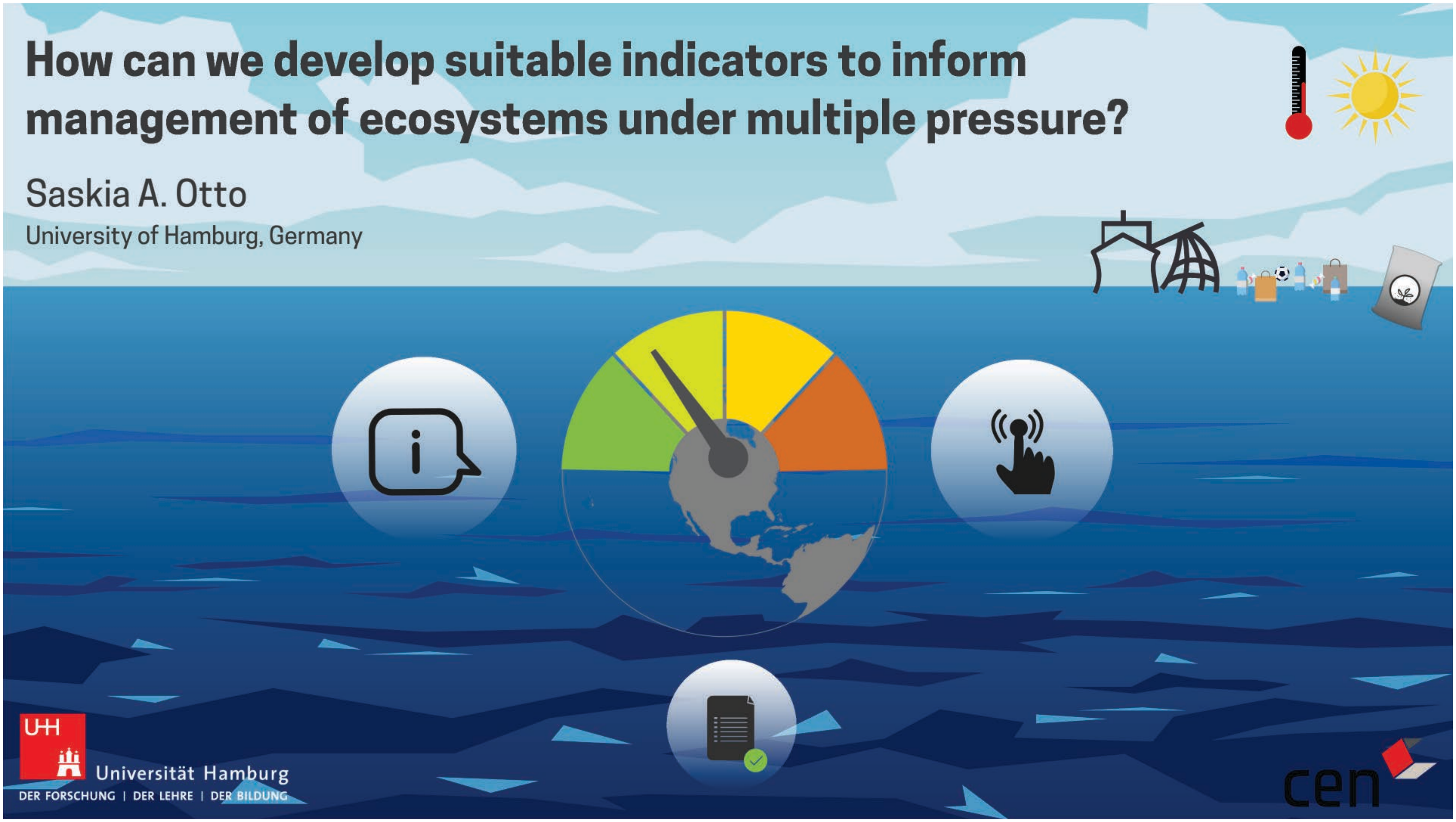
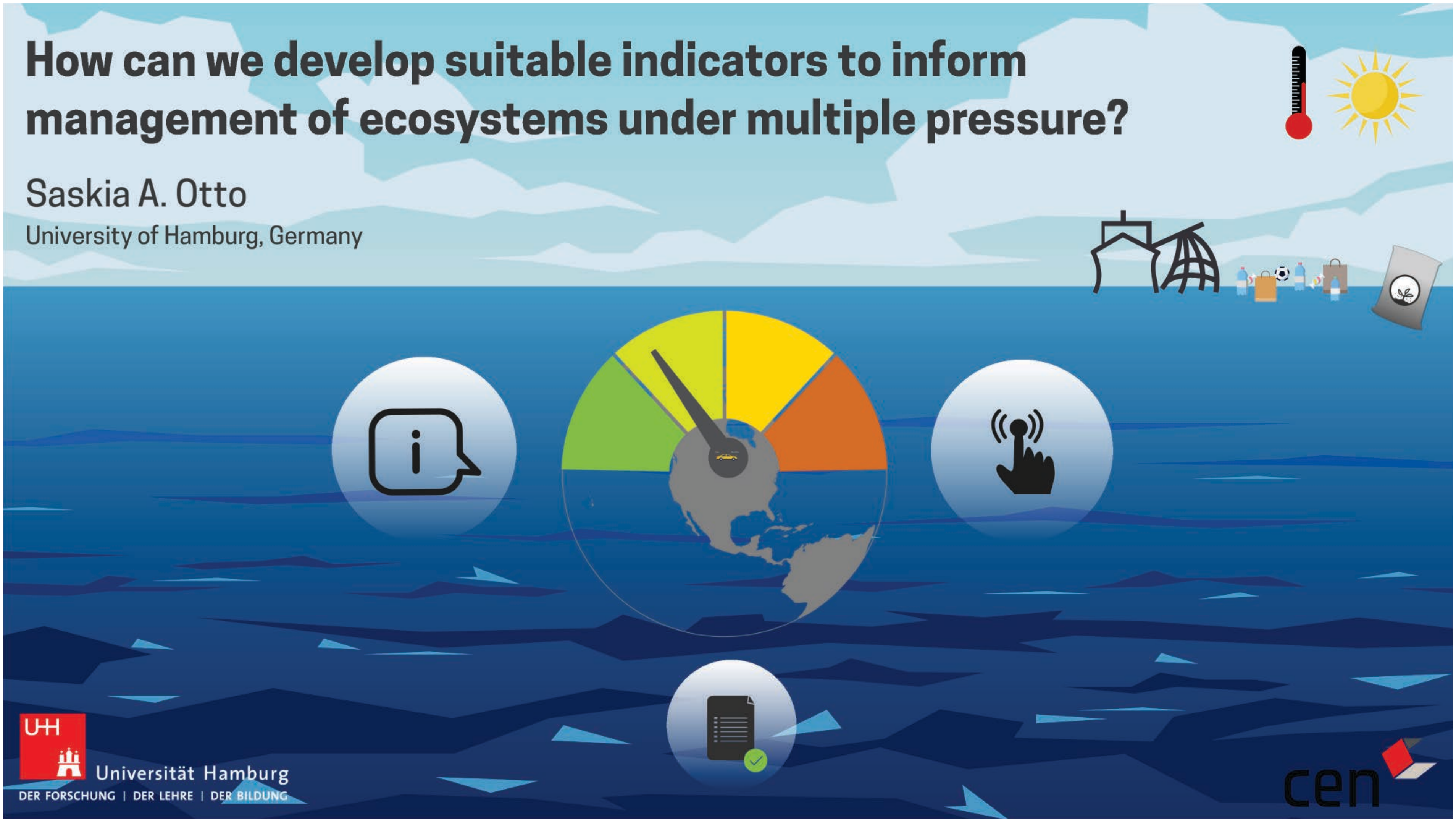

How can we develop suitable indicators to inform management of ecosystems under multiple pressure?
Saskia A. Otto
University of Hamburg, Germany
UHH
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG
cen


Informs
Causes Action


15:01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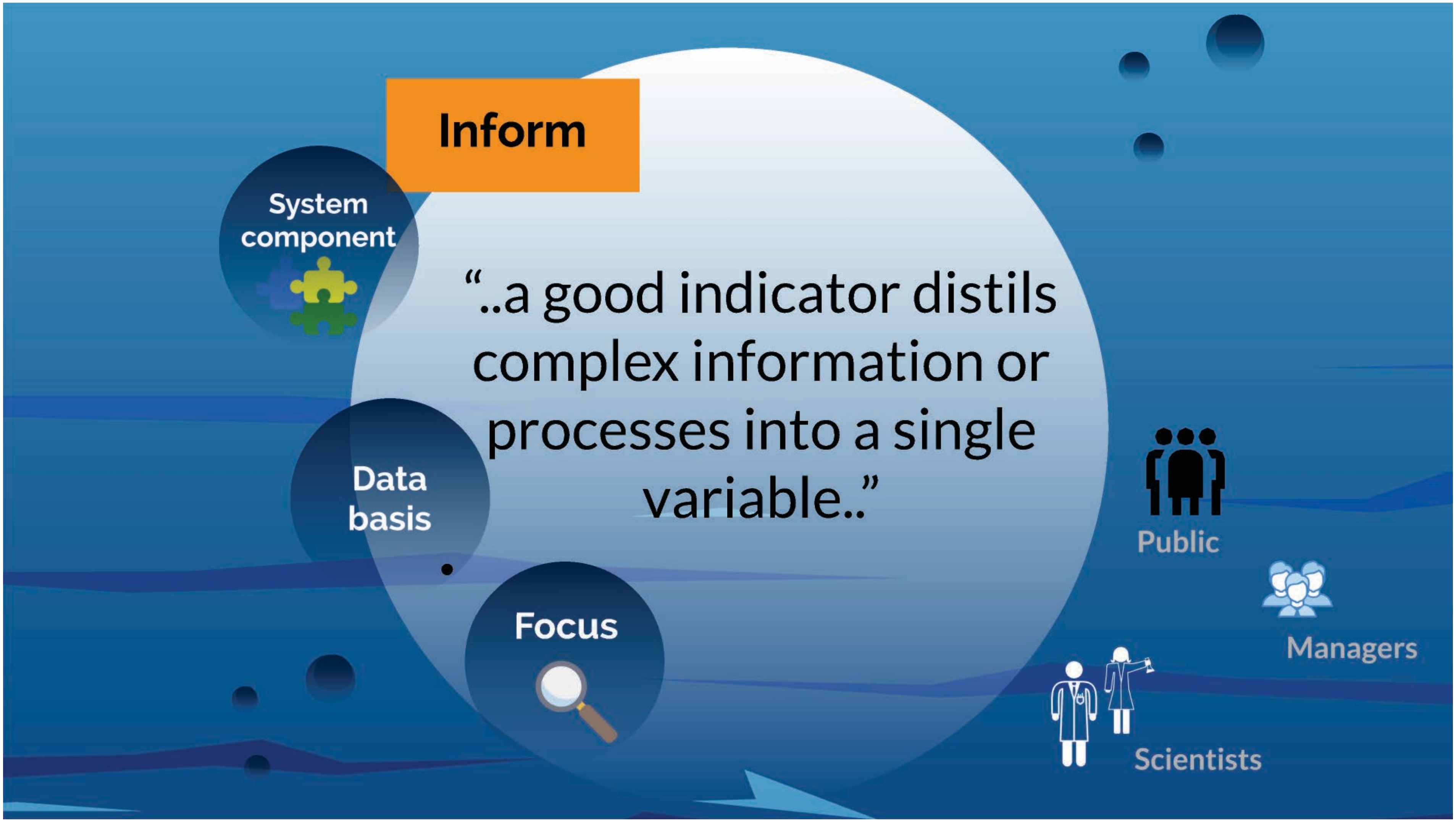
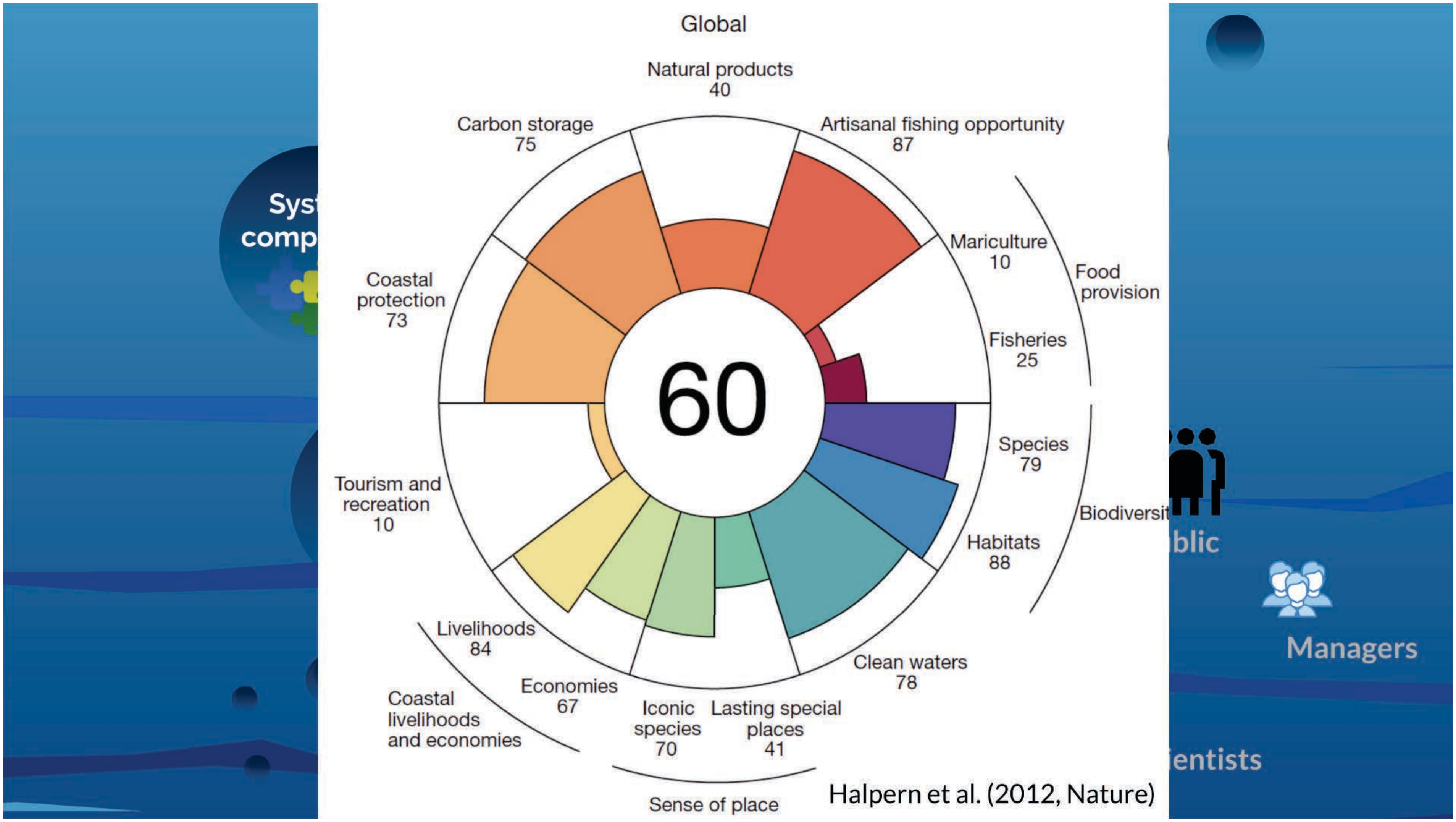
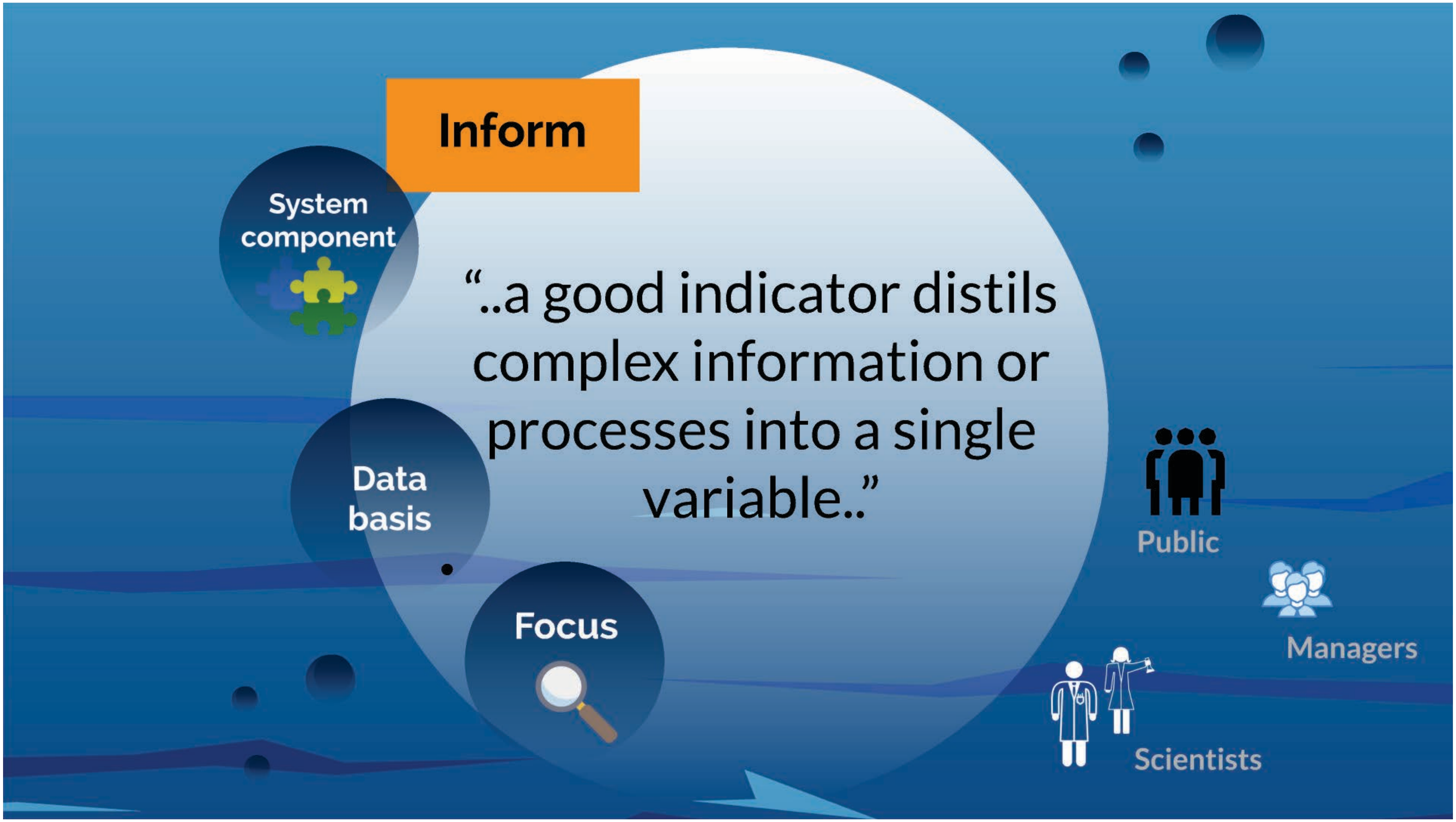

