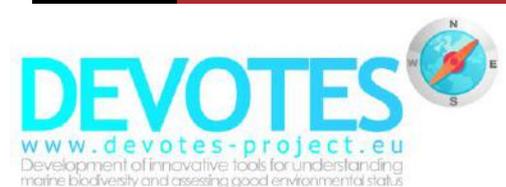


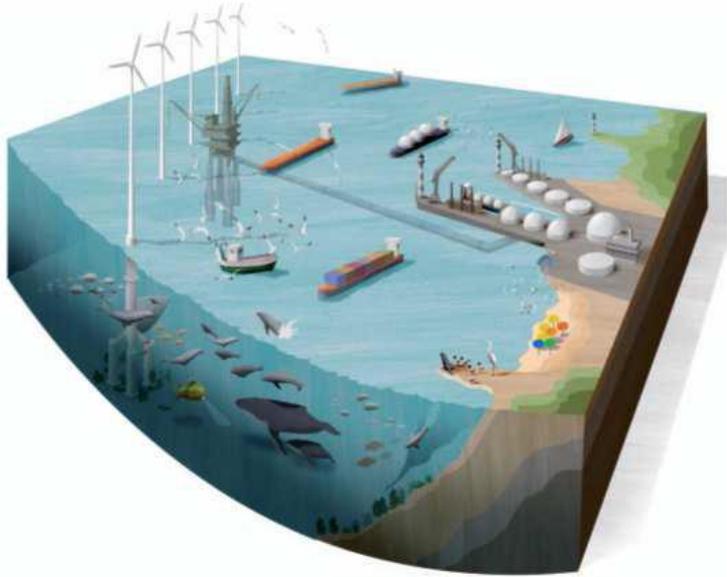
# Marine risk assessment and management using the Bow-tie approach and its practical applications

*Professor Mike Elliott, Sue Boyes & Dr Katie Smyth*

*Institute of Estuarine and Coastal Studies (IECS), University of Hull, Hull HU6 7RX, UK*



- 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?
-



There is only one big idea in marine management: *how to maintain and protect ecological structure and functioning while at the same time allowing the system to produce ecosystem services from which we derive societal benefits.*

**MSFD**

**MSPD**

- Recovery/coping with historical legacy
- Endangered coastal and marine ecosystem functions
- Legal & administrative framework
- Economic prosperity and delivery of societal benefits
- Coping with climate change & moving baselines

## 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

= Risk Assessment & Risk Management (RA&RM):

- Hazard Identification:
- Risk Assessment:
- Risk Management:
- Risk Communication:

Ocean & Coastal Management 93 (2014) 88–99



Contents lists available at [ScienceDirect](#)

Ocean & Coastal Management

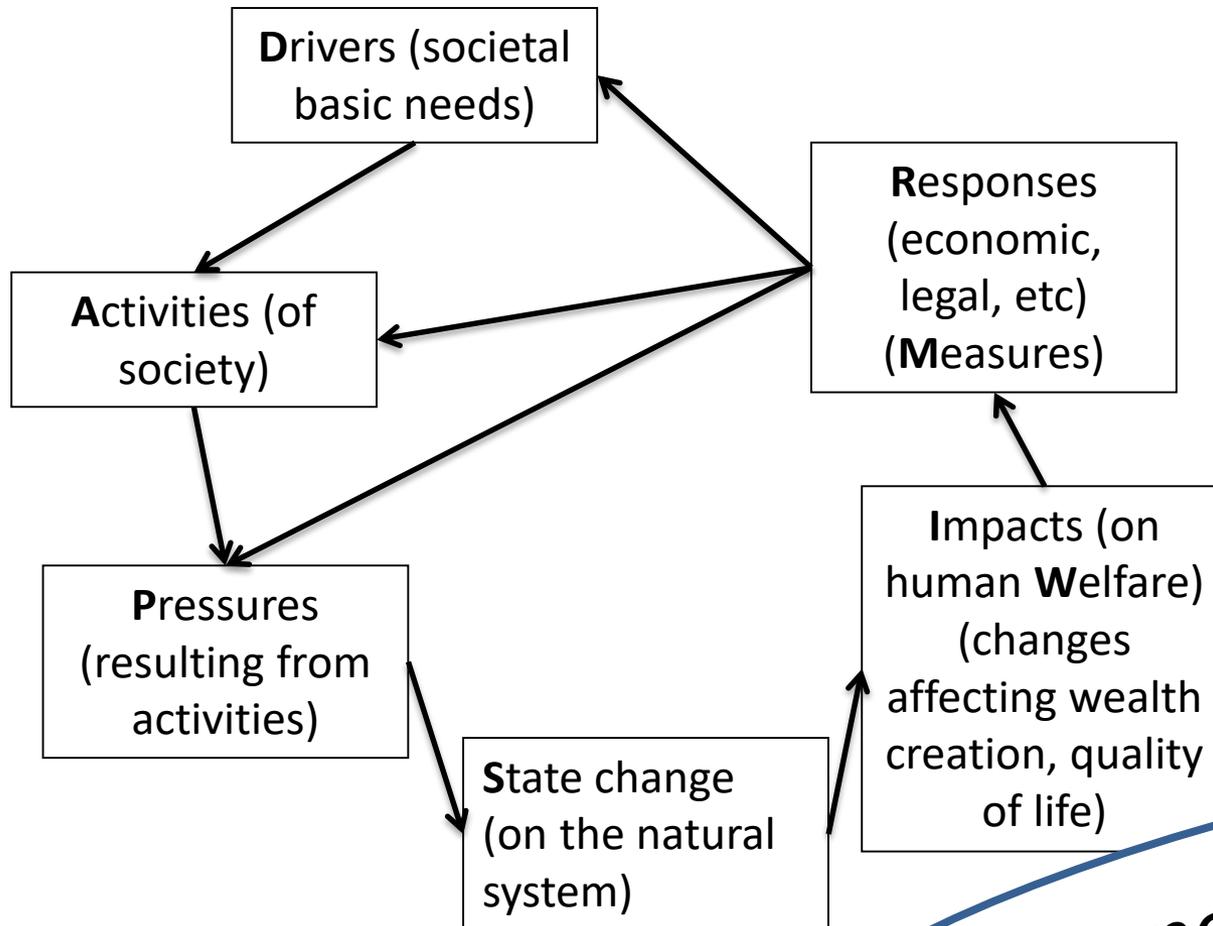
journal homepage: [www.elsevier.com/locate/ocecoaman](http://www.elsevier.com/locate/ocecoaman)

Review

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

Michael Elliott<sup>a,\*</sup>, Nicholas D. Cutts<sup>a</sup>, Anna Trono<sup>b</sup>

# DAPSI(W)R(M) framework



*(for each EnMP cf. Ex)*

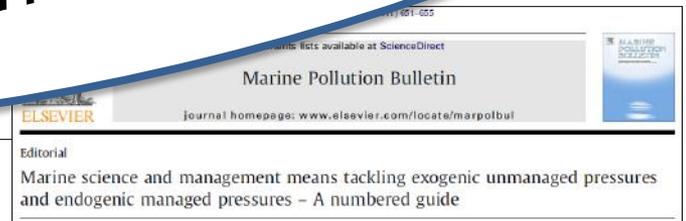
Pronounced "dapsiworm"!



