Land2Sea) | <<MSFDp10 | Indicator of pressure |
| 18 | Level 2 (indica | P3.1(indicator) | TP load (from agricultural land into rivers and coast) | Higher level scenarios (Land2Sea) | <<MSFDp10 | Indicator of pressure |
| 19 | Level 2 (indica | P3.1(indicator) | TN concentration in effluents from water treatment plants | Higher level scenarios (Land2Sea) | <<MSFDp10 | Indicator of pressure |
| 20 | Level 2 (indica | P3.1(indicator) | TP concentration in effluents from water treatment plants | Higher level scenarios (Land2Sea) | <<MSFDp10 | Indicator of pressure |
| 21 | Level 2 | P3.2 | Input of organic matter — diffuse sources and point sources | MSFD list (amended EU 2017/845) | MSFDp11 (<< MAFDpt3) | included in MSFDpt3 |
| 22 | Level 3 | P3.2.1 | Sediments in water due to erosion | Higher level scenarios (Land2Sea) | <<MSFDp11 | Pressure is input of se |
| 23 | Level 2 (indica | P3.2 (+3.1&3.3 | Quantity of wastewater (reaching treatment plants) | Higher level scenarios (Land2Sea) | >>MSFDp10 & MSFDp11 & MSFDp12 | Indicator of pressure ( |
| 24 | Level 2 (indica | P3.2 (+3.1&3.3 | Inflow of untreated waste water (from scattered dwellings into rivers) | Higher level scenarios (Land2Sea) | >>MSFDp10 & MSFDp11 & MSFDp12 | Indicator of pressure |
| 25 | Level 2 | P3.3 | Input of other substances (e.g. synthetic substances, non-synthetic substances, radic | MSFD list (amended EU 2017/845) | MSFDp12 (<< MAFDpt3) | included in MSFDpt3 |
| 26 | Level 2 | P3.4 | Input of litter (solid waste matter, including micro-sized litter) | MSFD list (amended EU 2017/845) | MSFDp13 (<< MAFDpt3) | included in MSFDpt3 |
| 27 | Level 2 | P3.4+P3.2 | Human impacts (litter, sewage, emissions) | Higher level scenarios (Land2Sea) | >>MSFDp12 & MSFDp13 | |
| 28 | Level 2 | P3.5 | Input of anthropogenic sound (impulsive, continuous) | MSFD list (amended EU 2017/845) | MSFDp14 (<< MAFDpt3) | included in MSFDpt3 |
| 29 | Level 2 | P3.6 | Input of other forms of energy (including electromagnetic fields, light and heat) | MSFD list (amended EU 2017/845) | MSFDp15 (<< MAFDpt3) | included in MSFDpt3 |
| 30 | Level 2 | P3.7 | Input of water — point sources (e.g. brine) | MSFD list (amended EU 2017/845) | MSFDp16 (<< MAFDpt3) | included in MSFDpt3 |
| 31 | Level 1 | P4 | **CLIMATE CHANGE** | - | - | not included in MSFD |
| 32 | Level 2 (indica | P4.1(indicator) | Mean annual air temperature | Higher level scenarios (Land2Sea) | - | Indicator of pressure ( |

metadata | CAUSES_Vocabulary1-Activities | CAUSES_Vocabulary2-Pressures | CAUSES from BBT Bow-ties



# Step 3: Consequences and opportunities

- What are the consequences (negative) arising from the central event/problem if no actions were to be taken?
- Are there any opportunities (positive consequences) that arise from the central event/problem happening?
- What management measures can be applied to reduce the magni-tude of or likelihood of the consequences?
- What enhancement measures can be applied to reduce increase the benefits from any opportunities (positive consequences)?
- What factors can enhance the management measures and what factors can cause them to fail?