Inform
System component
"..a good indicator distils complex information or processes into a single variable.."
Data basis
Focus
Public
Managers
Scientists


Syst
comp
Global
Natural products
40
Carbon storage
75
Artisanal fishing opportunity
87
Mariculture
10
Food
provision
Coastal
protection
73
Fisheries
25
60
Species
79
Tourism and
recreation
10
Biodiversit
Habitats
88
blic
Livelihoods
84
Managers
Clean waters
78
Economies
67
Coastal
livelihoods
and economies
Iconic
species
70
Lasting special
places
41
ientists
Sense of place
Halpern et al. (2012, Nature)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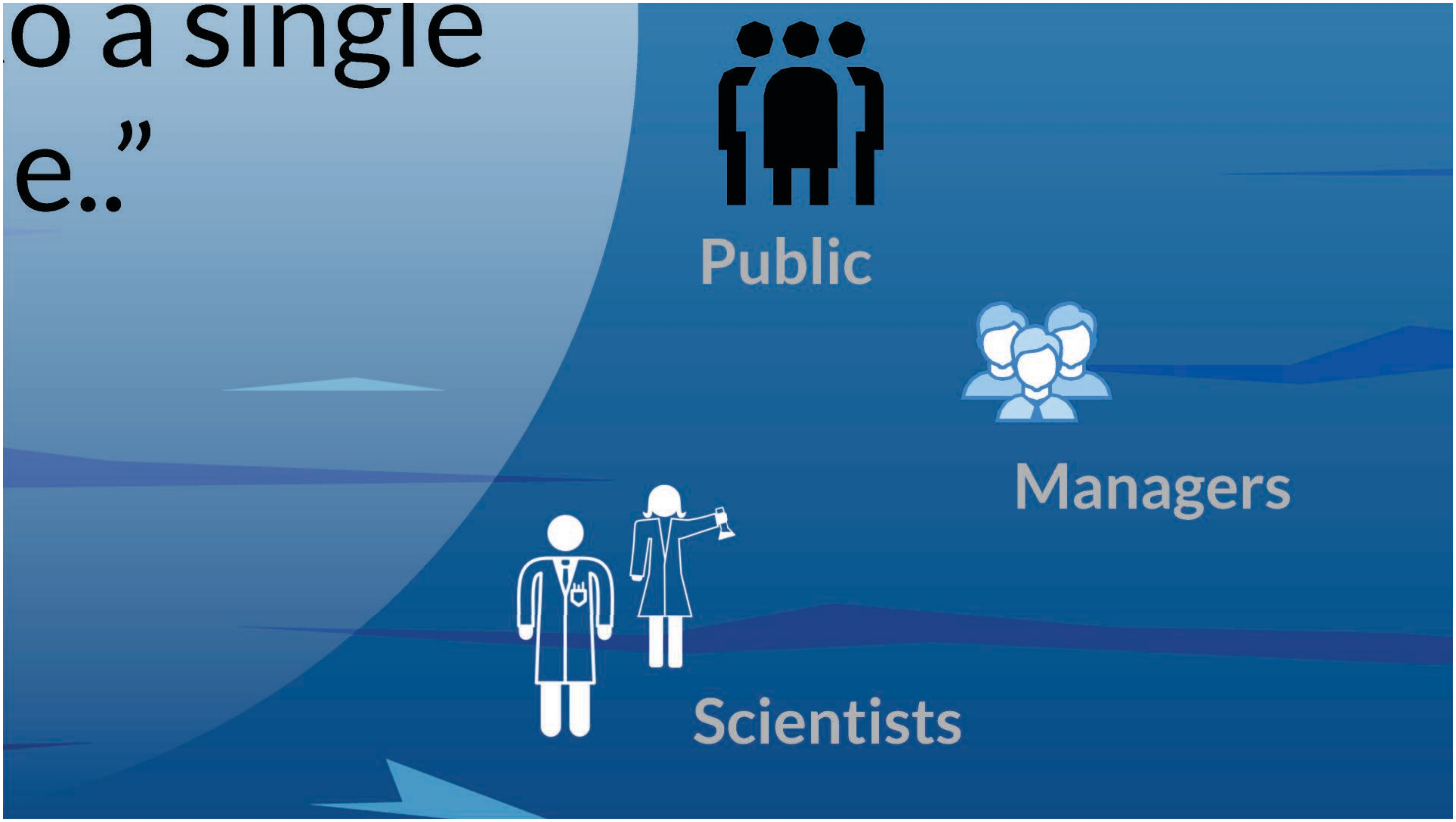
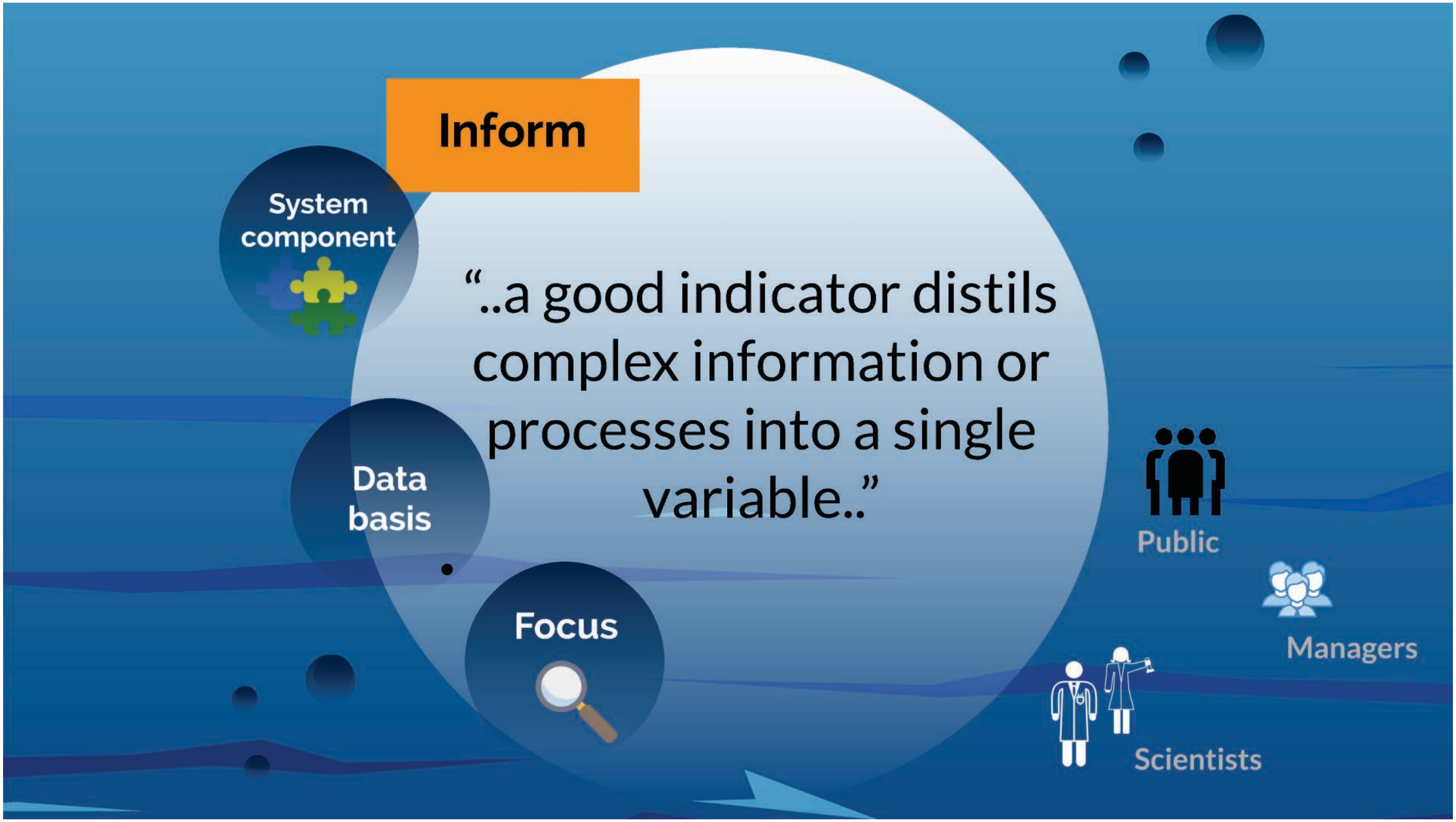
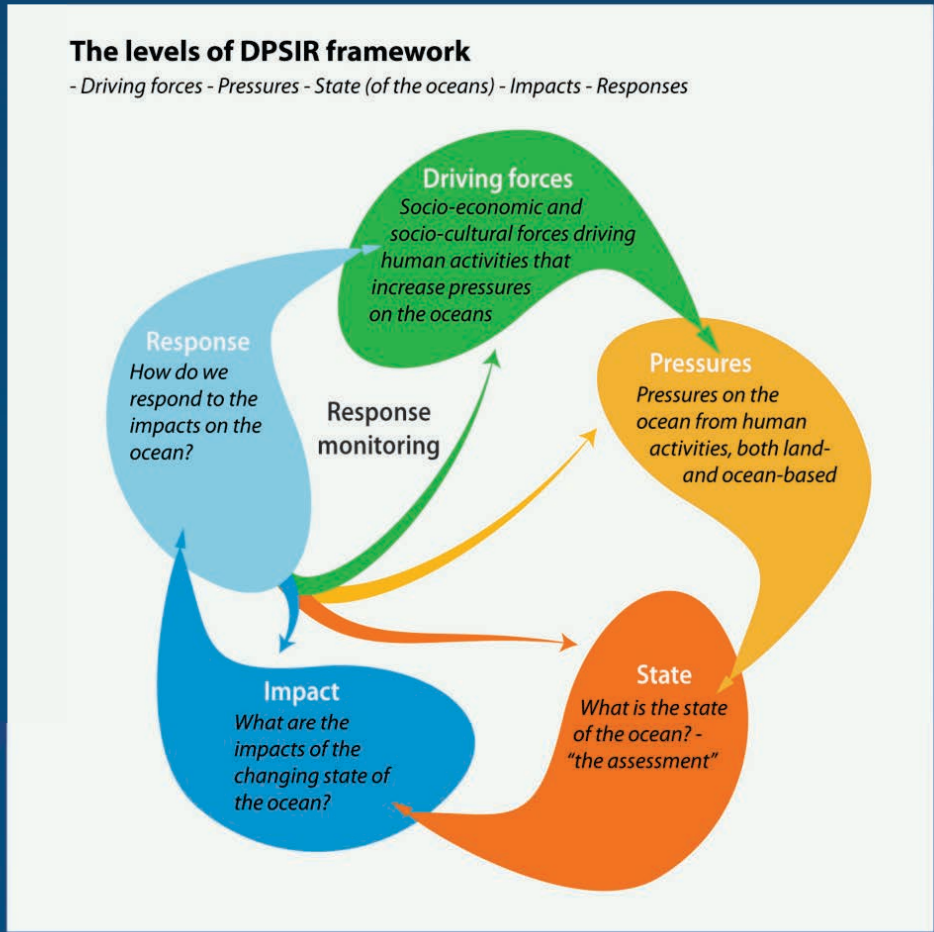

o a single
e..”
Public
Managers
Scientists


Inform
System component
Data basis
Focus
"..a good indicator distils complex information or processes into a single variable.."
Public
Managers
Scientists