Editorial  
Integrated marine science and management: Wading through the morass



Analysis  
Processes for the sustainable stewardship of marine environments  
Henrik Scharin<sup>1,2\*</sup>, Siv Ericsdotter<sup>3</sup>, Michael Elliott<sup>4</sup>, R. Kerry Turner<sup>5</sup>, Susa Niiranen<sup>6</sup>, Thorsten Blenckner<sup>6</sup>, Kari Hyytiäinen<sup>6</sup>, Lassi Ahlvik<sup>1</sup>, Heini Ahtainen<sup>1</sup>, Janne Artell<sup>1</sup>, Linus Hasselström<sup>6</sup>, Tore Söderqvist<sup>1</sup>, Johan Rockström<sup>4</sup>



Editorial  
Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – A numbered guide

In managing an area (estuary, coastline, sea region), we use **Risk Analysis and Risk Management:**

For the *Endogenic Managed Pressures* – we manage the causes and the consequences;

For the *Exogenic Unmanaged Pressures* – we only manage and respond to the consequences as the causes have to be tackled at a wider (e.g. global) scale

From the DAPSI(W)R(M) framework – we **measure and assess** the Pressures, State changes and Impacts on human Welfare but we **manage** (using Responses and Measures) the Drivers and Activities

$$(D+P+A) + R(M) \neq S + I(W)$$

# The 10-tenets:

**To be successful, management measures or responses to changes resulting from human activities should be:**

- Ecologically sustainable
- Technologically feasible
- Economically viable
- Socially desirable/tolerable
- Legally permissible
- Administratively achievable
- Politically expedient
- Ethically defensible (morally correct)
- Culturally inclusive
- Effectively communicable

The UK and Marine Scotland vision:  
*“clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long-term needs of people and nature”.*



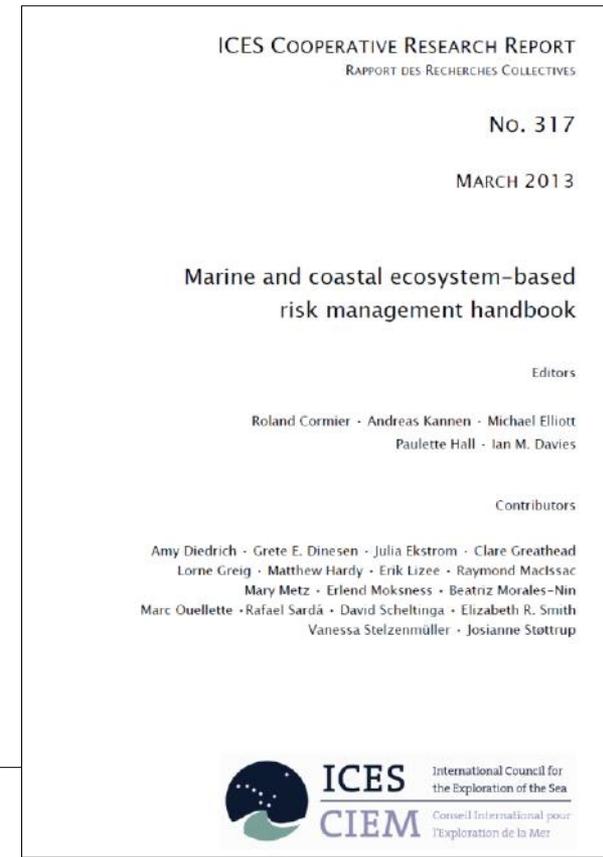
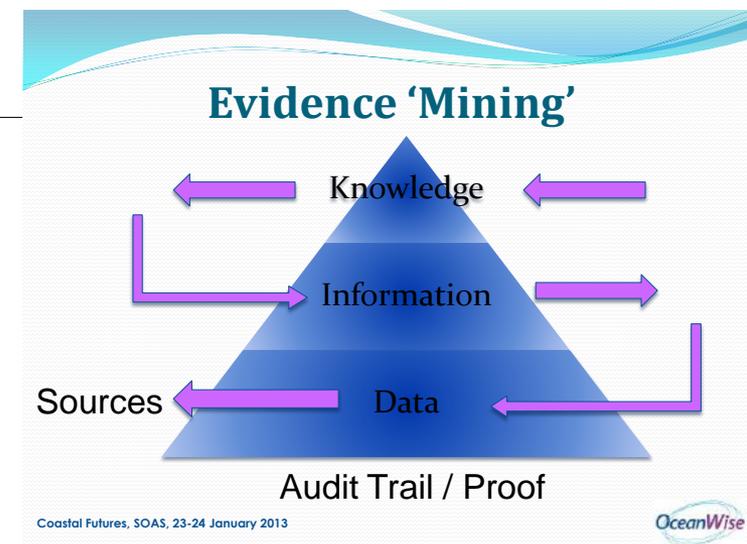
*(NB spellcheck - not “a good night in Scotland”!)*