# Bow-tie analysis in MARBEFES - Standardised vocabularies

## Consequences

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | CONSEQUENCES of Biodiversity change: Standardised vocabulary | | | | | |
| 2 | Hierarcl | New ID | Consequences_name | Source | ID# and relation | Remarks |
| 3 | Level 1 | C1 | **Impacts on NATURE** | Harmonisation of BTs from BBTs | | Higher level consequence (theme); includes specific consequences of the biodivers |
| 4 | Level 2 | C1.1 | Change in ecosytem /marine processes | Harmonisation of BTs from BBTs | << C1 | This may include change in marine process that is behind the ability to deliver an E |
| 5 | Level 2 | C1.2 | Decrease* in provisioning ES | Harmonisation of BTs from BBTs | << C1 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 6 | Level 3 | C1.2.1 | Decrease* in provision of fish & shellfish | Harmonisation of BTs from BBTs | << C1.2 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 7 | Level 3 | C1.2.2 | Decrease* in provision of algae & seaweed | Harmonisation of BTs from BBTs | << C1.2 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 8 | Level 3 | C1.2.3 | Decrease* in provision of genetic resources | Harmonisation of BTs from BBTs | << C1.2 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 9 | Level 3 | C1.2.4 | Decrease* in provision of water supply | Harmonisation of BTs from BBTs | << C1.2 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 10 | Level 2 | C1.3 | Decrease* in regulating ES | Harmonisation of BTs from BBTs | << C1 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 11 | Level 3 | C1.3.1 | Decrease* in Climate regulation | Harmonisation of BTs from BBTs | << C1.3 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 12 | Level 3 | C1.3.2 | Decrease* in Natural Hazard Protection | Harmonisation of BTs from BBTs + Higher l | << C1.3 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 13 | Level 3 | C1.3.3 | Decrease* in Waste breakdown and detoxification | Harmonisation of BTs from BBTs | << C1 | *impact assumed to be decrease, but it may also be increase in case of arising opp |
| 14 | Level 2 | C1.4 | Change in landscape/seascape | Harmonisation of BTs from BBTs | << C1 | |
| 15 | Level 2 | C1.5 | Impacts on nature GOVERNANCE | Harmonisation of BTs from BBTs | << C1 | changes in nature that are related to requierements of nature conservation policie |
| 16 | Level 1 | C2 | **Impacts on ECONOMY** | Harmonisation of BTs from BBTs | | Higher level consequence (theme); includes specific consequences of the biodivers |
| 17 | Level 2 | C2.1 | Increased costs | Harmonisation of BTs from BBTs | << C2 | economic impact where specified as increased costs to undertake/increase additio |
| 18 | Level 2 | C2.2 | Decreased income | Harmonisation of BTs from BBTs | << C2 | economic impact where specified as decreased income (e.g., from reduction of bus |
| 19 | Level 2 | C2.3 | Decreased economic value | Harmonisation of BTs from BBTs | << C2 | economic impact where specified as decreaed economic value of assets |
| 20 | Level 2 | C2.4 | Negative impact on labor market | Harmonisation of BTs from BBTs | << C2 | economic impact where specified as affectig labor market |
| 21 | Level 2 | C2.5 | Negative impact on the Blue Economy development | Harmonisation of BTs from BBTs | << C2 | economic impact where specified as affectig Blue economy development |
| 22 | Level 2 | C2.6 | Other economic impact | Harmonisation of BTs from BBTs | << C2 | economic impact specified otherwise |
| 23 | Level 1 | C3 | **Impacts on SOCIETY** | Harmonisation of BTs from BBTs | | Higher level consequence (theme); includes specific consequences of the biodivers |
| 24 | Level 2 | C3.1 | Decrease of aesthetic value/benefits | Harmonisation of BTs from BBTs | << C3 | |
| 25 | Level 2 | C3.2 | Decrease in human health (and benefits for it) | Harmonisation of BTs from BBTs | << C3 | also expressed as increased human health risk (may be physical and/or mental hea |
| 26 | Level 2 | C3.3 | Impact on sense of place | Harmonisation of BTs from BBTs | << C3 | |
| 27 | Level 2 | C3.4 | Decrease in other cultural benefits | Harmonisation of BTs from BBTs | << C3 | including decrease in activitoes leading to spiritual and cultural wellbeing (relaxati |
| 28 | Level 2 | C3.5 | Changed perception/behaviour | Harmonisation of BTs from BBTs | << C3 | change may have positive or negative connotation (to specify) |
| 29 | | | | | | |
| 30 | | | | | | |
| 31 | | | | | | |
| 32 | | | | | | |