Components

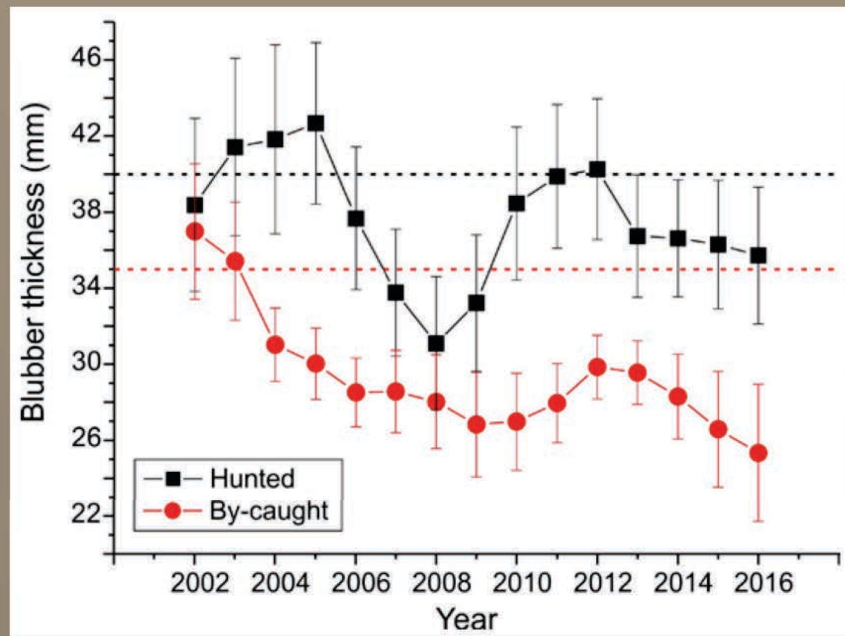


by Kristina Thygesen (http://www.grida.no/resources/8124)

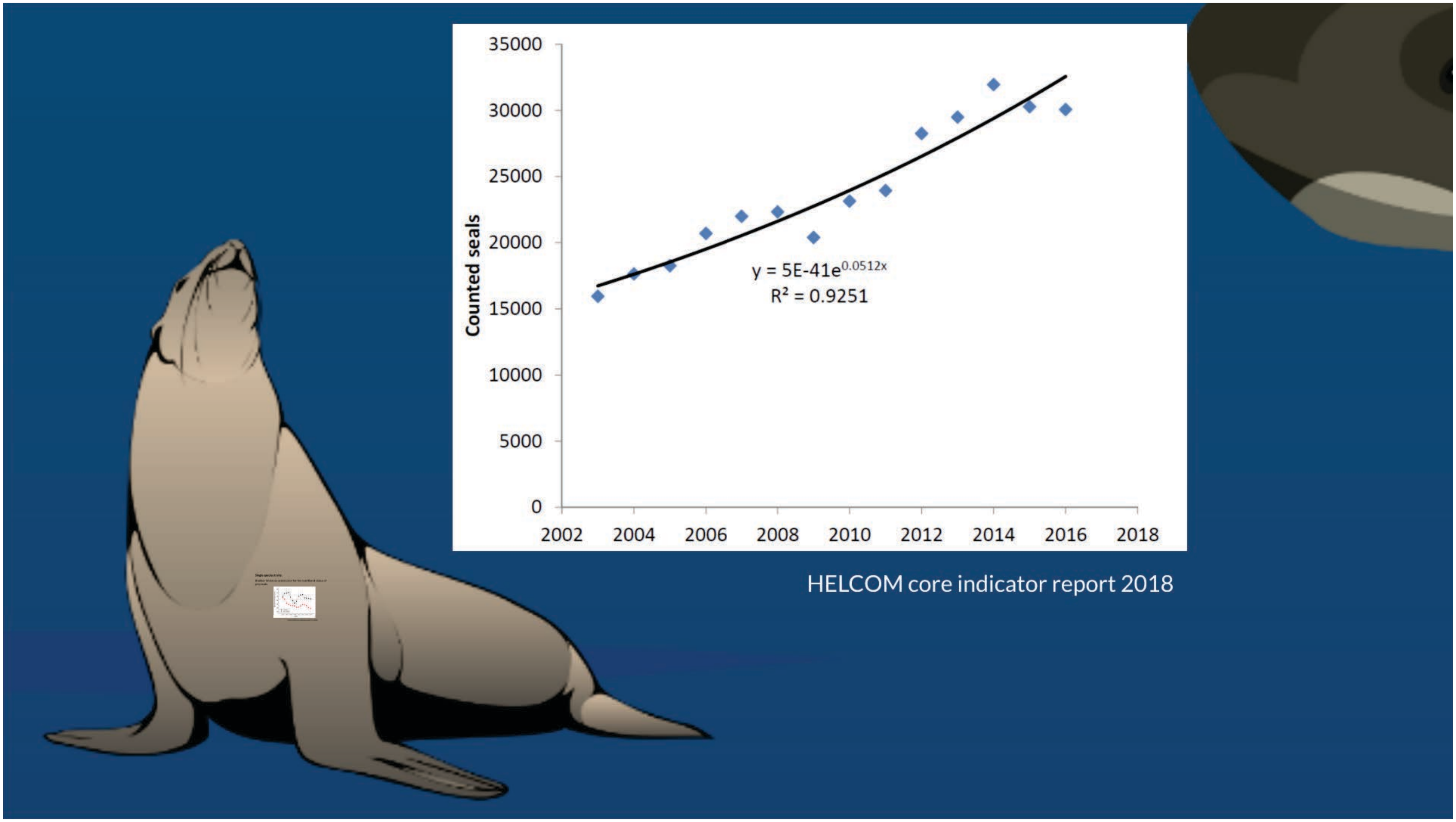

Food web components
& taxonomic resolution

Single species traits:

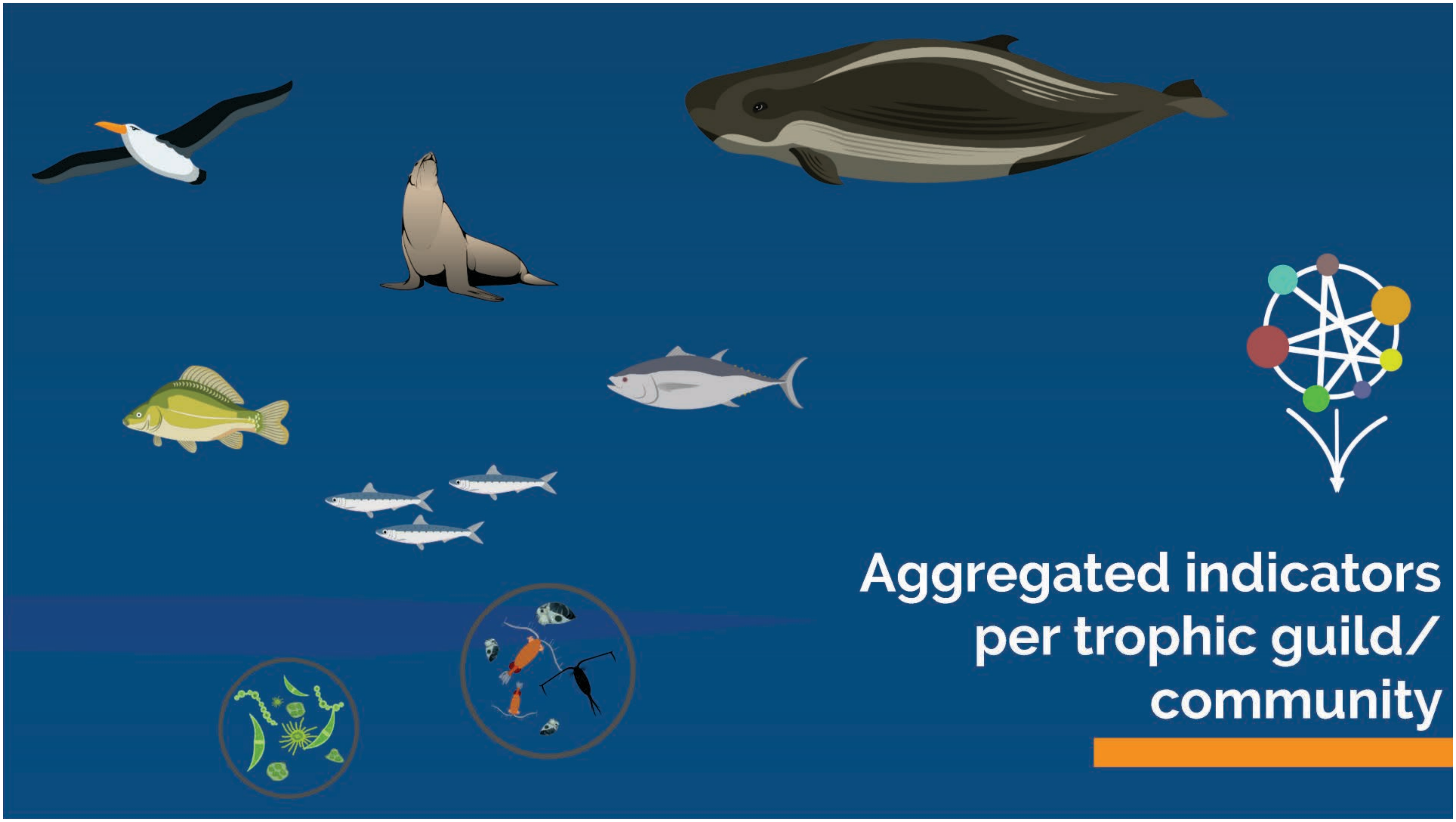
Blubber thickness as indicator for the nutritional status of grey seals

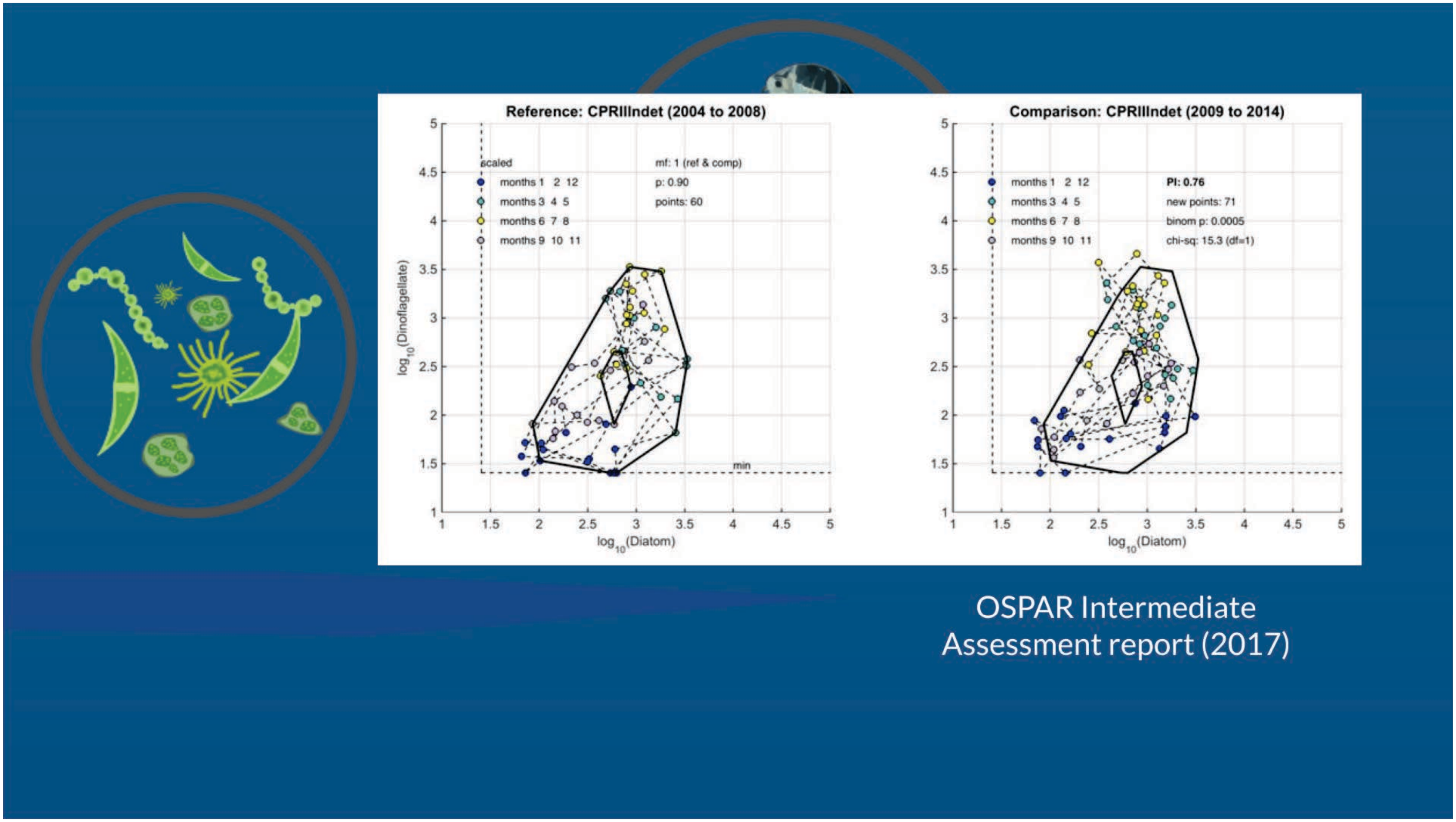


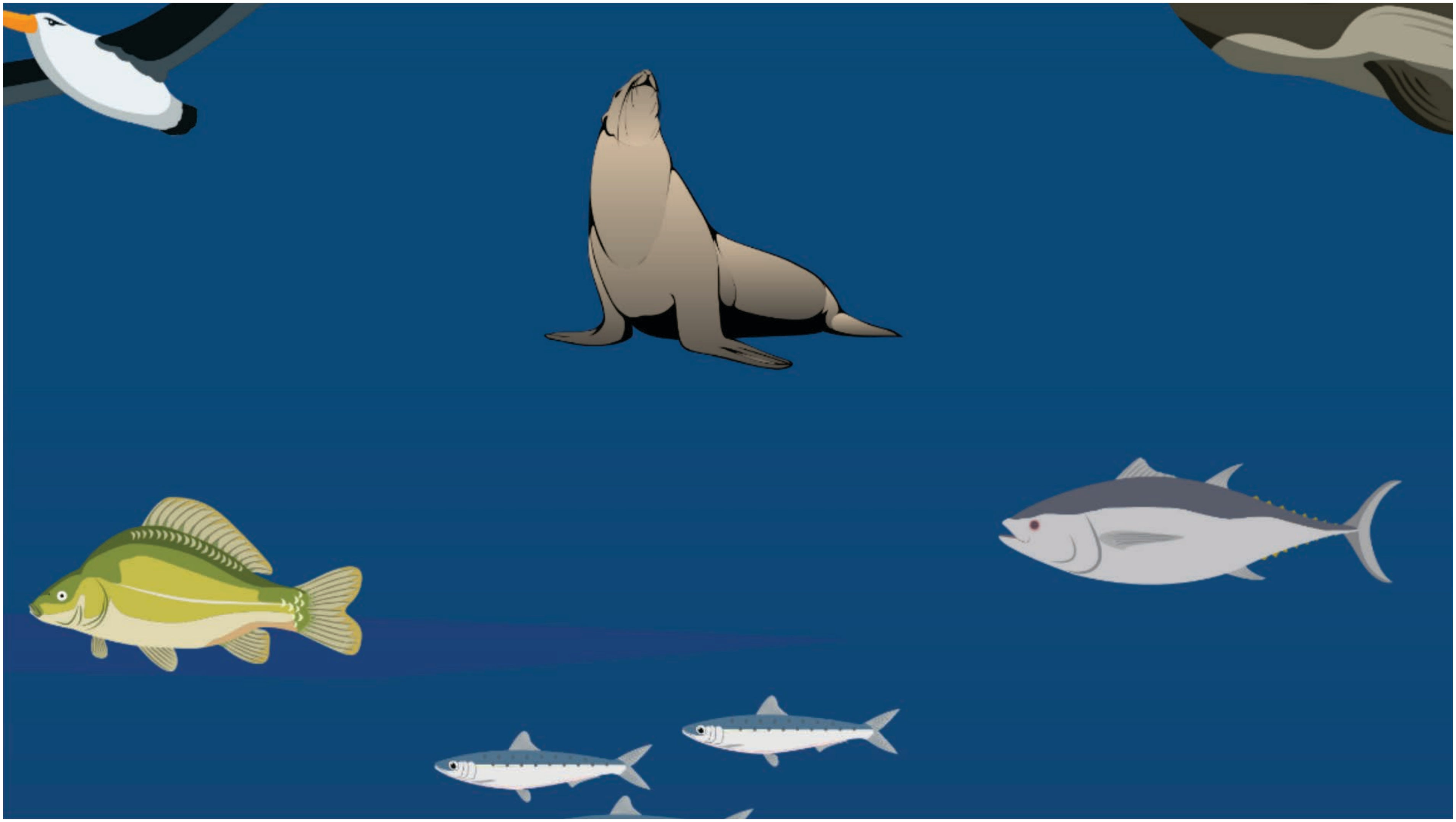
HELCOM core indicator report (2018)