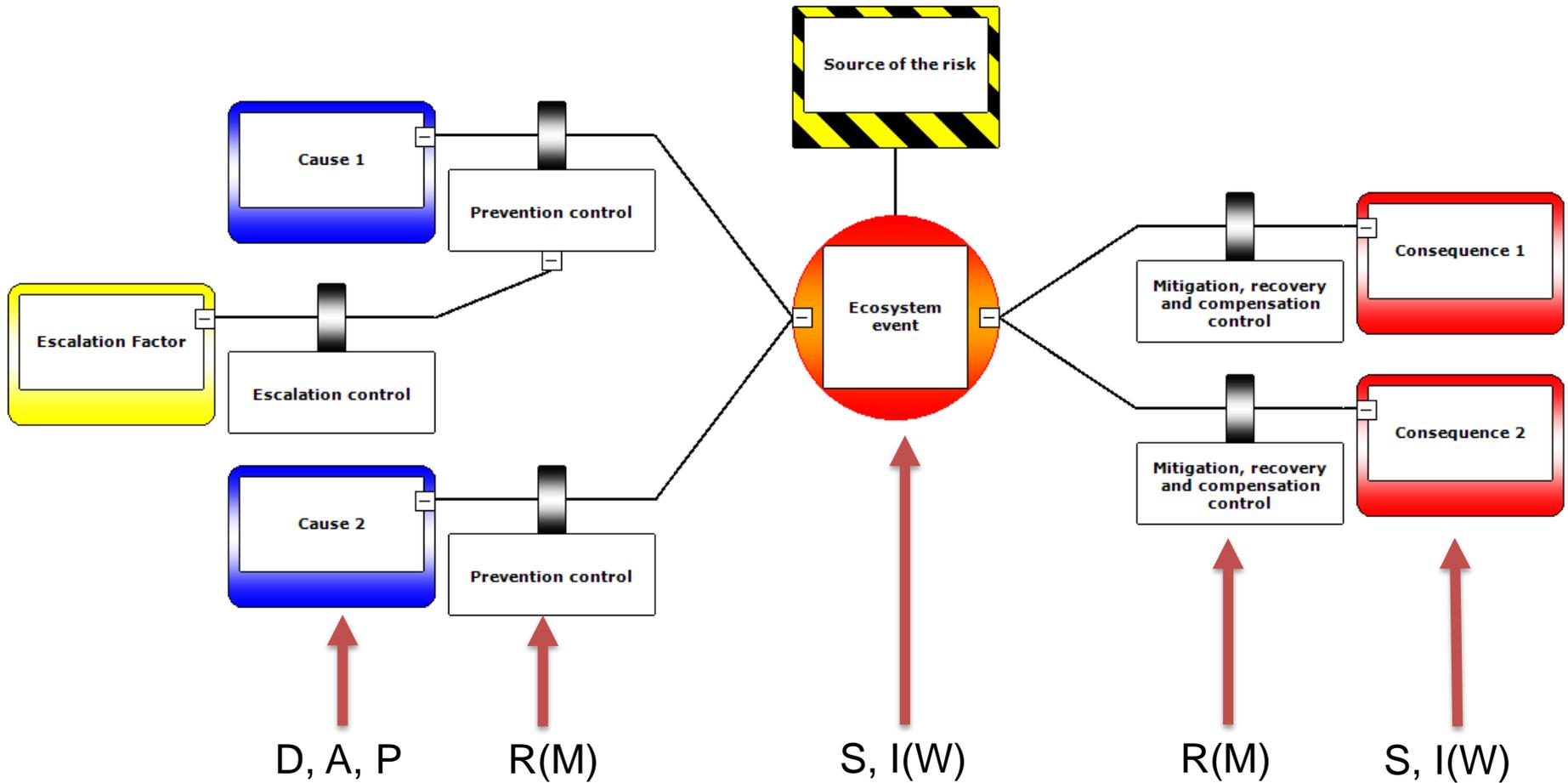
# Bow-Tie analysis

- Bow-Tie analysis is an ISO certified method
- a simple graphical way to describe and analyse risk pathways from hazards linked to the outcomes of management measures.
- a systematic approach of assuring control over environmental, health and safety hazards and now adopted for the ecosystem approach

*Importance of audit trails, defensible actions and policies*

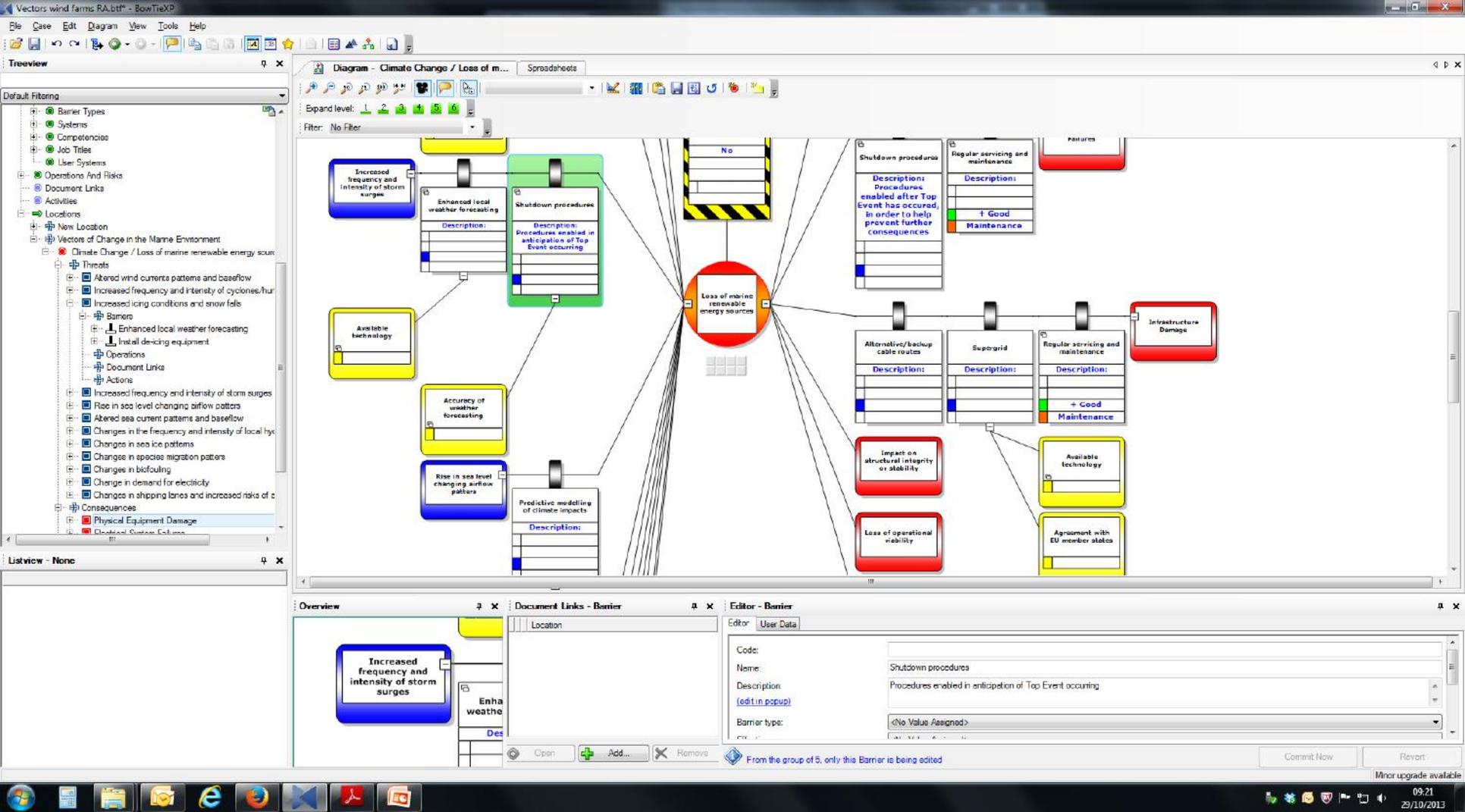


# Bow-Tie Analysis linked to **DAPSI(W)R(M)** Framework for Risk Assessment and Risk Management with Responses (using Measures) based on the 10-tenets