metadata | CONSEQUENCES_Vocabulary | CONSEQUENCES from BBT Bow-ties

# Bow-tie analysis in MARBEFES - Standardised vocabularies

## Controls

*From CERES project + 10-tenets*

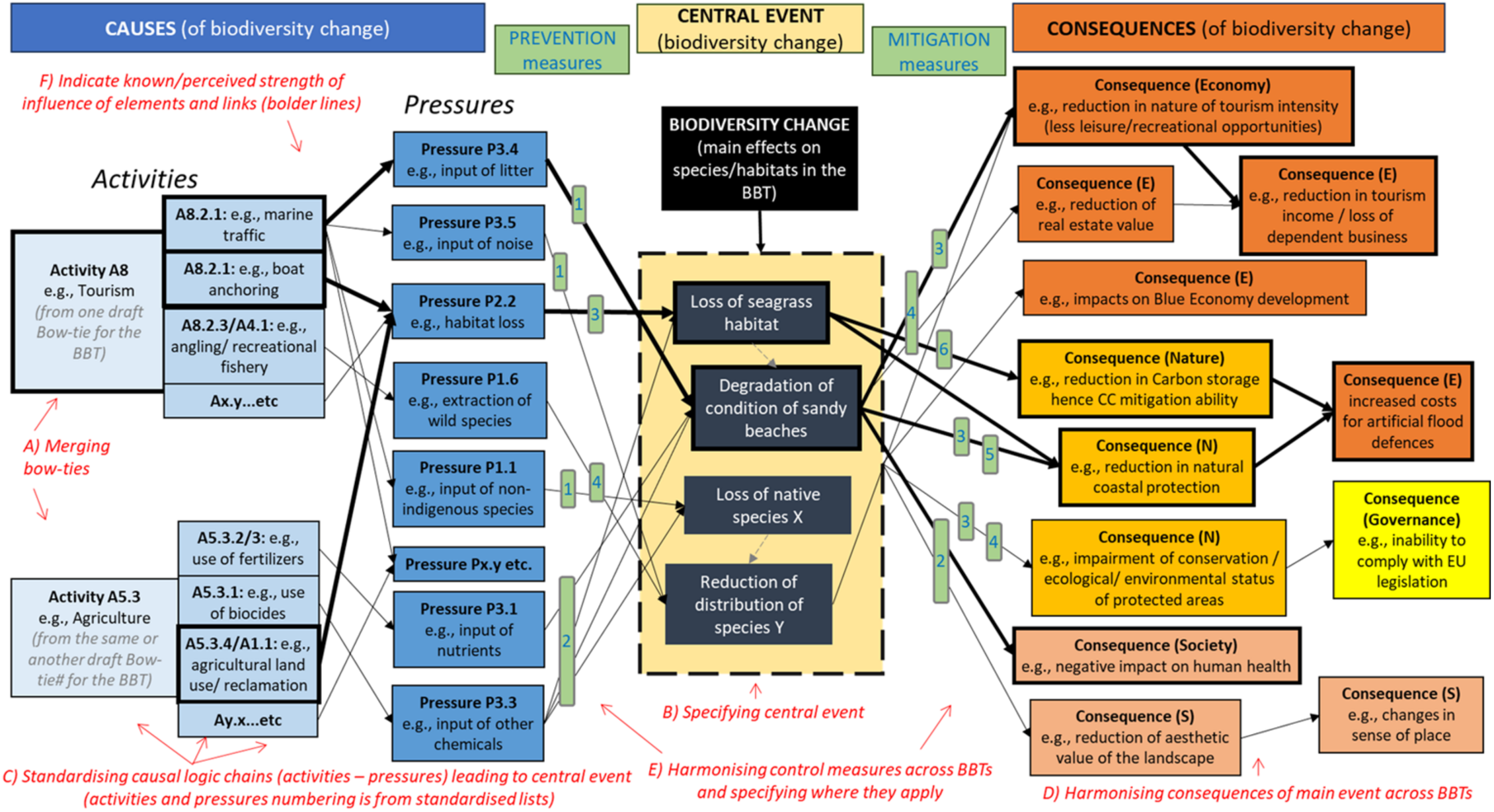
| CONTROLS of Biodiversity change: Standardised vocabulary | | | |
|---|---|---|---|
| Hierarchy | New ID# | ID qualifier | Controls_name |
| Level 1 | Ctrl1 | | NATURE PROTECTION |
| Level 1 | Ctrl2 | | INNOVATION: TECHNOLOGY/ PRACTICES TOWARDS HIGHER SUSTAINABILITY |
| Level 1 | Ctrl3 | | KNOWLEDGE BUILDING (MONITORING & RESEARCH) |
| Level 1 | Ctrl4 | | GOVERNANCE (LEGAL & ADMINISTRATIVE MEASURES) |
| Level 1 | Ctrl5 | | ECONOMIC CONTROLS |
| Level 1 | Ctrl6 | | CULTURAL & SOCIAL MEASURES (BEHAVIOUR / EDUCATION / MARKETING) |