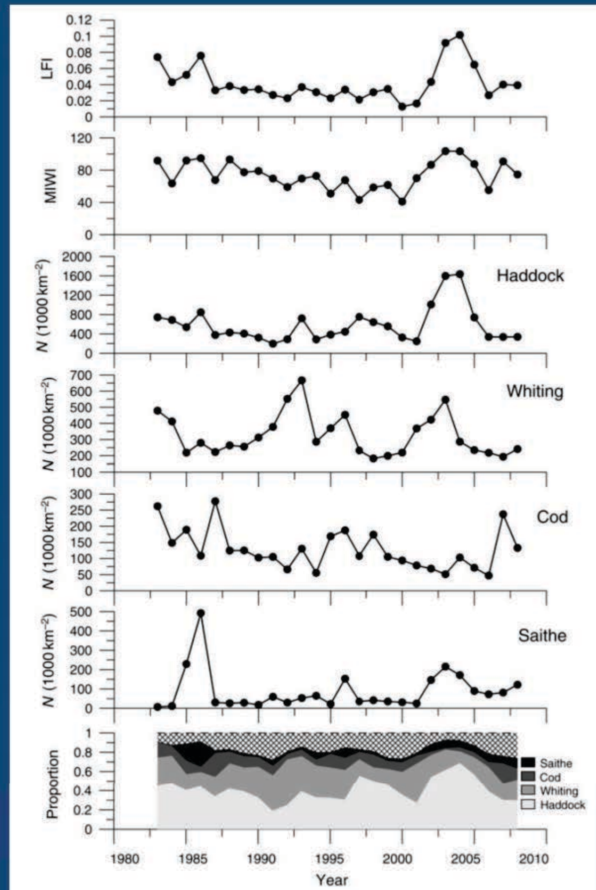


HELCOM core indicator report 2018

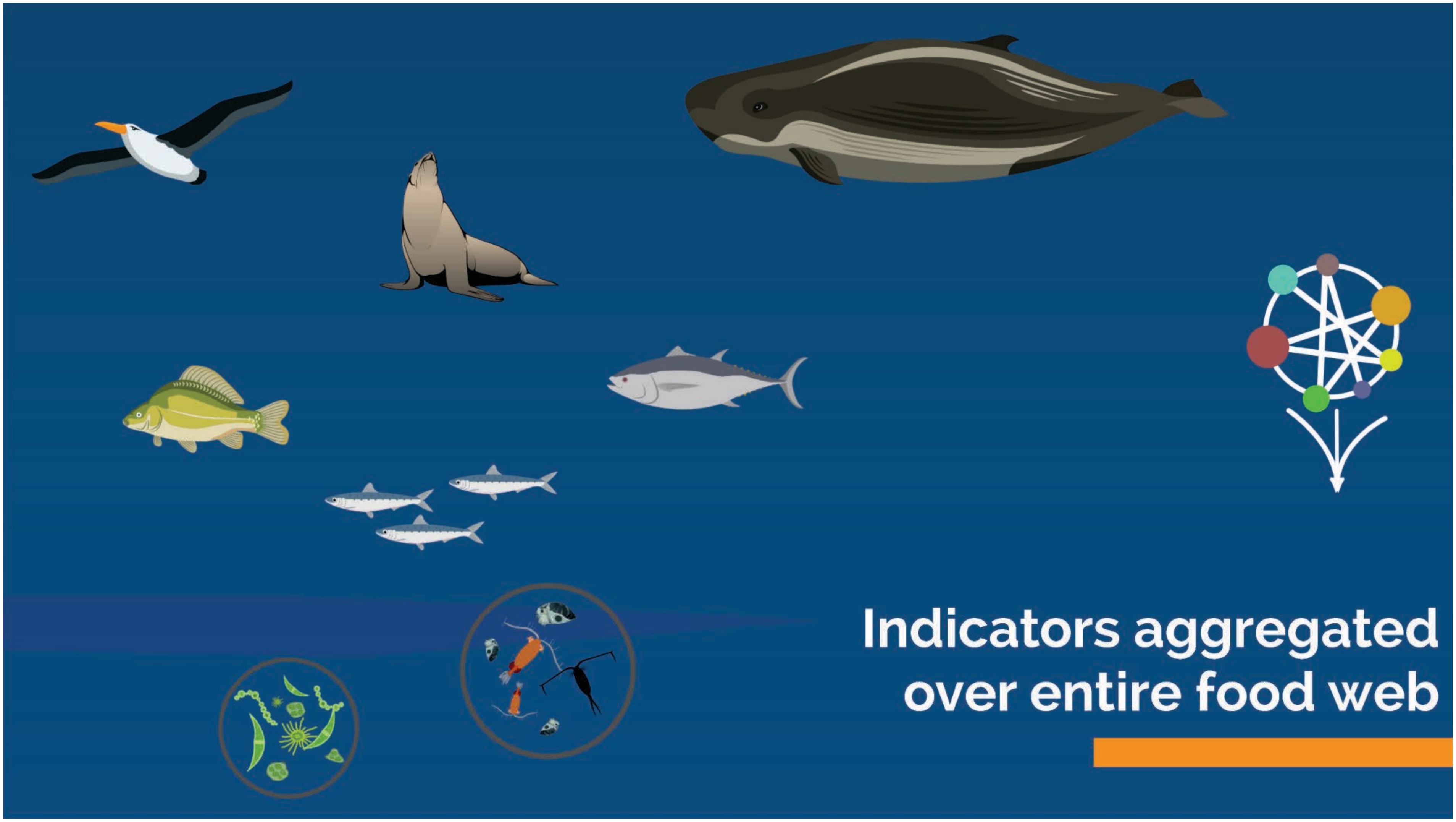

Aggregated indicators
per trophic guild/
community

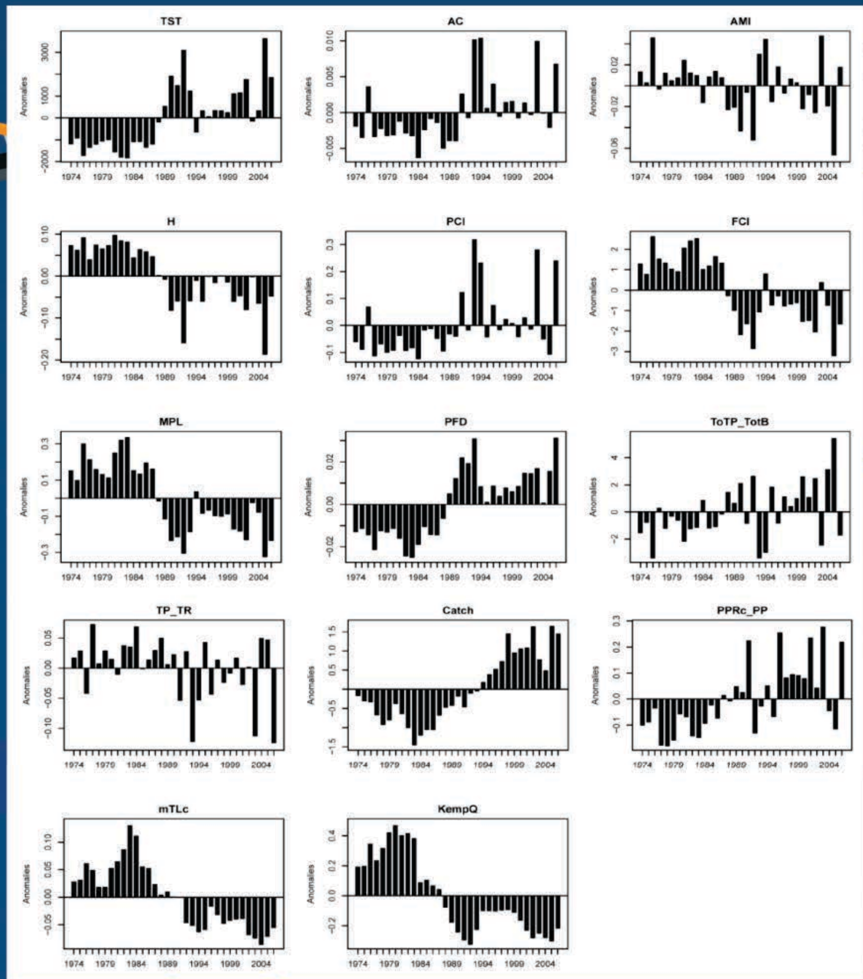

Reference: CPRIIIndet (2004 to 2008)
scaled
months 1 2 12
months 3 4 5
months 6 7 8
months 9 10 11
mf: 1 (ref & comp)
p: 0.90
points: 60
min
log10(Dinoflagellate)
log10(Diatom)
Comparison: CPRIIIndet (2009 to 2014)
months 1 2 12
months 3 4 5
months 6 7 8
months 9 10 11
PI: 0.76
new points: 71
binom p: 0.0005
chi-sq: 15.3 (df=1)
log10(Diatom)
OSPAR Intermediate
Assessment report (2017)

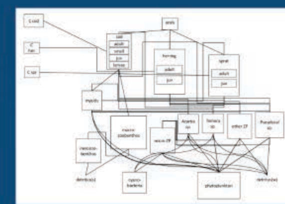




Greenstreet et al. (2011, ICES JMS)