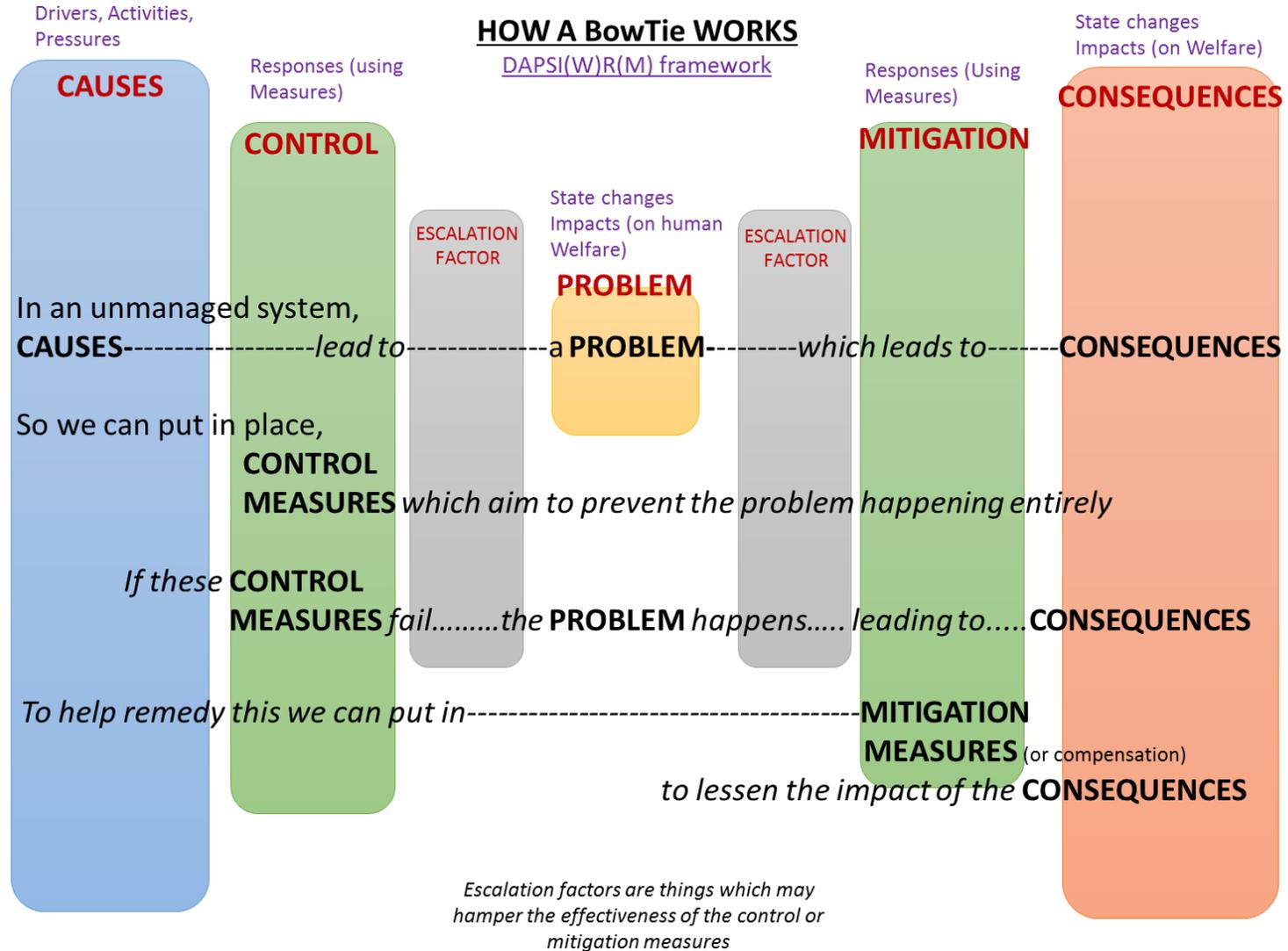


*Stakeholder consultation – to determine causes and consequences and to agree the responses throughout the sequence*





Screen capture of the BowTie program in action.



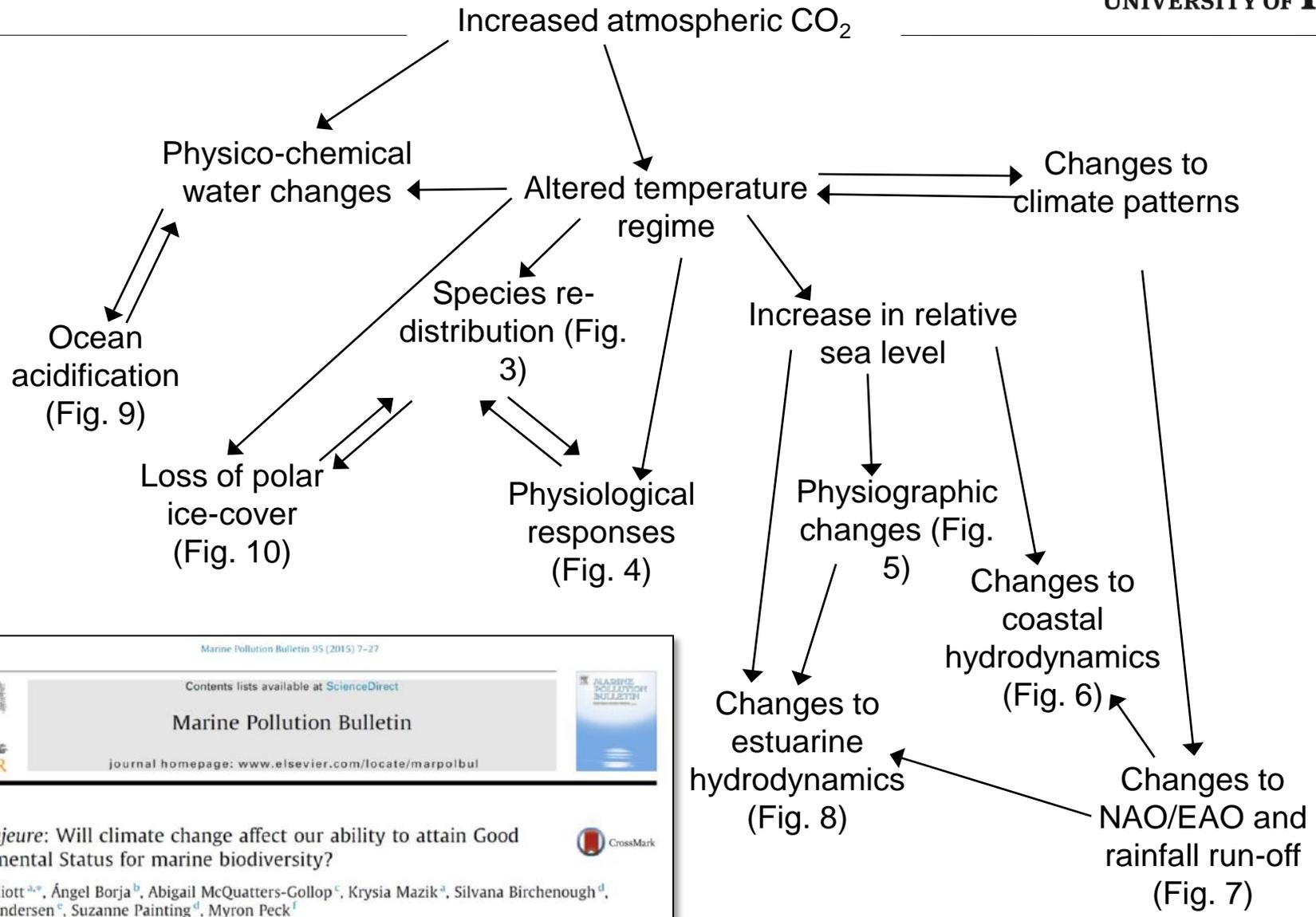
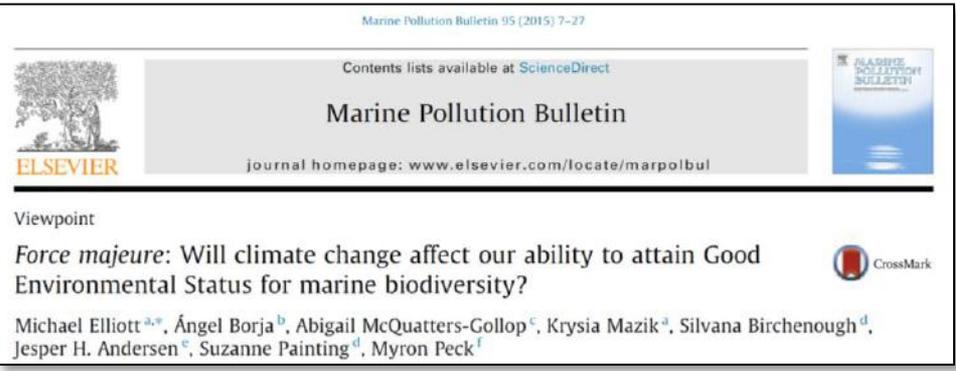