| | A | B | C | D | | | |
|---|---|---|---|---|---|---|---|
| 1 | CONTROLS of Biodiversity change: Standardised vocabulary | | | | | | |
| 2 | Hierarchy | New ID# | ID qualifier | Controls_name | | | |
| 3 | **Level 1** | **Ctrl1** | | **NATURE PROTECTION** | | | |
| 4 | Level 2 | Ctrl1.1 | strategy | Nature conservation/management | | | |
| 5 | Level 2 | Ctrl1.2 | strategy | Nature restoration/enhancement | | | |
| 6 | Level 3 | Ctrl1.2.1 | tool | Habitat/Ecosystem restoration/remediation/enhancement | - | <<Ctrl1.2 | |
| 7 | Level 3 | Ctrl1.2.2 | tool | Species populations restocking (incl. of threatened and declining species) | CERES bow-ties | <<Ctrl1.2 | |
| 8 | Level 3 | Ctrl1.2.3 | tool | Habitat creation or offsetting (compensation) | CERES bow-ties | <<Ctrl1.2 | |
| 9 | Level 2 | Ctrl1.3 | strategy | Activities regulation (spatial, temporal and/or intensity) | CERES bow-ties | <<Ctrl1 | Pressure reduction via activities regulation |
| 10 | Level 3 | Ctrl1.3.1 | tool | Setting limits and restrictions (e.g. fishing quotas, number of visitors per season) t | CERES bow-ties | <<Ctrl1.3 | including limiting carrying capacity for acti |
| 11 | Level 3 | Ctrl1.3.2 | strategy | Spatial (and temporal) management/planning | | <<Ctrl1.3 | |
| 12 | Level 3 | Ctrl1.3.3 | tool | Relocate activities | CERES bow-ties | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 13 | Level 3 | Ctrl1.3.4 | tool | Promote co-development of activities | - | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 14 | Level 3 | Ctrl1.3.5 | tool | Enforce/improve/establish MPAs or other protection measures (e.g. corridors) | - | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 15 | Level 3 | Ctrl1.3.6 | tool | Flexible spatial limits for management to improve habitats and productivity, inclu | CERES bow-ties | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 16 | Level 3 | Ctrl1.3.7 | tool | Protect essential habitats, including temporal closure/dynamic MPAs | CERES bow-ties | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 17 | Level 3 | Ctrl1.3.8 | tool | Adapt seasonality of activity based on species/habitat ecology (eg. reproduction n | CERES bow-ties | <<Ctrl1.3 | may overlap/be part of spatial/temporal p |
| 18 | Level 3 | Ctrl1.3.9 | tool | Implement mitigation measures to reduce pressures | - | <<Ctrl1.3 | e.g. measures to mitigate pressures arising |
| 19 | **Level 1** | **Ctrl2** | | **INNOVATION: TECHNOLOGY/ PRACTICES TOWARDS HIGHER SUSTAINABILITY** | **-** | | Use/application of technological improven |
| 20 | Level 2 | Ctrl2.1 | strategy | Reduce fossil fuel consumption (and CO2 emissions) or increase alternative energy | CERES bow-ties | <<Ctrl2 | included in CTRLT5 |
| 21 | Level 2 | Ctrl2.2 | strategy | Technology improvements or adoption of alternative practices towards reduction/ | CERES bow-ties | <<Ctrl2 | (e.g., more selective fishing and gears) |
| 22 | Level 3 | Ctrl2.2.1 | tool | Building with nature-based solutions | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | |
| 23 | Level 3 | Ctrl2.2.2 | tool | Organic farming | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 24 | Level 3 | Ctrl2.2.3 | tool | Sustainable meat production | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 25 | Level 3 | Ctrl2.2.4 | tool | Arable land for crops | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 26 | Level 3 | Ctrl2.2.5 | tool | Crop rotation | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 27 | Level 3 | Ctrl2.2.6 | tool | Regionalised agriculture | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 28 | Level 3 | Ctrl2.2.7 | tool | Growth of non-native plantations | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | not that relevant for marine systems? |
| 29 | Level 3 | Ctrl2.2.8 | tool | Controlled drainage | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 30 | Level 3 | Ctrl2.2.9 | tool | Erosion control on fields | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | applied to catchment |
| 31 | Level 3 | Ctrl2.2.10 | tool | Environmentally friendly energy generation | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | |
| 32 | Level 3 | Ctrl2.2.11 | tool | Technical improvements of waste water treatment plants related to aspects other | Higher level scenarios (Land2Sea) | <<Ctrl2.2 | |