Indicators aggregated
over entire food web



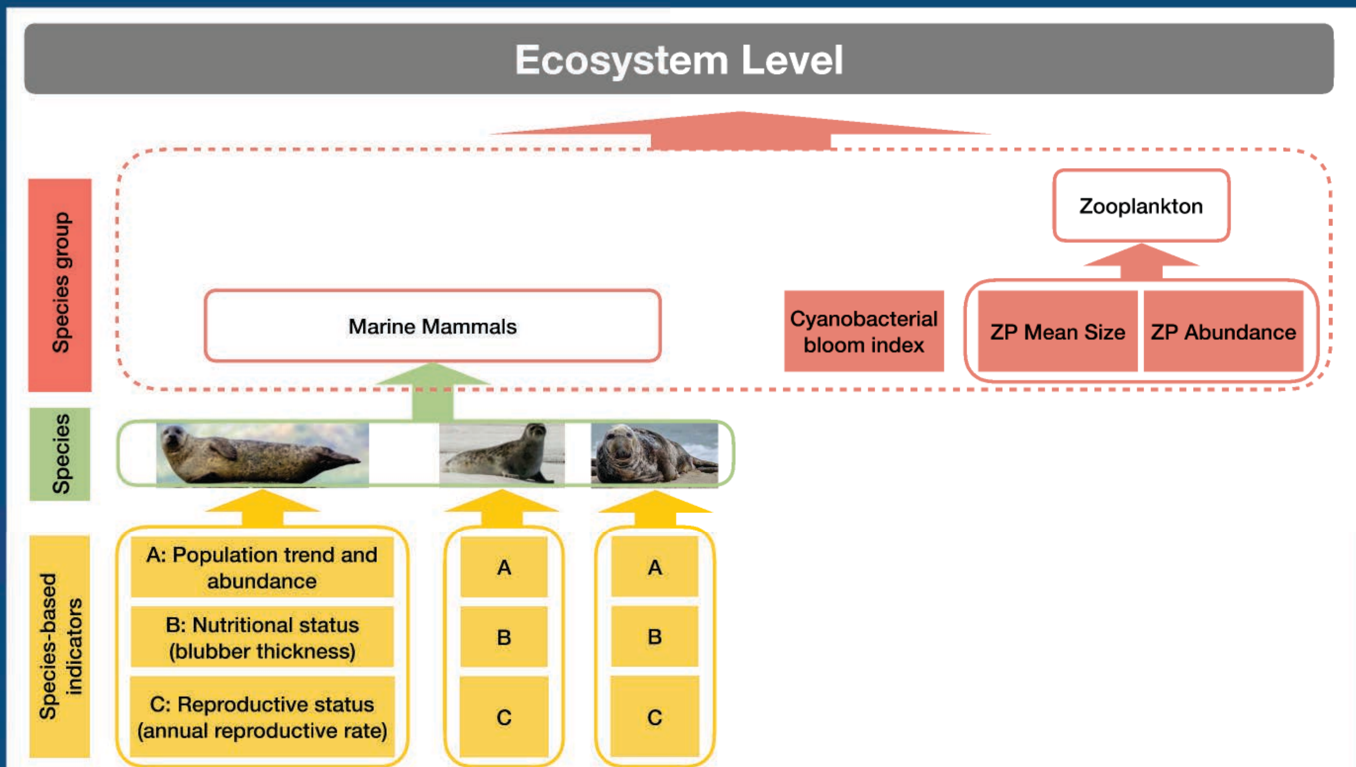


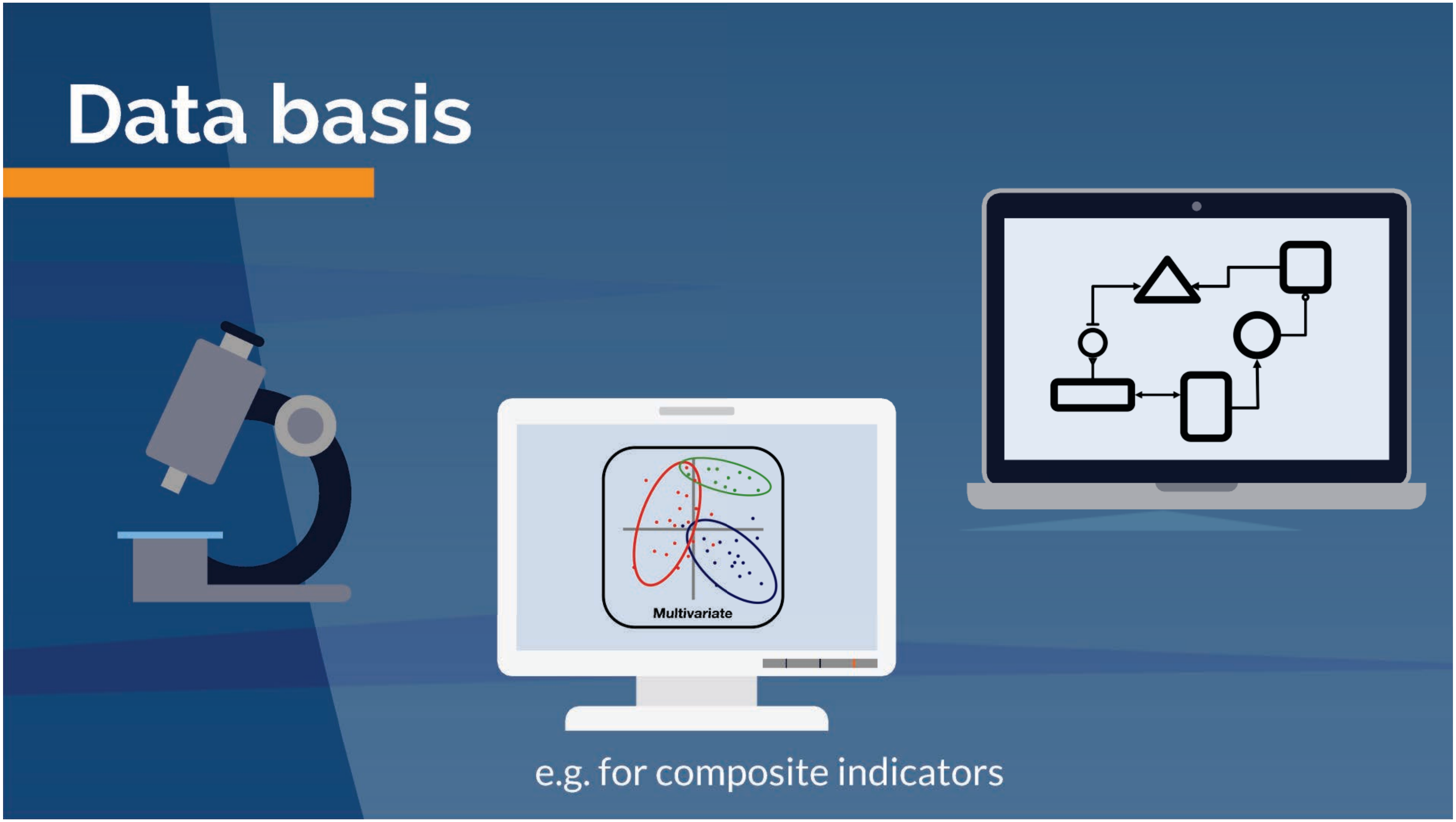
Tomzcak et al. (2013, PLOS One)

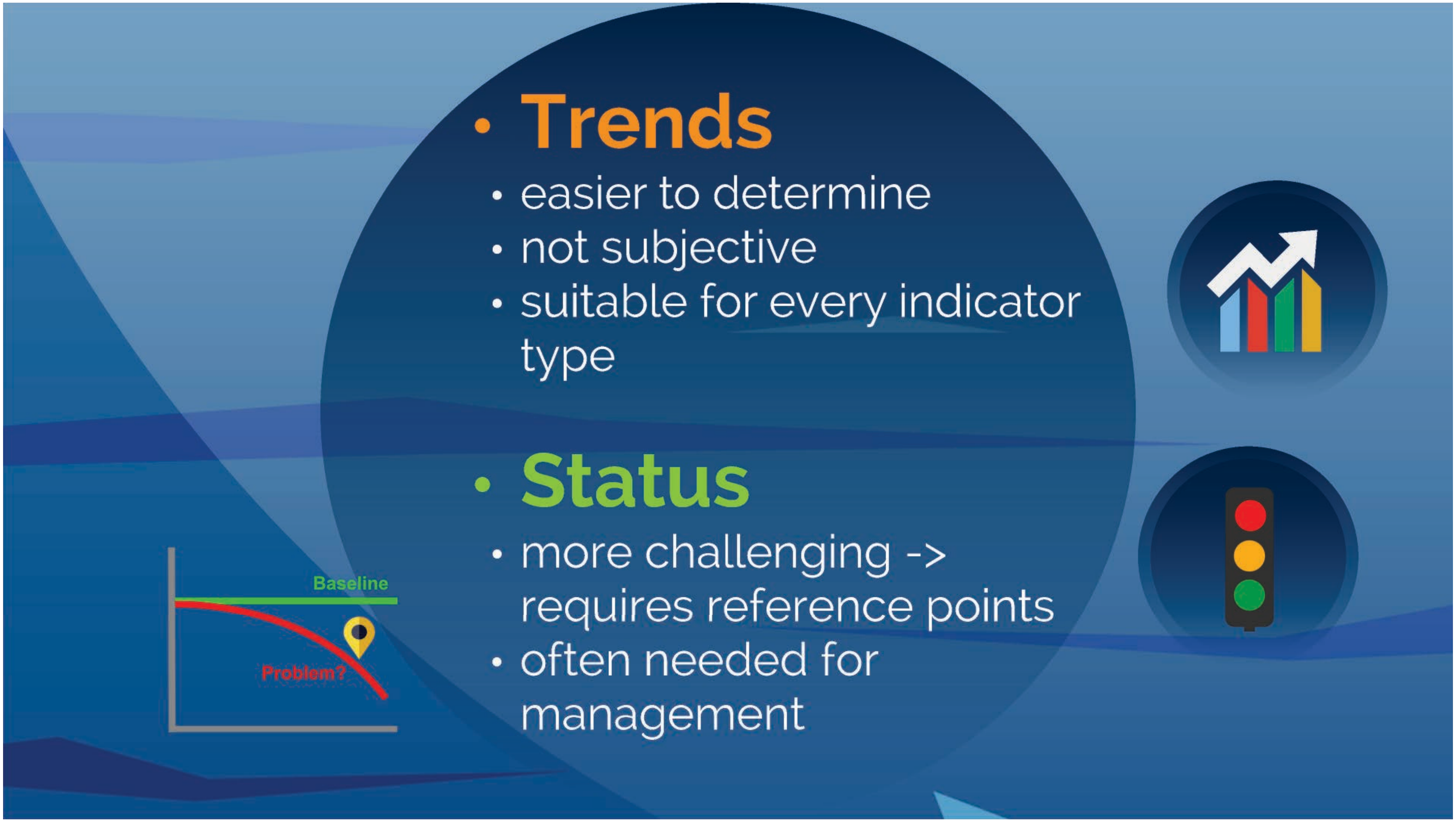
Indicators aggregated over entire food web

Challenge

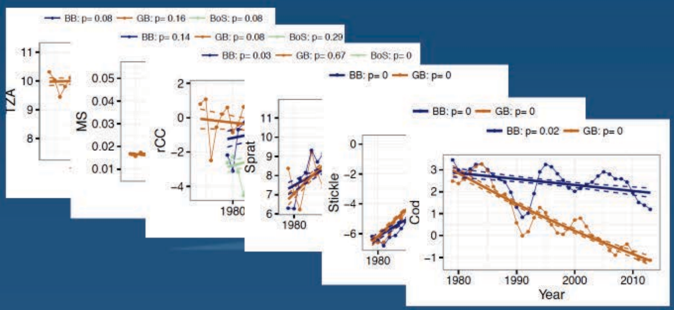
How to integrate indicators for ecosystem-wide assessment?



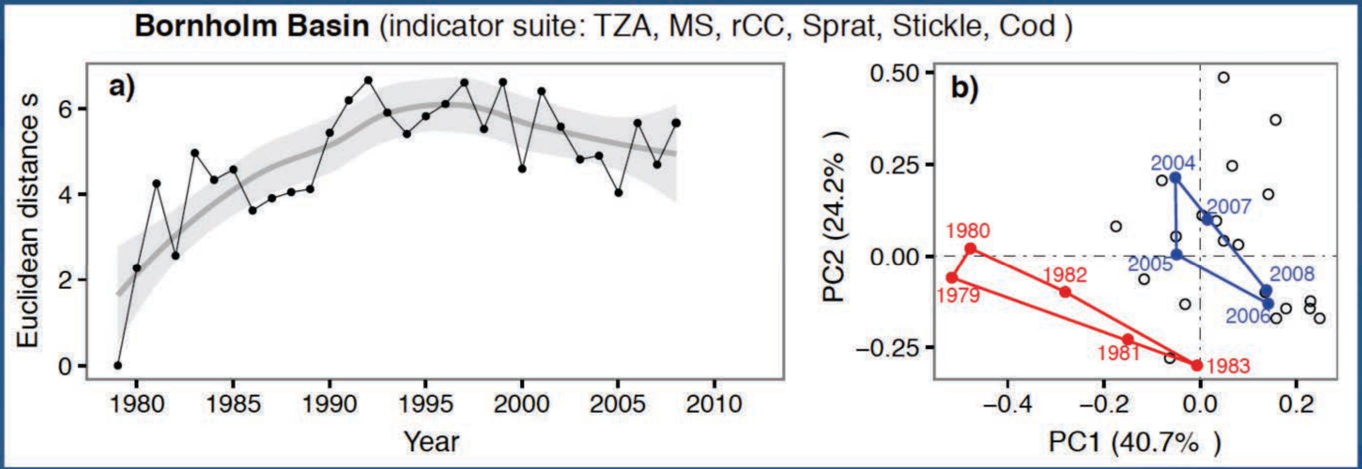

Data basis
Multivariate
e.g. for composite indicators


• Trends
• easier to determine
• not subjective
• suitable for every indicator type
• Status
• more challenging -> requires reference points
• often needed for management
Baseline
Problem?

Combining single indicator trends

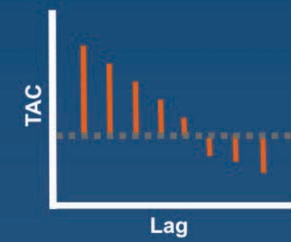


Otto et al. (2018, Ecol Ind)



But, detection of trend depends on:

- sample size
- presence of autocorrelation



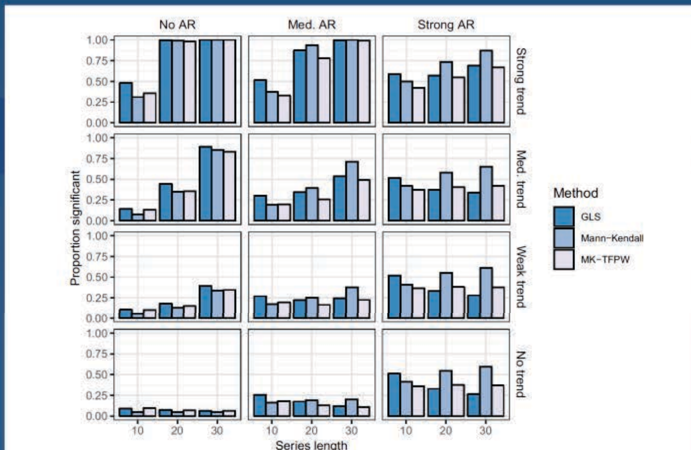


Figure 2. Test rejection rates of simulated time series ($p < 0.05$) among different combinations of AR(1) process strength ($\rho_1 = 0, 0.43, 0.9$) and trend strength ($\alpha_1 = 0, 0.026, 0.051, 0.147$). Bar colour indicates the test for trend that was applied.

Hardison et al. (2019, ICESJMS)

When N is small (< 30) or autocorrelation is present any method will often poorly characterize the true trend

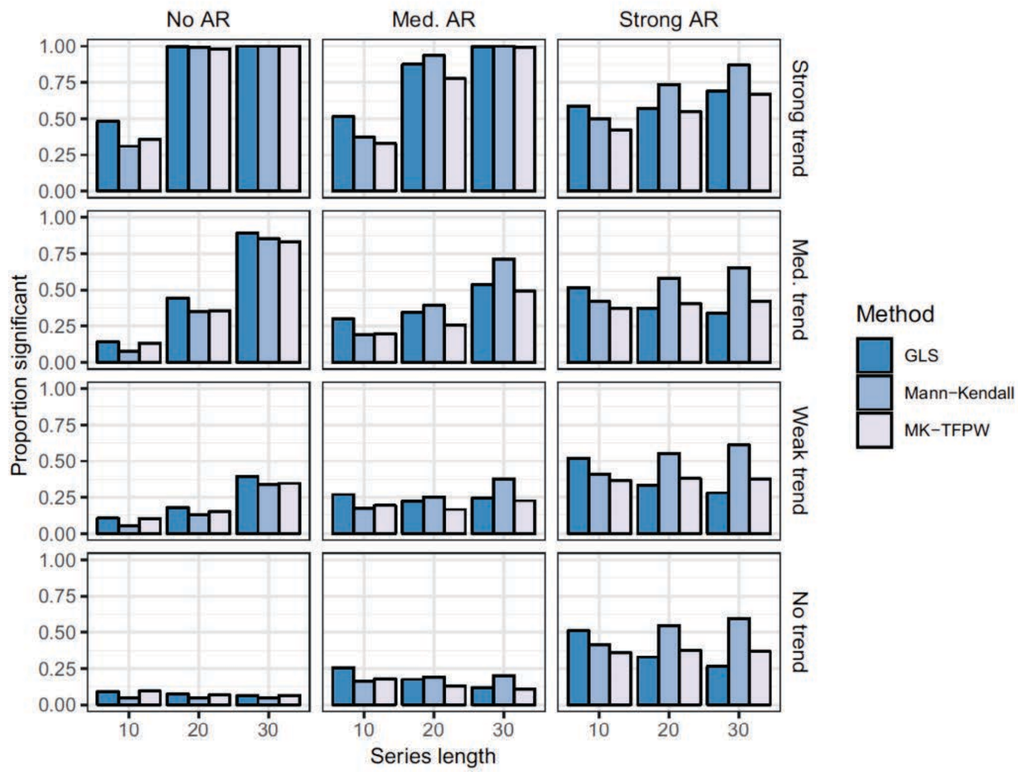


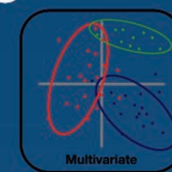
Figure 2. Test rejection rates of simulated time series ($p < 0.05$) among different combinations of AR(1) process strength ($\rho_1 = 0, 0.43, 0.9$) and trend strength ($\alpha_1 = 0, 0.026, 0.051, 0.147$). Bar colour indicates the test for trend that was applied.