Figure 2 Primary drivers and consequences of marine global climate change (cross-referring to other figures)



# MARINE AQUACULTURE RISKS

## CAUSES

## CONSEQUENCE



## CONTROL

## MITIGATION

## ESCALATION FACTORS

## PROBLEM

Loss of or reduction in abundance of an aquaculture stock

Adoption of legislation by member states  
Enforcement  
Shifts in public perception  
Finance available to enact control measures

Adoption of legislation by member states  
Enforcement  
Shifts in public perception  
Finance available to enact mitigation measures

Legislation (e.g.. EU directives) (3)  
Regulations (3)  
Penalties (1,3)  
Subsidies for use of alternative technology/renewable power etc. (1,3)  
Fisheries management e.g. Quotas/seasons/closures to take pressure off threatened resources (3,4)  
Use of alternative technology (e.g.. renewables) (2,3)  
Carbon capture (2)  
Stock enhancements (4)  
Reduction of CO2 emissions (2)  
Reduce the other pressures which make the resource more vulnerable to climate change (2)

Promote alternative resources (1,2)  
Legislation (e.g. EU directives) (3)  
Stock enhancements (4)  
Fisheries management e.g.. Quotas/seasons/closure (3,4)  
Promote alternative technologies (1,2,3)  
Compensation payouts (1)  
Habitat offsetting (2,4)  
Greater controls on trade in marine aquatic species (e.g.. aquarium trade) (2,3,4)  
Habitat creation (2,4)

Job losses (3,4,6)  
Job creation (3,4,6)  
Changing employment markets (3,4,6,7)  
Changing aquaculture gears/technology (1,2,3,4,6,7,8)  
Change the resource fished (1,2,3,9)  
Increased pressure on substitute/alternative species (1,8,9)  
Changes to food webs (1)  
Human hunger (3,4,5,6,8,9)  
Changes/impacts on artisanal fisheries (8,9)  
Changes/impacts on traditions/values (4,8,9)  
Permanent ecosystem changes (compositions and proportions of components) (1)

- Umbrella categories for risks (CC related)**
1. Altered temperature regime
  2. Physico-chemical water changes
  3. Weather changes / climate pattern changes
  4. Sea level rise
  5. Anthropogenic influences
  6. Changes to rainfall and runoff
  7. Loss of polar ice cover
  8. Ocean acidification
  9. Hydrodynamic changes

- Umbrella categories for control and mitigation measures**
1. Fiscal incentives
  2. Physical barrier/mitigation
  3. Governance incentives
  4. Biological intervention

- Umbrella categories for consequences based on the ten-tenets**
1. Ecological
  2. Technological
  3. Economical
  4. Social
  5. Legal
  6. Administrative
  7. Political
  8. Ethical
  9. Cultural
  10. Communicable

# CAUSES

- Decreased survival (1,2,5,7,9)
- Decreased tolerance (1,2,5,6,9)
- Decreased growth conditions (1,2,5,7,9)
- Decreased reproduction (1,2,5,7,9)
  - Decreased recruitment (1,2,3,4,5,7,9)
- Loss of habitat (3,4,5,6,7,9)
- Loss of spawning areas (3,4,5,6,7,9)
- Loss of nursery areas (3,4,5,6,7,9)
- Decrease in habitat connectivity (3,4,5,6,7,9)
- Decrease in larval transport (2,3,4,6,7,9)
- Species range shifts (1,2,3,7,9)
- Seasons change (1,2,3,7,9)
- Decreased food/prey availability (1,2,3,4,5,6,7,8,9)
- Increased competition from non native and invasive species (1,2,3,6,7,8,9)
- Modified governance (5)
- Altered technologies (5)
- Anthropogenic CC related direct contaminants (5)

## Umbrella categories for risks (CC related)

1. Altered temperature regime
2. Physico-chemical water changes
3. Weather changes / climate pattern changes
4. Sea level rise
5. Anthropogenic influences
6. Changes to rainfall and runoff
7. Loss of polar ice cover
8. Ocean acidification
9. Hydrodynamic changes

# MARINE FISHERIES RISKS



## CONTROL

- Legislation (e.g. EU directives) (3)
- Regulations (3)
- Penalties (1,3)
- Subsidies for use of alternative technology/renewable power etc. (1,3)
- Fisheries management e.g. Quotas/seasons/closures to take pressure off threatened resources (3,4)
- Use of alternative technology (e.g.. renewables) (2,3)
- Carbon capture (2)
- Stock enhancements (4)
- Reduction of CO2 emissions (2)
- Reduce the other pressures which make the resource more vulnerable to climate change (2)

Adoption of legislation by member states

Enforcement

Shifts in public perception

Finance available to enact control measures

## ESCALATION FACTORS

### PROBLEM

Loss of or reduction in abundance of an fishery stock

## MITIGATION

- Promote alternative resources (1,2)
- Legislation (e.g. EU directives) (3)
- Stock enhancements (4)
- Fisheries management e.g.. Quotas/seasons/closure (3,4)
- Promote alternative technologies (1,2,3)
- Compensation payouts (1)
- Habitat offsetting (2,4)
- Greater controls on trade in marine aquatic species (e.g.. aquarium trade) (2,3,4)
- Habitat creation (2,4)

## Umbrella categories for control and mitigation measures

1. Fiscal incentives
2. Physical barrier/mitigation
3. Governance incentives
4. Biological intervention

# CONSEQUENCE

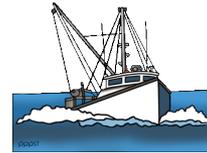
- Job losses (3,4,6)
- Job creation 3,4,6
- Changing employment markets (3,4,6,7)
- Changing fisheries gears (1,2,3,4,6,7,8)
- Change the resource fished (1,2,3,9)
- Increased pressure on substitute/alternative species (1,8,9)
- Changes to food webs (1)
- Human hunger (3,4,5,6,8,9)
- Changes/impacts on artisanal fisheries (8,9)
- Changes/impacts on traditions/values (4,8,9)
- Permanent ecosystem changes (compositions and proportions of components) (1)