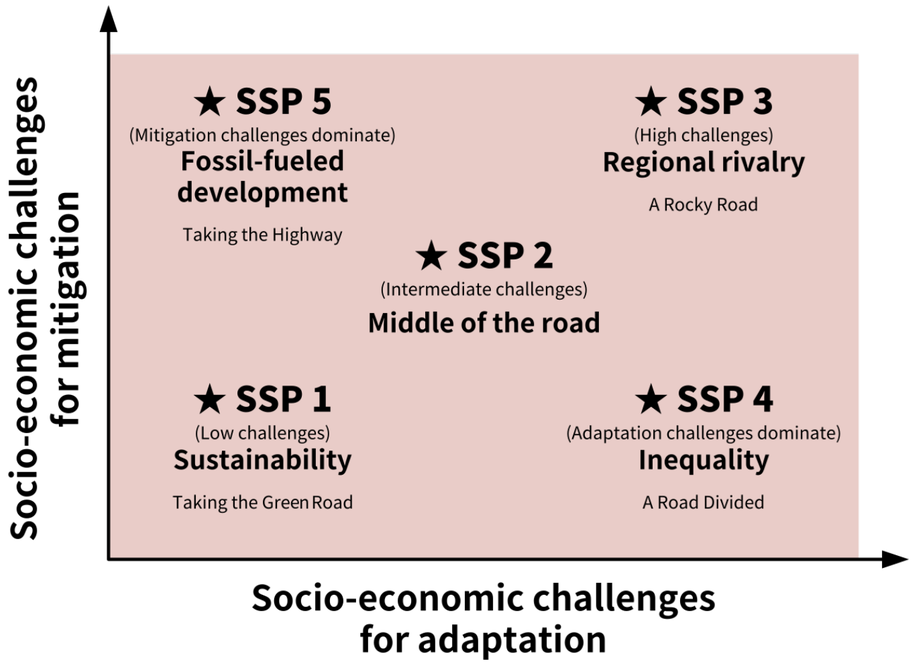
metadata | CONTROLS_Vocabulary | CONTROLS from BBT Bow-ties

# Bow-tie template used by BBTs in MARBEFES

Example of final Bow-tie diagram for a BBT (mock-up) *(in red are suggested changes for finalisation – see explanation in the text below)*



# High-level scenarios




## Additional novel application of the Bow-tie:

## Downscaling high-level socio-economic scenarios of change into the case-specific (BBT) Bow-tie

IPCC 6th assessment 2023
Shared Socio-Economic Pathways

*Table 3. MARBEFES 3 high-level scenarios.*

| Shared Socioeconomic Pathways | Name |
|---|---|
| SSP1 | Sustainability |
| SSP3 | Regional rivalry |
| SSP5 | Fossil-fuelled development |

*"Taking the green road"*

*"A rocky road"*

*"Taking the Highway"*

Representative Concentration Pathway[4] (RCP) scenarios will be chosen at a later stage for modelling purposes.

# High-level scenarios - Storyline overviews

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Shared socioeconomic pathway (SSP)** | **SSP1: Sustainability - Taking the green road** | **SSP3: Regional rivalry—A rocky road** | **SSP5: Fossil Fueled Development – Taking the Highway** | **Comment** | |
| 2 | **Mitigation** | High | Low | Low | Mitigation is the reduction of the sources or enhancement of the sinks of greenhouse gases. | |
| 3 | **Adaptation** | High | Low | High | Adaptation is the adjustment in natural or human system in response to actual or expected climate stimuli or their effects, which moderates harm or exploits benefitial opportunities | |
| 4 | **Short description** | The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity. | A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions. | This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the twenty-first century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary. | | |
| 5 | **Main objective** | Global sustainability | Regional security | Economic growth | | |
| 6 | **Drivers** | Increasing evidence of social, cultural, economic costs of environmental degradation and inequality | Nationalism; competitiveness; security; regional conflicts | Economic success of industrialized and emerging economies | | |
| | **Economy** | Reduced inequality; connected markets; regional production | High inequality across countries; restricted markets; regional security | Reduced inequality; high international trade with strong specialization of production | | |

Explanatory notes | Storyline Overviews | Template for downscaling | Example from Dublin - Land2Sea