When N is small (< 30) or autocorrelation is present any method will often poorly characterize the true trend

Hardison et al. (2019, ICESJMS)

Biological Reference Points (RPs)

- Difficult to define for some type of indicators



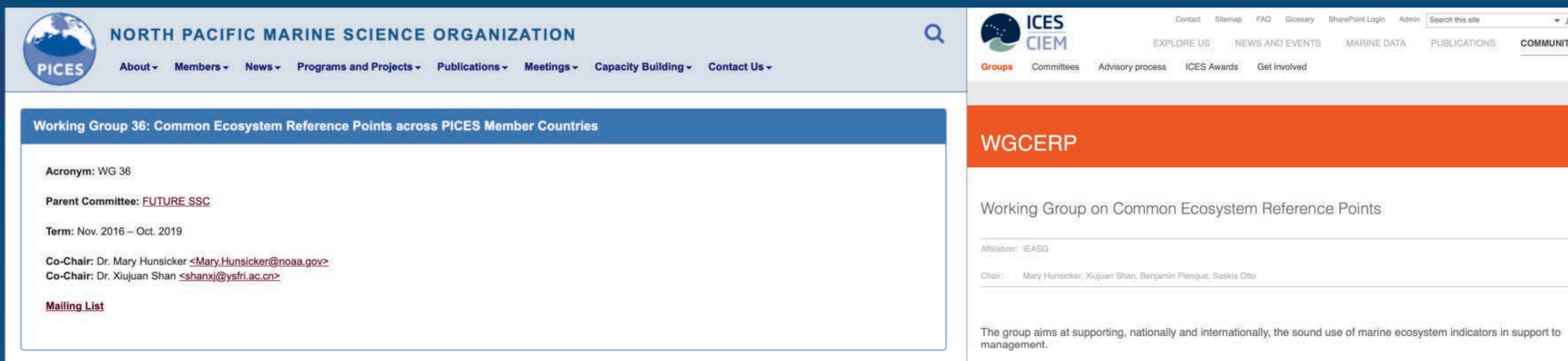
- Fuzzy usage of term

- Narrow to broad context
  - In **single-species-based** stock assessment models RPs are widely used to define safe levels of harvesting for marine fish populations.
  - In the context of **ecosystem-based management** (EBM), RPs need to be re-defined as ecosystem-level biological reference points.


target reference level
limit reference level
reference state
limit
target
environmental target
boundaries
action threshold
historical reference point
threshold
reference value
threshold value
baseline
reference condition

- In **single-species-based s**tock assessment models RPs are widely used to define safe levels of harvesting for marine fish **populations**.
- In the context of **ecosystem-based management** (EBM), RPs need to be re-defined as **ecosystem-level** biological reference points.

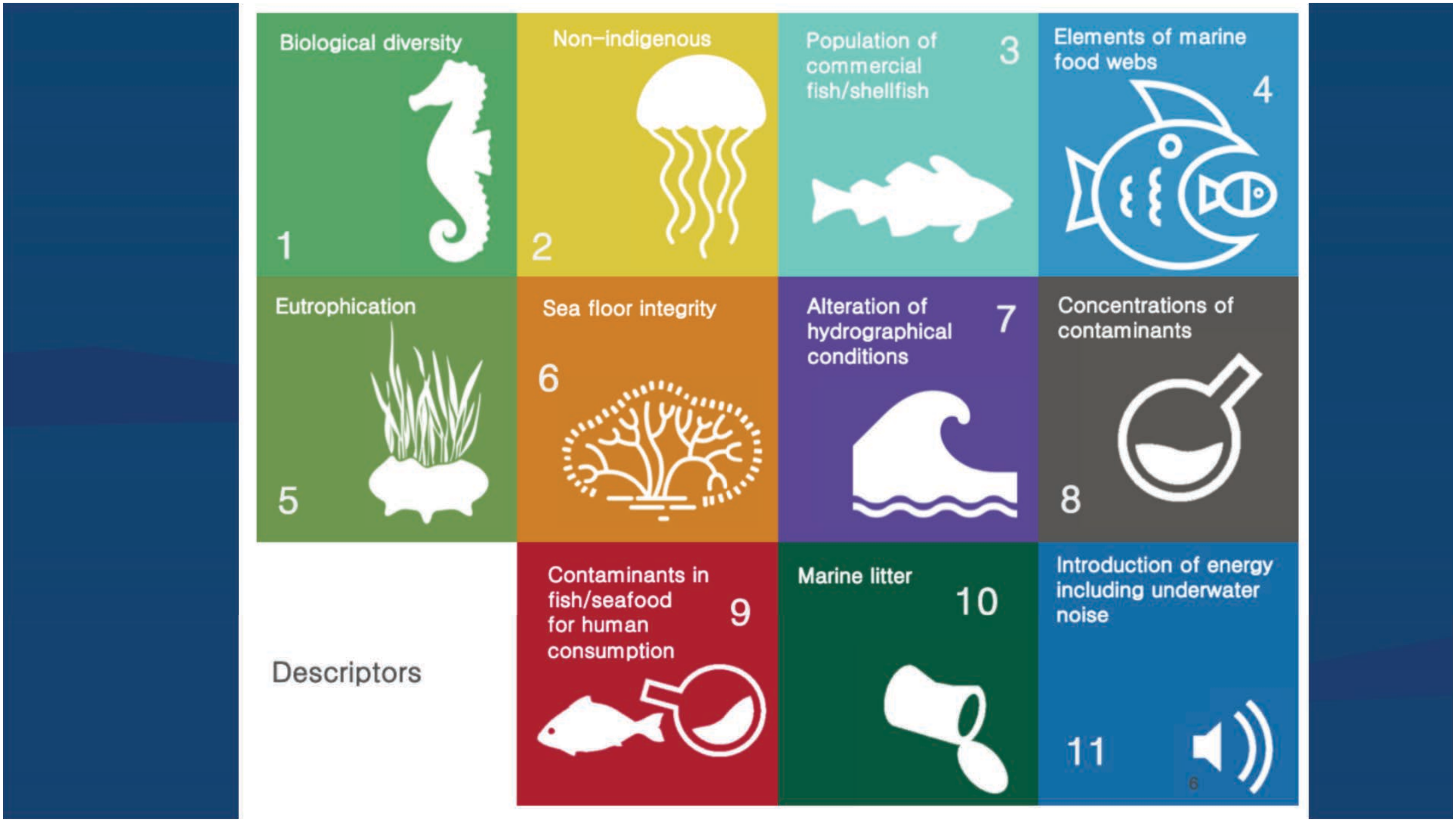
Working Groups on Common RPs



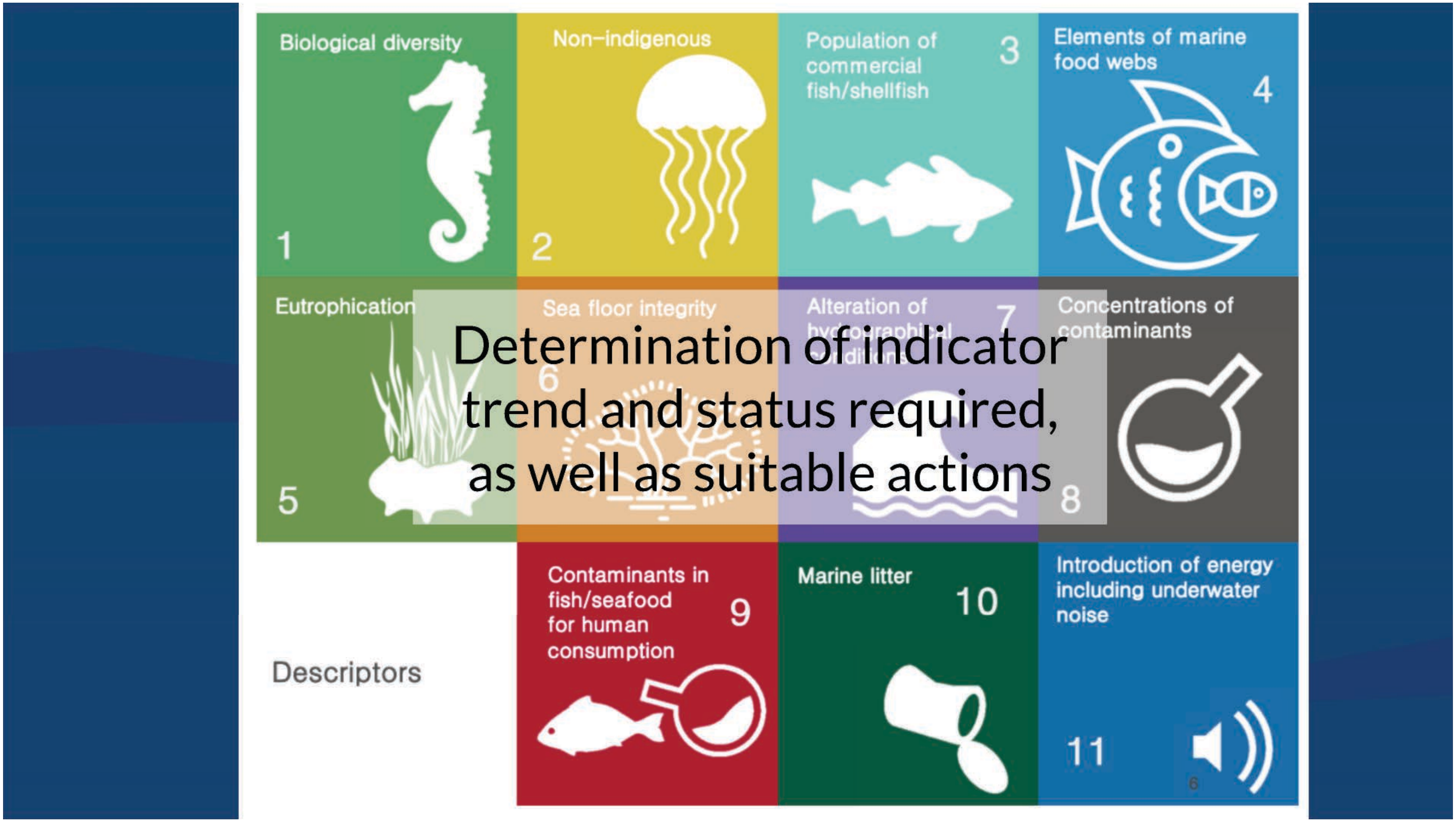
Marine Strategy Framework Directive (MSFD)

„This Directive establishes a framework within which Member States shall take the necessary measures to **achieve** or **maintain good environmental status** in the marine environment by the year **2020** at the latest."

–Directive 2008/56/EG



Biological diversity
1
Non–indigenous
2
Population of commercial fish/shellfish
3
Elements of marine food webs
4
Eutrophication
5
Sea floor integrity
6
Alteration of hydrographical conditions
7
Concentrations of contaminants
8
Descriptors
Contaminants in fish/seafood for human consumption
9
Marine litter
10
Introduction of energy including underwater noise
11


Biological diversity
1
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3
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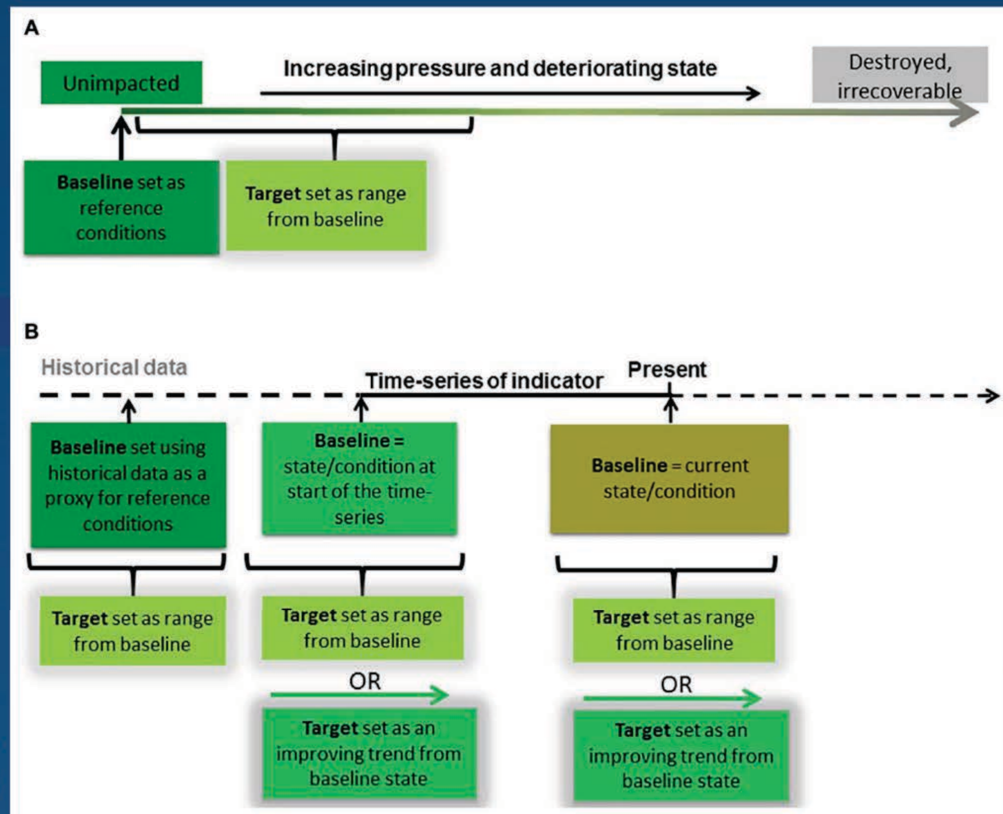
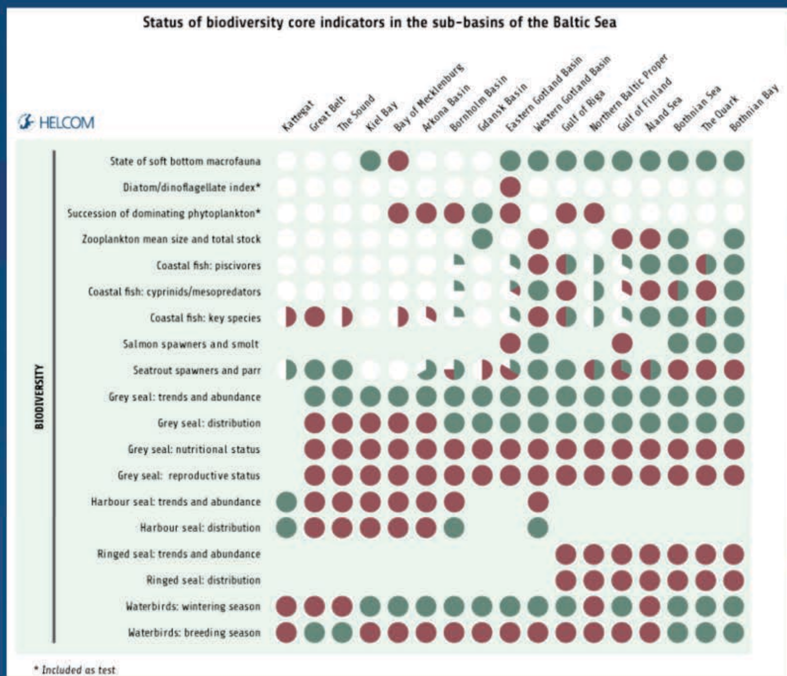
4
Eutrophication
5
Sea floor integrity
6
Alteration of
7
Concentrations of contaminants
8
Determination of indicator trend and status required, as well as suitable actions
Descriptors
Contaminants in fish/seafood for human consumption
9
Marine litter
10
Introduction of energy including underwater noise
11