## Umbrella categories for consequences based on the ten-tenets

1. Ecological
2. Technological
3. Economical
4. Social
5. Legal
6. Administrative
7. Political
8. Ethical
9. Cultural
10. Communicable

- The cause and effect pathways described for risk assessment and risk management can also be used to indicate opportunity assessment and opportunity management,
    - not only will climate change cause risks to inland and marine fisheries and aquaculture but also it may present opportunities.
  - Some of those opportunities will be the result of risks:
    - for example if climate change causes a target species to be lost or have migrated out of an area but it is replaced by another harvestable or culturable species then this is an additional consequence of the risk;
    - alternatively, a species may move into an area and become available for harvesting irrespective of whether it replaced another species.
  - As with the Bow-Tie diagrams for risk, enabling features are added at both sides of the central opportunity and which may enhance the opportunity.
-

# Marine wild fisheries opportunities



## CAUSES

- Increased survival of southern spp (1,2,5,7,9)
- Increased tolerance (1,2,5,6,9)
- Increased growth conditions (1,2,5,7,9)
- Increased reproduction (1,2,5,7,9)
- Increased recruitment (1,2,3,4,5,7,9)
- Gain of habitat (3,4,5,6,7,9)
- Gain of spawning areas (3,4,5,6,7,9)
- Gain of nursery areas (3,4,5,6,7,9)
- Increases in habitat connectivity (3,4,5,6,7,9)
- Increase in larval transport (2,3,4,6,7,9)
- Species range shifts (1,2,3,7,9)
- Seasons change (1,2,3,7,9)
- Increased food/prey availability (1,2,3,4,5,6,7,8,9)
- Decreased competition by loss of "native" species (1,2,3,6,7,8,9)
- Modified governance (5)
- Altered technologies (5)
- Different stock species available for harvest (2,5)

### Umbrella categories for opportunities (CC related)

1. Altered temperature regime
2. Physico-chemical water changes
3. Weather changes / climate pattern changes
4. Sea level rise
5. Anthropogenic influences
6. Changes to rainfall and runoff
7. Loss of polar ice cover
8. Ocean acidification
9. Hydrodynamic changes

## ENHANCE OPPORTUNITY

- Legislation (e.g. EU directives) (3)
- Regulations (3)
- Penalties (1,3)
- Subsidies for use of alternative technology/renewable power etc. (1,3)
- Fisheries management e.g. Quotas/seasons/closures to take pressure off threatened resources (3,4)
- Use of alternative technology (e.g.. renewables) (2,3)
- Carbon capture (2)
- Stock enhancements (1,3,4)
- Reduction of CO2 emissions (2)
- Reduce the other pressures which make the resource more vulnerable to climate change (2)

## ESCALATION FACTORS OPPORTUNITY

- Adoption of legislation
- Enforcement of control measures
- Shifts in public perception
- Finance available to enact enhancement measures

**New or increased abundance of a marine fishery stock**

- Adoption of legislation
- Enforcement of mitigation measures
- Shifts in public perception
- Finance available to enact exploitation measures

## EXPLOITATION MEASURE

- Promote resource to industry and consumers (2,4)
- Remove restricting legislation (2,3)
- Subsidies (1,3)
- Fisheries management: Quotas/seasons/closures/MLS to allow stock to grow/develop (3)
- Promote alternative technologies (2,4)
- Habitat creation to support growth of new stock (2,3)

### Umbrella categories for exploitations and enhancement measures

1. Fiscal incentives
2. exploitation of opportunity
3. governance incentives
4. developing synergisms (synergy = things together produce a combined effect greater than the sum of their separate effects)

## BENEFITS

- Job creation (3,4,6,)
- Changing employment markets (3,4,6,7)
- Changing fisheries gears (1,2,3,4,6,7,8)
- Fishing new spp/stock takes pressure off "old" spp/stock (1,8)
- Decreased pressure on substitute/alternative species (1,8)
- Opportunity for exporting products (2,3)
- Processing (2,3,6)

### Umbrella categories for benefits based on the ten-tenets

1. Ecological
2. Technological
3. Economical
4. Social
5. Legal
6. Administrative
7. Political
8. Ethical
9. Cultural
10. Communicable

# Marine aquaculture opportunities



## CAUSES

- Increased survival of southern spp (1,2,5,7,9)
- Increased tolerance (1,2,5,6,9)
- Increased growth conditions (1,2,5,7,9)
- Increased reproduction (1,2,5,7,9)
- Increased recruitment (1,2,3,4,5,7,9)
- Gain of habitat (3,4,5,6,7,9)
- Gain of spawning areas (3,4,5,6,7,9)
- Gain of nursery areas (3,4,5,6,7,9)
- Increases in habitat connectivity (3,4,5,6,7,9)
- Increase in larval transport (2,3,4,6,7,9)
- Species range shifts (1,2,3,7,9)
- Seasons change (1,2,3,7,9)
- Increased food/prey availability (1,2,3,4,5,6,7,8,9)
- Decreased competition by loss of "native" species (1,2,3,6,7,8,9)
- Modified governance (5)
- Altered technologies (5)
- Different stock species available for harvest (2,5)

## ENHANCE OPPORTUNITY

- Government incentives (2,3)
- Subsidies (2,3)
- Fisheries management (Quotas/seasons/closures/MLS to allow stock to grow/develop) (1,2,3)
- Use of alternative technology (e.g.. renewables) (2,3)
- Reduction of CO2 emissions (2)
- Stock enhancements (1,3,4)
- Habitat creation to support growth of new stock (2,3)
- Marine spatial planning (2)

## ESCALATION FACTORS

- Adoption of legislation
- Enforcement of control measures
- Shifts in public perception
- Finance available to enact enhancement measures

## OPPORTUNITY

New or increased abundance of a **marine aquaculture stock**

- Adoption of legislation
- Enforcement of mitigation measures
- Shifts in public perception
- Price of harvesting technology
- Finance available to enact exploitation measures

## EXPLOITATION MEASURE

- Promote resource to industry and consumers (2,4)
- Remove restricting legislation (2,3)
- Subsidies (1,3)
- Fisheries management: Quotas/seasons/closures/MLS to allow stock to grow/develop (3)
- Promote alternative technologies (2,4)
- Habitat creation to support growth of new stock (2,3)

## BENEFITS

- Job creation (3,4,6,)
- Changing employment markets (3,4,6,7)
- Changing fisheries gears (1,2,3,4,6,7,8)
- Culturing new spp/stock takes pressure off "old" spp/stock (1,8)
- Decreased pressure on substitute/alternative species (1,8)
- Opportunity for exporting products (2,3)
- Processing (2,3,6)

### Umbrella categories for opportunities (CC related)

1. Altered temperature regime
2. Physico-chemical water changes
3. Weather changes / climate pattern changes
4. Sea level rise
5. Anthropogenic influences
6. Changes to rainfall and runoff
7. Loss of polar ice cover
8. Ocean acidification
9. Hydrodynamic changes