# High-level scenarios - Downscaling

| New ID# | Activity/Pressure | Sustainability | Regional rivalry | Fossil-fuelled development |
|---|---|---|---|---|
| | | SSP1 | SSP3 | SSP5 |
| | Mitigation measures | High | Low | Low |
| | Adaptation measures | High | Low | High |
| ACTIVITIES | | | | |
| A1 | PHYSICAL RESTRUCTURING OF RIVERS, COASTLINE OR SEABED (WATER MANAGEMENT) | | | |
| A1.1 | Land claim | -3 | +2 | +1 |
| A1.5 | Restructuring of seabed morphology, including dredging and depositing of materials | -1 | +1 | 0 |
| A4 | EXTRACTION LIVING RESOURCES | | | |
| A4.1 | Fish and shellfish harvesting (professional, recreational) | -2 | +3 | +1 |
| A6 | TRANSPORT | | | |
| A6.1 | Transport infrastructure | 0 | +1 | +2 |
| A6.2 | Transport — shipping | -1 | +1 | +2 |
| A7 | URBAN AND INDUSTRIAL USES | | | |
| A7.1 | Urban uses | 0 | -1 | +2 |
| A7.1(indicator) | Number of secondary homes | 0 | -1 | +2 |
| A7.2 | Industrial uses | -1 | +2 | +2 |
| A8 | TOURISM AND LEISURE | | | |
| A8.1 | Tourism and leisure infrastructure | 0 | +1 | +2 |
| A8.2 | Tourism and leisure activities | +2 | +1 | +2 |
| A8.2 + A4.1 | Local recreation (angling, walking, canoeing, ...) | +2 | +1 | +2 |
| A8.2(indicator) | Number of visitors | +2 | -2 | +3 |
| PRESSURES | | | | |
| P1 | BIOLOGICAL PRESSURES | | | |
| P1.1 | Input or spread of non-indigenous species | +1 | +1 | +2 |
| P1.5 | Disturbance of species (e.g. where they breed, rest and feed) due to human presence | -3 | +2 | 0 |
| P2 | PHYSICAL PRESSURES | | | |
| P2.1 | Physical disturbance to seabed (temporary or reversible) | -2 | +3 | +1 |
| P2.2 | Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate) | -3 | +2 | +1 |
| P2.3 | Changes to hydrological conditions | 0 | +1 | +1 |
| P3 | SUBSTANCES, LITTER AND ENERGY | | | |
| P3.1 | Input of nutrients — diffuse sources, point sources, atmospheric deposition | -3 | +1 | 0 |
| P3.2 | Input of organic matter — diffuse sources and point sources | -3 | +1 | 0 |
| P3.2.1 | Sediments in water due to erosion | -3 | +2 | +1 |

Explanatory notes | Storyline Overviews | Bay of Biscay

BBTs scored the expected change in each variable (causes, i.e. activities and pressures used in the Bow-tie) on a scale from -3 (strong negative change) to +3 (strong positive change) under the three scenarios

*Downscaling completed by almost all BBTs (BBT1 and BBT7 missing)*

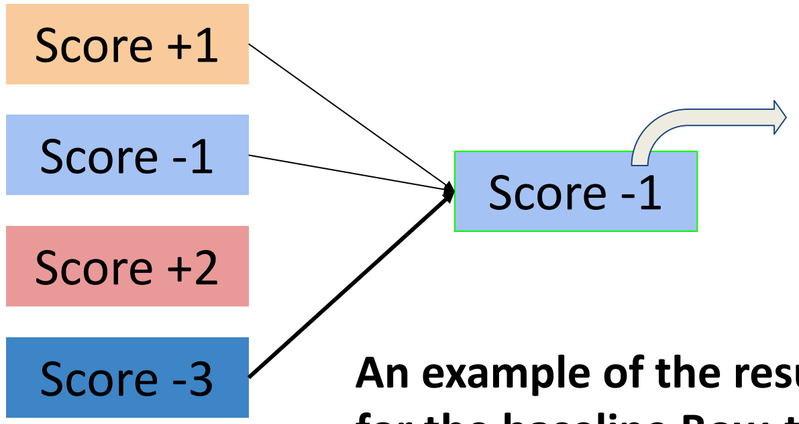
# Downscaling scenarios into Bow-ties

- Scenario scoring transferred into Bow-tie graphically using colour scale

| Downscaling scores | | | D/S score |
|---|---|---|---|
| +3 | Strong | positive change | +3 |
| +2 | Medium | | +2 |
| +1 | Weak | | +1 |
| 0 | No change | | 0 |
| -1 | Weak | negative change | -1 |
| -2 | Medium | | -2 |
| -3 | Strong | | -3 |
| | | | n/a |


- For causes (activities & pressures), colour reflects the score given by the BBT

- For other elements of the Bow-tie, colour reflects the average of the scores allocated to the previous connected elements