Setting baseline and threshold RPs

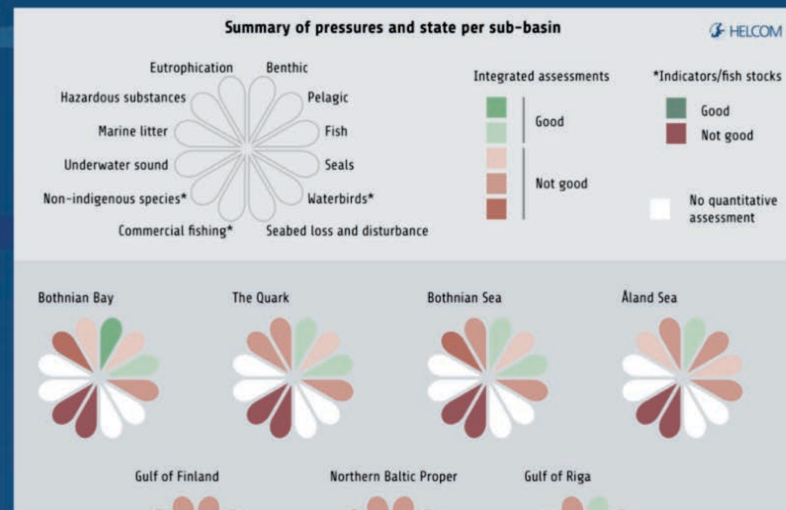


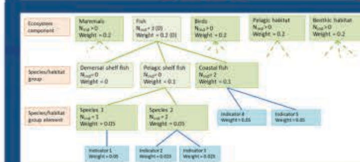
McQuatters-Gollop et al. (2019, FMAS)

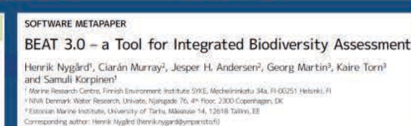
Integrated Assessment - Baltic Sea



HELCOM (2018)





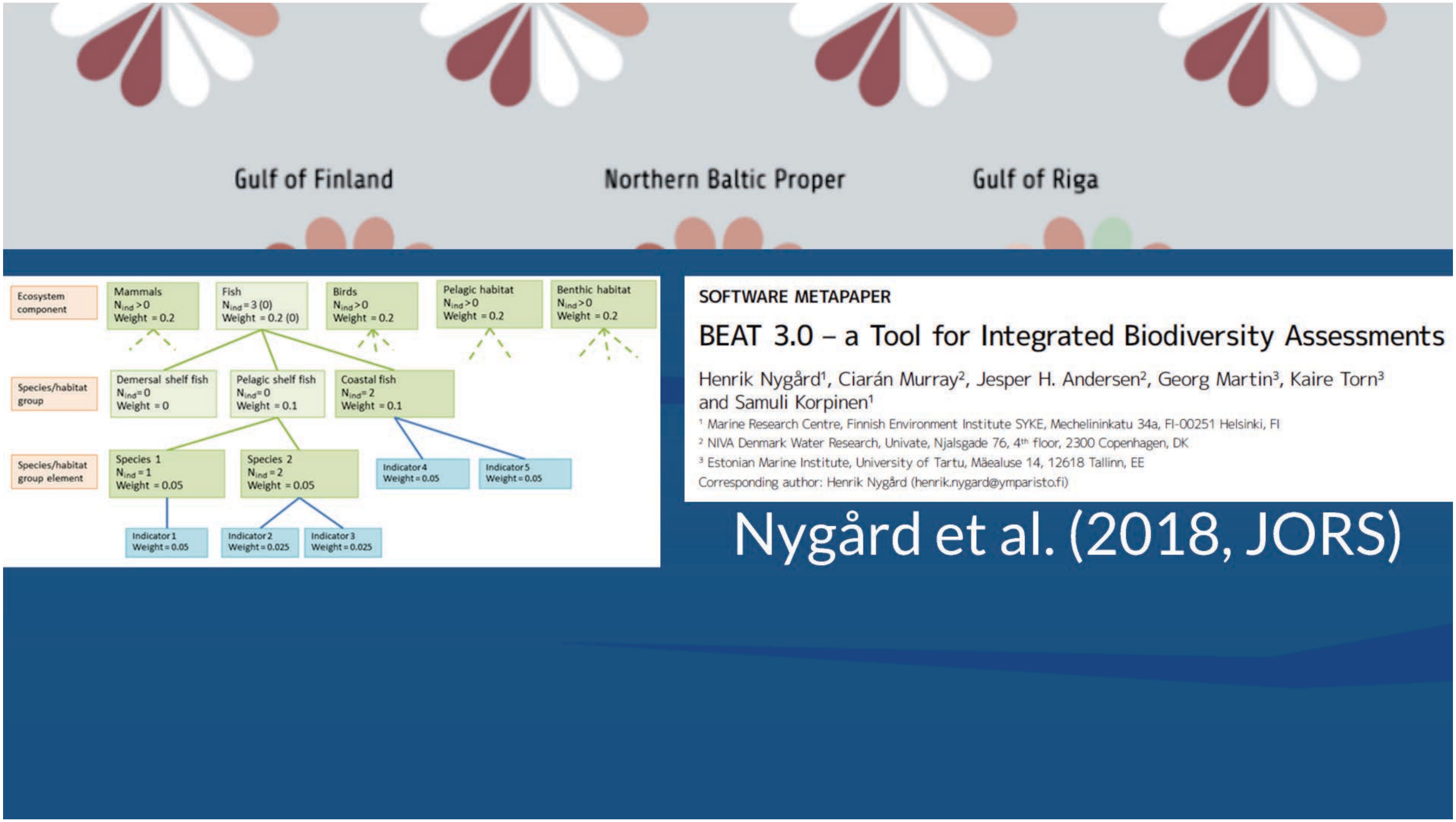


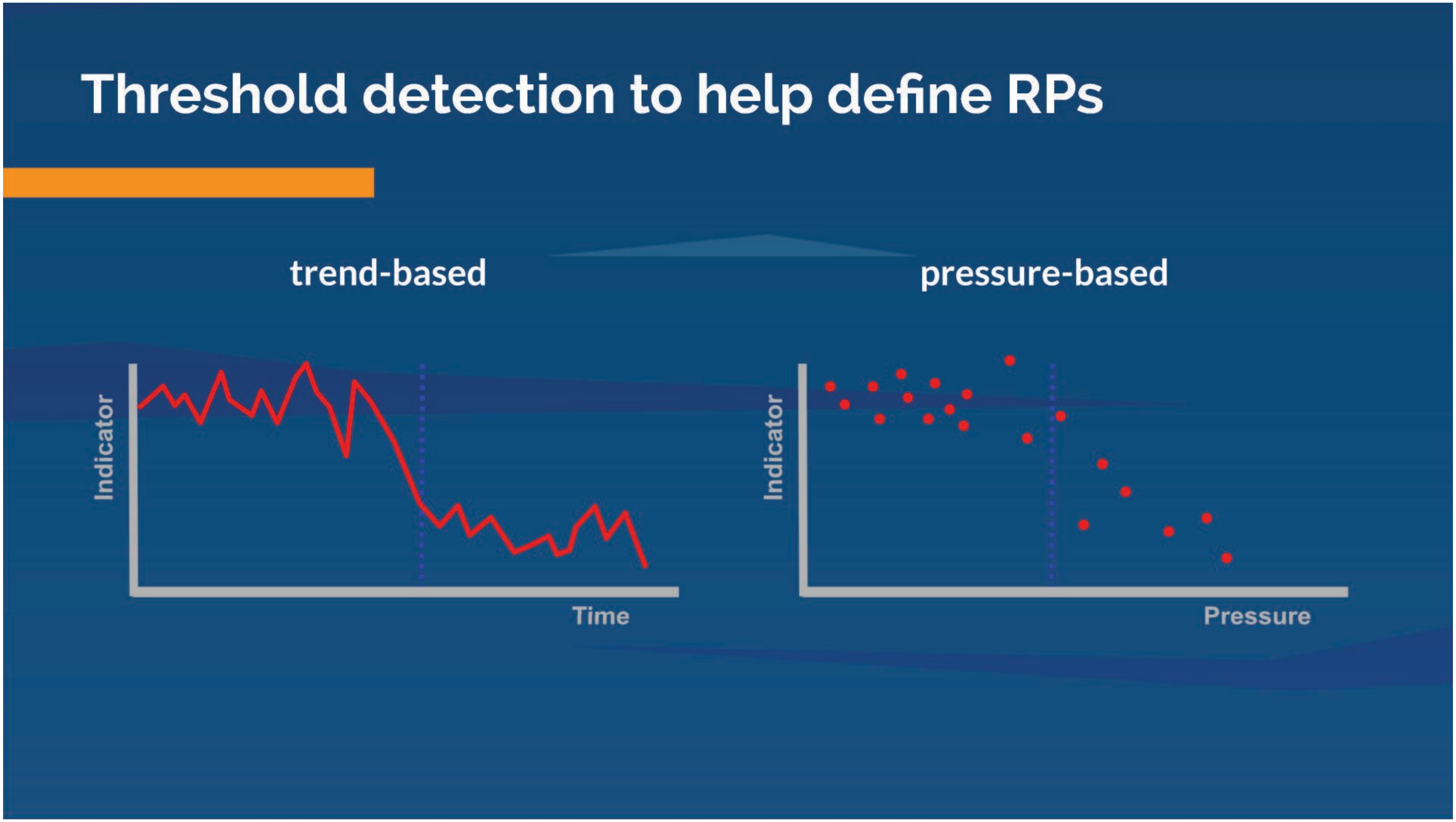
SOFTWARE METAPAPER

BEAT 3.0 – a Tool for Integrated Biodiversity Assessments

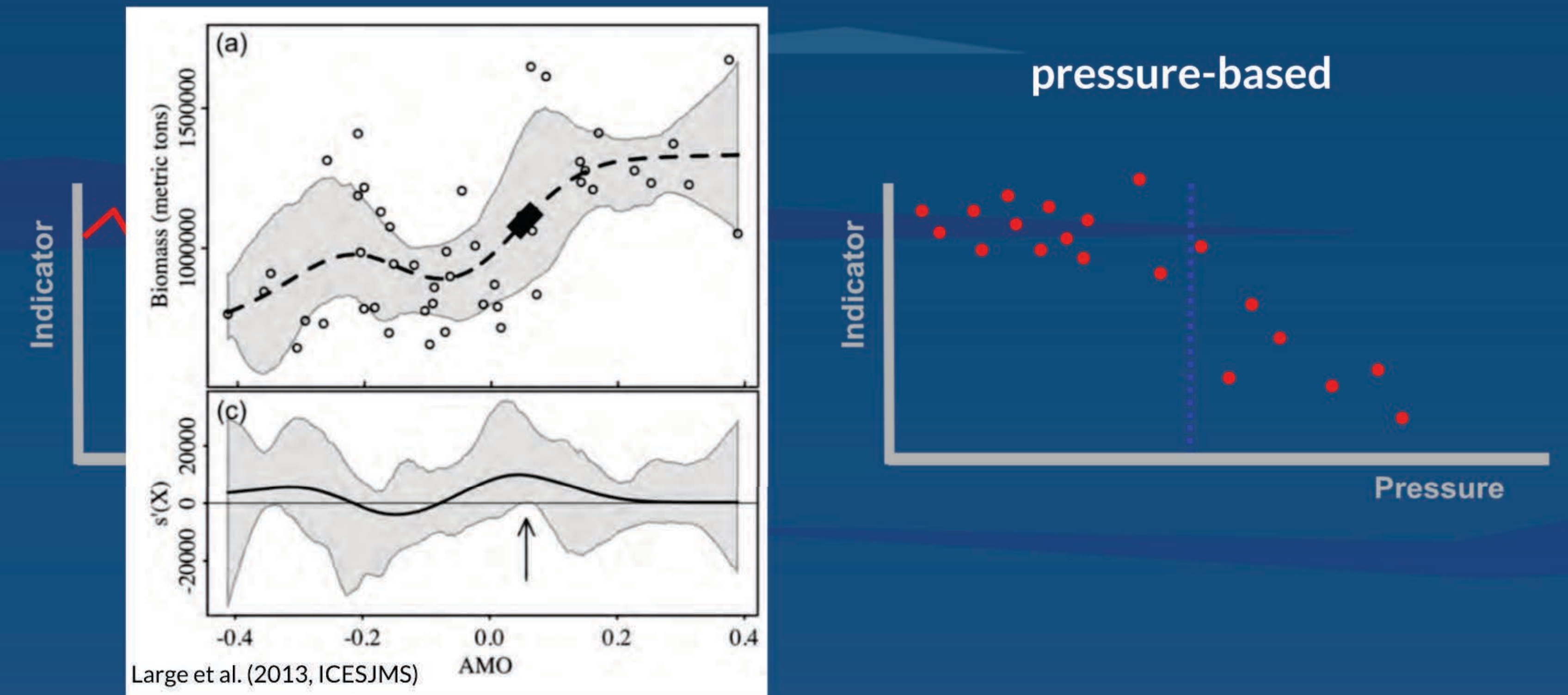
Henrik Nygård[1], Ciarán Murray[2], Jesper H. Andersen[2], Georg Martin[3], Kaire Torn[3] and Samuli Korpinen[1]

Nygård et al. (2018, JORS)


Gulf of Finland
Northern Baltic Proper
Gulf of Riga
Ecosystem component
Mammals N_ind > 0 Weight = 0.2
Fish N_ind = 3 (0) Weight = 0.2 (0)
Birds N_ind > 0 Weight = 0.2
Pelagic habitat N_ind > 0 Weight = 0.2
Benthic habitat N_ind > 0 Weight = 0.2
Species/habitat group
Demersal shelf fish N_ind = 0 Weight = 0
Pelagic shelf fish N_ind = 0 Weight = 0.1
Coastal fish N_ind = 2 Weight = 0.1
Species/habitat group element
Species 1 N_ind = 1 Weight = 0.05
Species 2 N_ind = 2 Weight = 0.05
Indicator 4 Weight = 0.05
Indicator 5 Weight = 0.05
Indicator 1 Weight = 0.05
Indicator 2 Weight = 0.025
Indicator 3 Weight = 0.025
SOFTWARE METAPAPER
BEAT 3.0 – a Tool for Integrated Biodiversity Assessments
Henrik Nygård[1], Ciarán Murray[2], Jesper H. Andersen[2], Georg Martin[3], Kaire Torn[3] and Samuli Korpinen[1]
[1] Marine Research Centre, Finnish Environment Institute SYKE, Mechelininkatu 34a, FI-00251 Helsinki, FI
[2] NIVA Denmark Water Research, Univate, Njalsgade 76, 4th floor, 2300 Copenhagen, DK
[3] Estonian Marine Institute, University of Tartu, Mäealuse 14, 12618 Tallinn, EE
Corresponding author: Henrik Nygård (henrik.nygard@ymparisto.fi)
Nygård et al. (2018, JORS)


Threshold detection to help define RPs
trend-based
pressure-based
Indicator
Time
Indicator
Pressure