### Umbrella categories for exploitations and enhancement measures

1. Fiscal incentives
2. exploitation of opportunity
3. governance incentives
4. developing synergisms (synergy = things together produce a combined effect greater than the sum of their separate effects)

### Umbrella categories for benefits based on the ten-tenets

- Ecological
- 1. Technological
- 2. Economical
- 3. Social
- 4. Legal
- 5. Administrative
- 6. Political
- 7. Ethical
- 8. Cultural
- 9. Communicable

# The Way Ahead: Next Steps (1)

ICES WKBNCS REPORT 2016

SCICOM STEERING GROUP ON ECOSYSTEM PRESSURES AND IMPACTS

ICES CM 2016/SSGEPI:22

REF. ACOM, SCICOM

Report of the Workshop on  
Bayesian Belief Network Case Studies  
(WKBNCS)

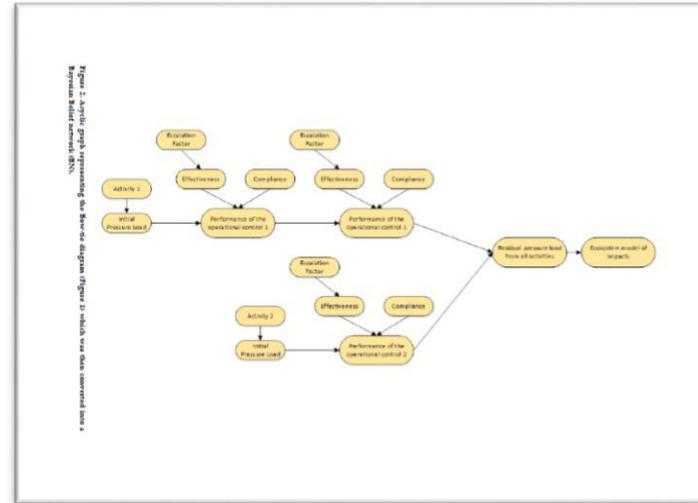
26–29 September 2016

London, Ontario, Canada



ICES  
CIEM

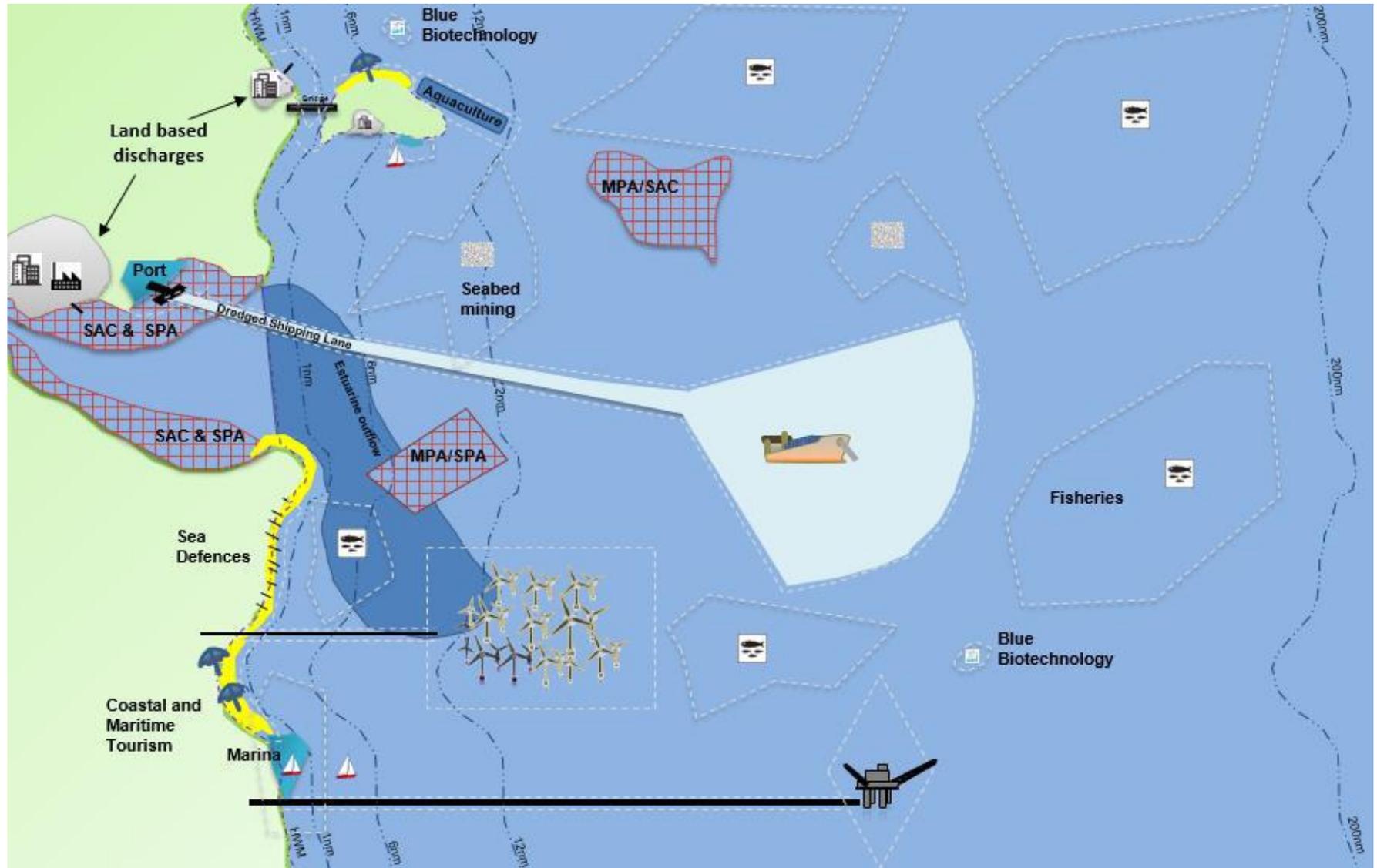
International Council for  
the Exploration of the Sea  
Conseil International pour  
l'Exploration de la Mer



Quantifying the ‘cause - prevention – problem – mitigation – consequences pathway’ using Bayesian Belief Network Modelling – use probabilistic relationships or expert judgement



# The Way Ahead: Next Steps (2)



Challenge – to merge marine environmental quality management (e.g. MSFD) with maritime spatial planning and Blue Growth initiatives (e.g. MSPD)

# But (*and there is always a 'but'*):

Does MSP mean an activity is allowed:

- Where the developer wants it to be?
- Where the regulator wants it to be?
- Where all the stakeholders want it to be?
- Where it can be?
- Where it should be?
- Where there is any space left for it?