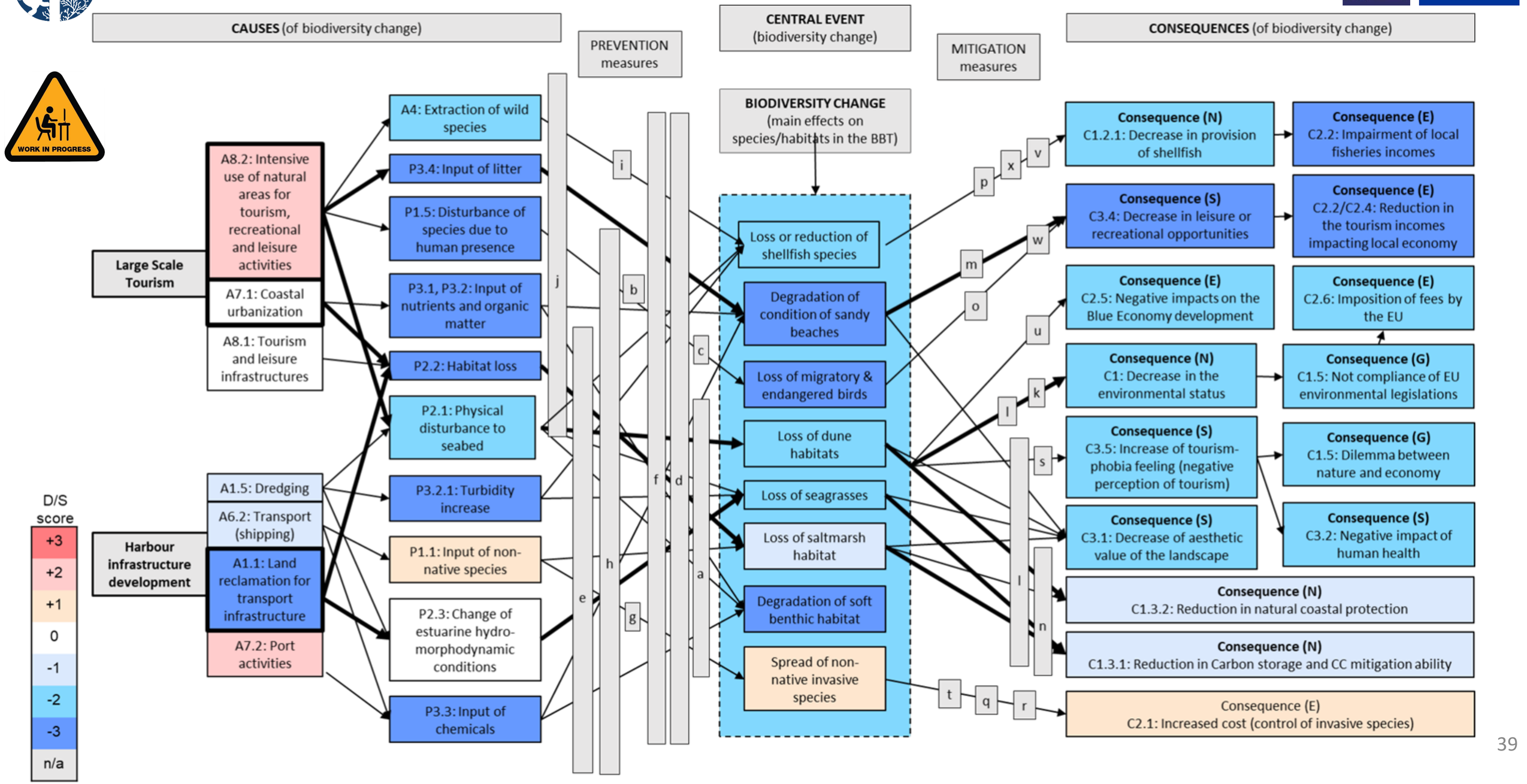



Calculated as average of +1, -1 and -3

*(at the moment simple average is used, but weights may be added to account for variable strength of the links as represented by variable thickness of the arrows in the bow-tie)*

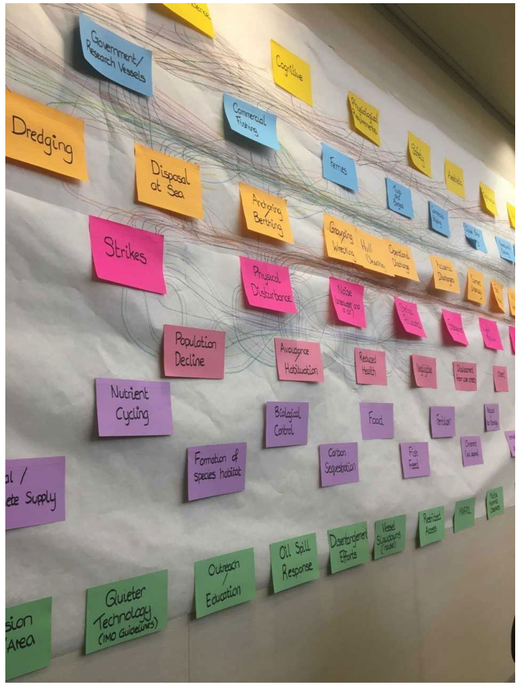
**An example of the resulting Bow-tie is shown in the next slides for BT9 (see slide #12 for the baseline Bow-tie which was the starting point for the downscaling)**

# BBT9 - Bow-tie, Scenario SSP1 Sustainability

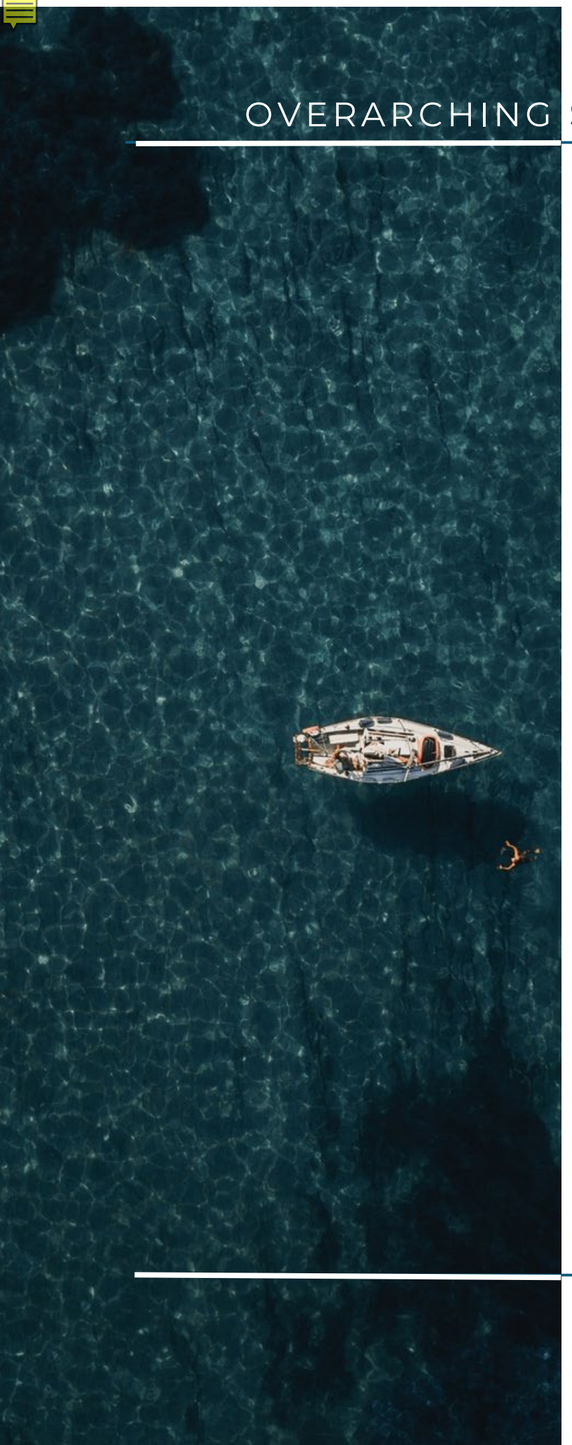


# Re-cap: Recipe for tackling the problem and identifying opportunities:

- Define the central problem and the framework for opportunities
- Create risk- and opportunity-based generic Bow-ties with Drivers and Activities
- Analyse previous experience, projects and literature
- Incorporate the 10-tenets for management responses
- Produce a ‘strawman’ for discussion with stakeholders
- Refine and produce the site- and topic-specific Bow-ties
- Interrogate Bow-Ties to show the gaps and opportunities for nature and society
- Interrogate Bow-Ties to show the gaps and opportunities for science and management
- Downscale the high-level IPCC scenarios to be relevant to local issues




(Photo. Lauren McWhinnie, UVIC workshop, 2018)



# Benefits of engaging with these tools...

- Reduce the complexity of a holistic, multi -sector approach to marine environmental management challenges
- Contribute local knowledge to inform the model, enhancing its practical applicability
- Allows the practitioner to identify points in the system where management measures will be effective
- Contribute to the development of these tools to ensure they are fit for purpose and suits your needs as a stakeholder .

# And now you have carried out all the management, assessment and reporting:

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Review

## Managing marine resources sustainably – But how do we know when marine management has been successful?

Michael Elliott [a,b,*], Ángel Borja [c], Roland Cormier [d]

# Thank you!

## Any Questions?

**Michael Elliott, Anita Franco, and Gemma Smith - IECS Ltd.**

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