Or

- Where the assimilative capacity of the system can accommodate it?(\*)

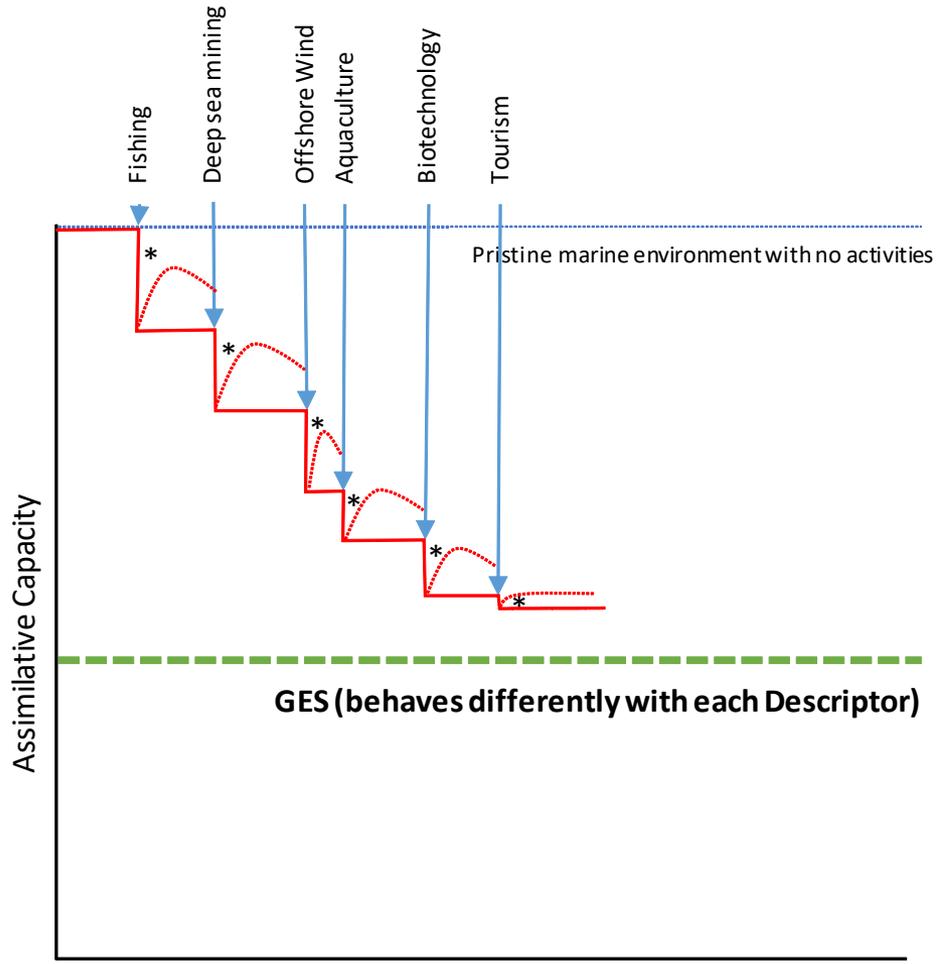
(\* and if not then will the environmental regulator say it cannot be allowed but the finance minister say it has to be allowed!!!)?



"I suppose I'll be the one to mention the elephant in the room."

*"How come it's always the old, bald-headed guy with glasses in cartoons?"*

	Previously	Proposed
Assimilative capacity	the ability of a body of water to assimilate a contaminant without showing adverse changes	the amount of an activity or activities allowed in a body of water before it adversely affects the quality
Carrying capacity	the amount of biota (e.g. number of birds or fishes) that a given habitat can support	the ability of a body of water to support a given amount of activity or activities or ecological component



Basis –

- (1) that an area has a finite assimilative capacity which is intact in the pristine state and then decreases with each activity permitted,
- (2) that the assimilative capacity is regained with mitigation or compensation,
- (3) that GES can still be achieved with the permitted activities in place

[\* Assumption: that the assimilative capacity used in an area depends on the precise activity, its spatial and temporal footprint, the cumulative and in-combination effects, any mitigation and/or compensation measures performed on any components/ habitat, and on the particular descriptor in question]

- Bow-tie as a **cause – prevention – problem – mitigation – consequences chain**
- An **ISO standard** risk assessment and risk management method – used and understood by industry
- Treats the **environment as an organisation** with the same input/output controls and constraints
- Maps on to **DAPSI(W)R(M) framework** to indicate where are the solutions to the problems
- Underpins the **quantitative** development and modelling



# Main messages (2):

---

- Gives an ability for **nested** Bow-ties and and consequence to become the problem in the next Bow-tie
- Has the potential for **opportunity analysis and management**
- Gives the development towards **cumulative and in-combination** effects, footprints of activities and footprints of laws
- Used to determine how much **assimilative capacity** can be used before breaching good status
- Potential to determine whether **Blue Growth vs. status-achievement** takes **precedence**





Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: [www.elsevier.com/locate/marpolbul](http://www.elsevier.com/locate/marpolbul)



Viewpoint

**Force majeure:** Will climate change affect our ability to attain Good Environmental Status for marine biodiversity?



Michael Elliott <sup>a,\*</sup>, Ángel Borja <sup>b</sup>, Abigail McQuatters-Gollop <sup>c</sup>, Krysia Mazik <sup>d</sup>, Silvana Birchenough <sup>d</sup>, Jesper H. Andersen <sup>e</sup>, Suzanne Painting <sup>d</sup>, Myron Peck <sup>f</sup>



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Marine Pollution Bulletin

journal homepage: [www.elsevier.com/locate/marpolbul](http://www.elsevier.com/locate/marpolbul)



Viewpoint

Is climate change an unforeseen, irresistible and external factor – *A force majeure* in marine environmental law?

Roxanne Saul <sup>a</sup>, Richard Barnes <sup>b</sup>, Michael Elliott <sup>a,\*</sup>

[Mike.Elliott@hull.ac.uk](mailto:Mike.Elliott@hull.ac.uk)

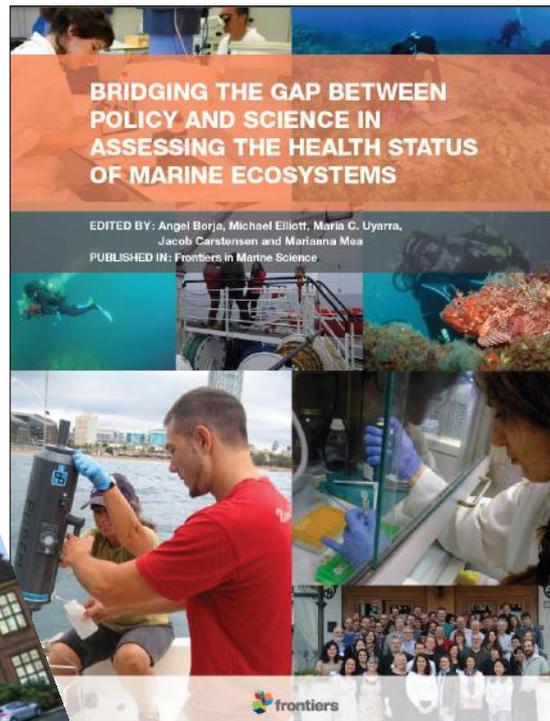
**DEVOTES**

[www.devotes-project.eu](http://www.devotes-project.eu)

Development of innovative tools for understanding marine biodiversity and assessing good environmental status



Open Access book:



Collector's item!!  
(If you don't want it or need it then leave it at the desk – there is a waiting list!!)