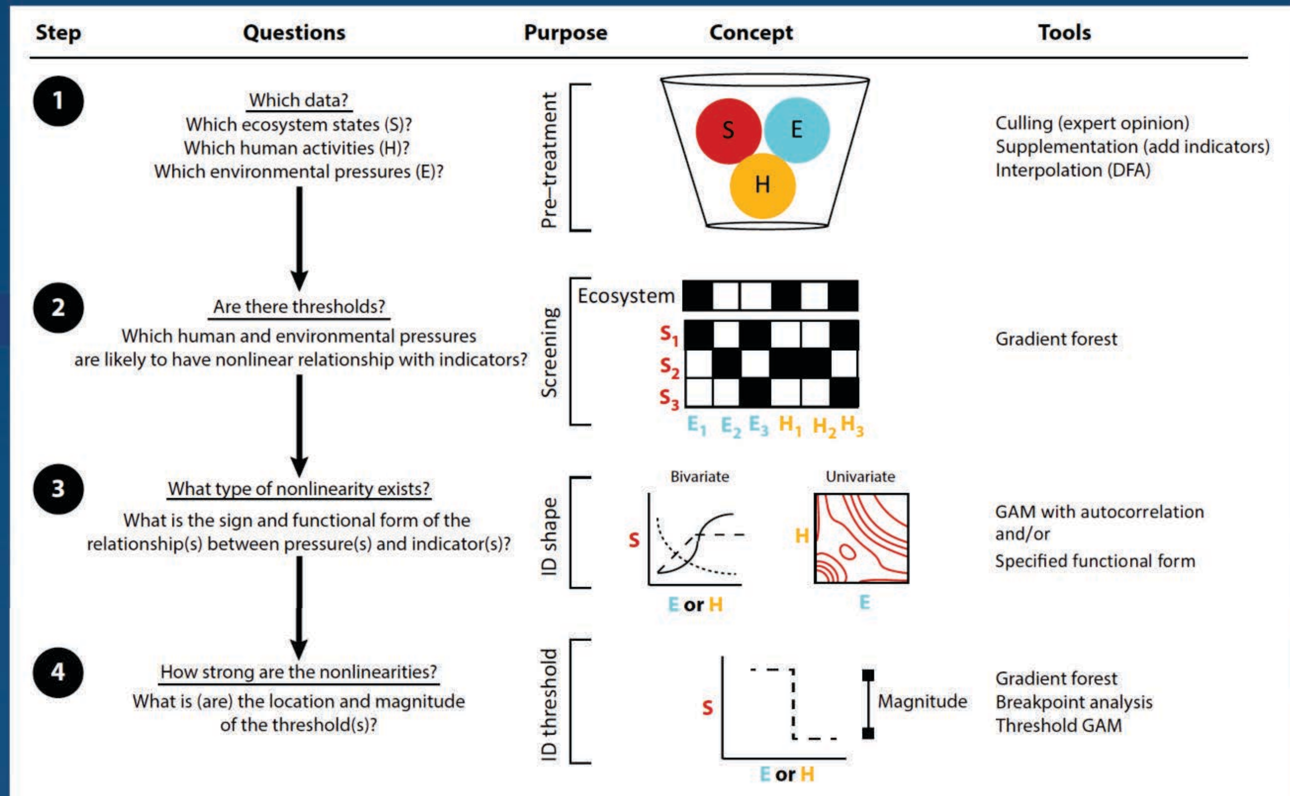
Threshold detection to help define RPs



Threshold detection to help define RPs

S = Ecosystem state indicator(s)
E = Environmental pressure indicator(s)
H = Human Impact indicator(s)

Samhouri et al. (2017, Ecosphere)



BUT: Number and location of thresholds method-dependent

Table 1: Comparison of number and location (loc) of change points (cpts) across time series dynamics and methods. Orange cells indicate good matches with the true dataset.

Time series (loc of true cpts)	AMOC	PELT-AIC	PELT-CROPS	bcp	GFT (F test)	Breakpoints	segmented	tree
1 change in mean (Nile data, #28)	28	(too many)	(too many)	28	28	28	3	28
1 change in mean (at #25)	25	25	13,14,23,24,25	25	25	25	14	25
3 changes in mean (at #10,25,45)	none	10,26,46	10,26,46	26	26	10,26,34	20	10,16,26,33,45
1 break in relationship (at #10)	6	3,8,13,18	3,8,13,18	8	8 (6)	10	11	6,14
Cubic decay function	35	(too many)	none	32,43	30 (34)	8,26,41	30	25,35,43
Highly non-linear (4 breaks at #10,25,45)	none	17,32	17,31,39,45	39,45	33 (39)	10,26,43	11,26,44	16,22,32,39,45

https://www.marinedatascience.co/blog/2019/09/28/comparison-of-change-point-detection-methods/

Table 1: Comparison of number and location (loc) of change points (cpts) across time series dynamics and methods. Orange cells indicate good matches with the true dataset.

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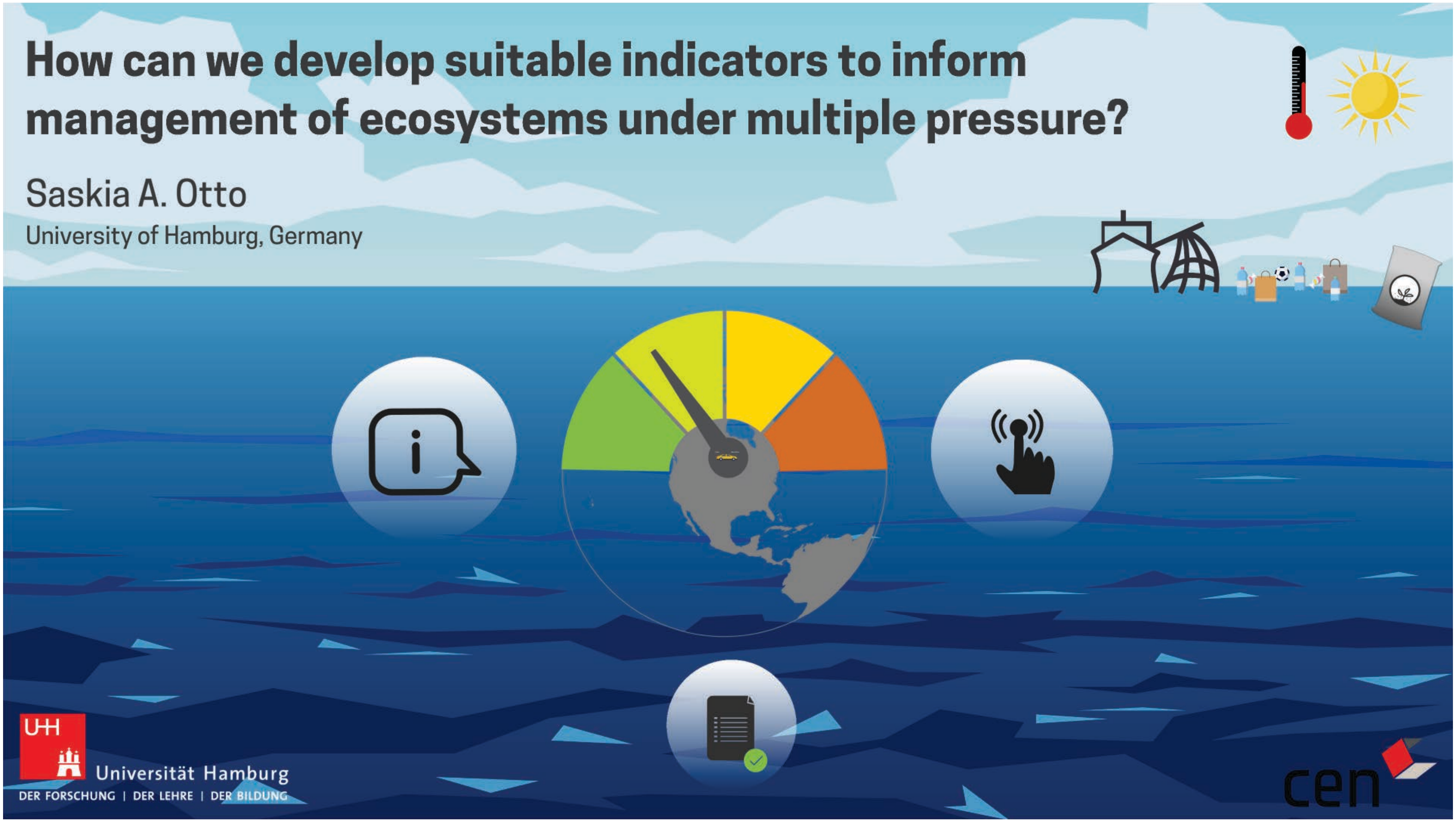
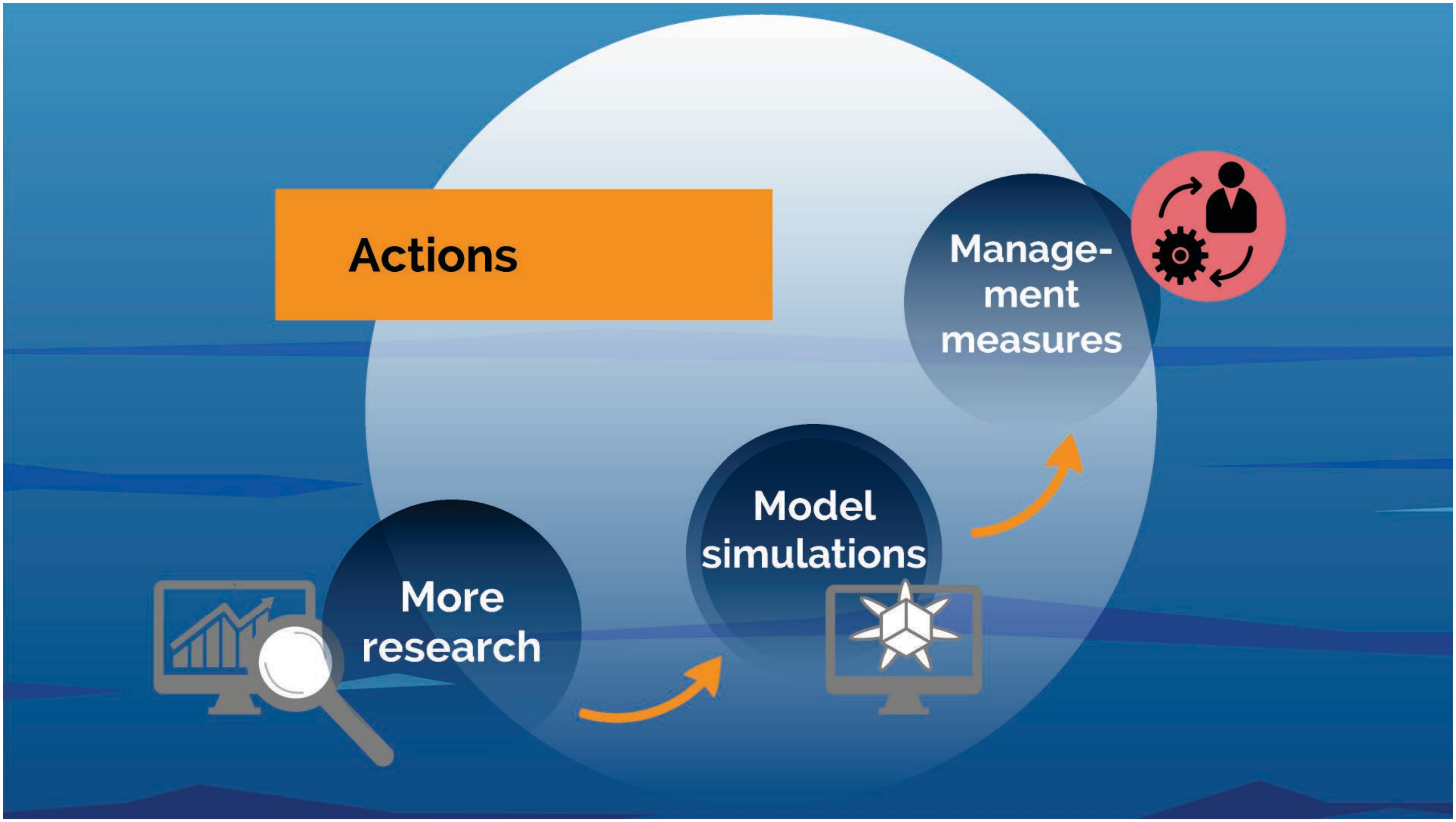
1 change in mean (at #25)	25	25	13,14,23,24,25	25	25	25	14	25
3 changes in mean (at #10,25,45)	none	10,26,46	10,26,46	26	26	10,26,34	20	10,16,26,33,45
1 break in relationship (at #10)	6	3,8,13,18	3,8,13,18	8	8 (6)	10	11	6,14
Cubic decay function	35	(too many)	none	32,43	30 (34)	8,26,41	30	25,35,43
Highly non-linear (4 breaks at #10,25,45)	none	17,32	17,31,39,45	39,45	33 (39)	10,26,43	11,26,44	16,22,32,39,45


How can we develop suitable indicators to inform management of ecosystems under multiple pressure?
Saskia A. Otto
University of Hamburg, Germany
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG
cen


Actions
Manage-
ment
measures
Model
simulations
More
research

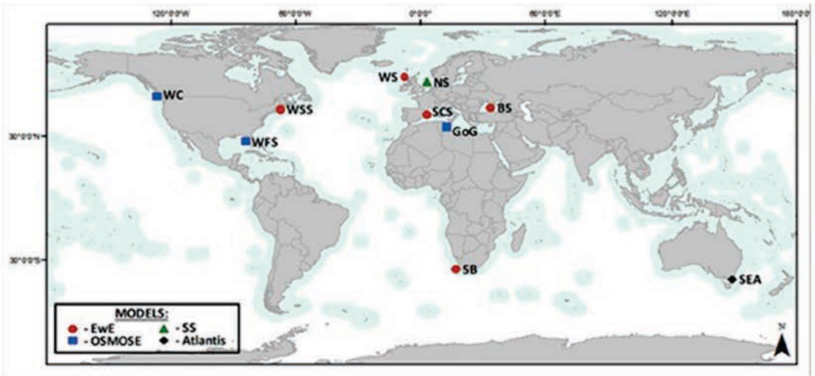
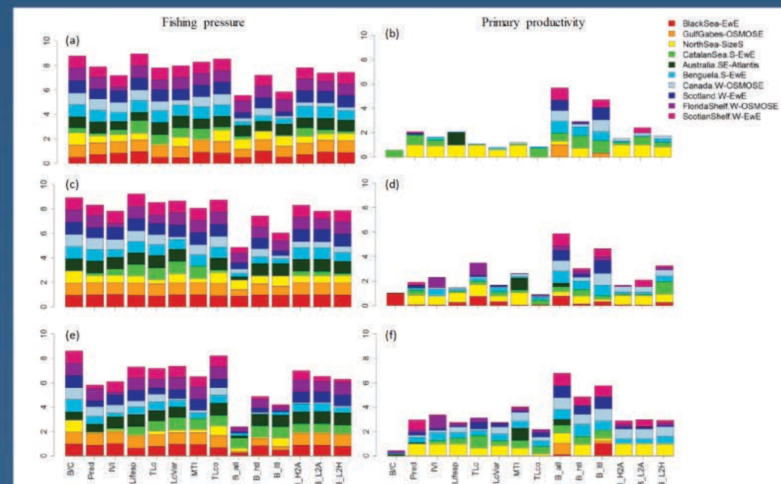
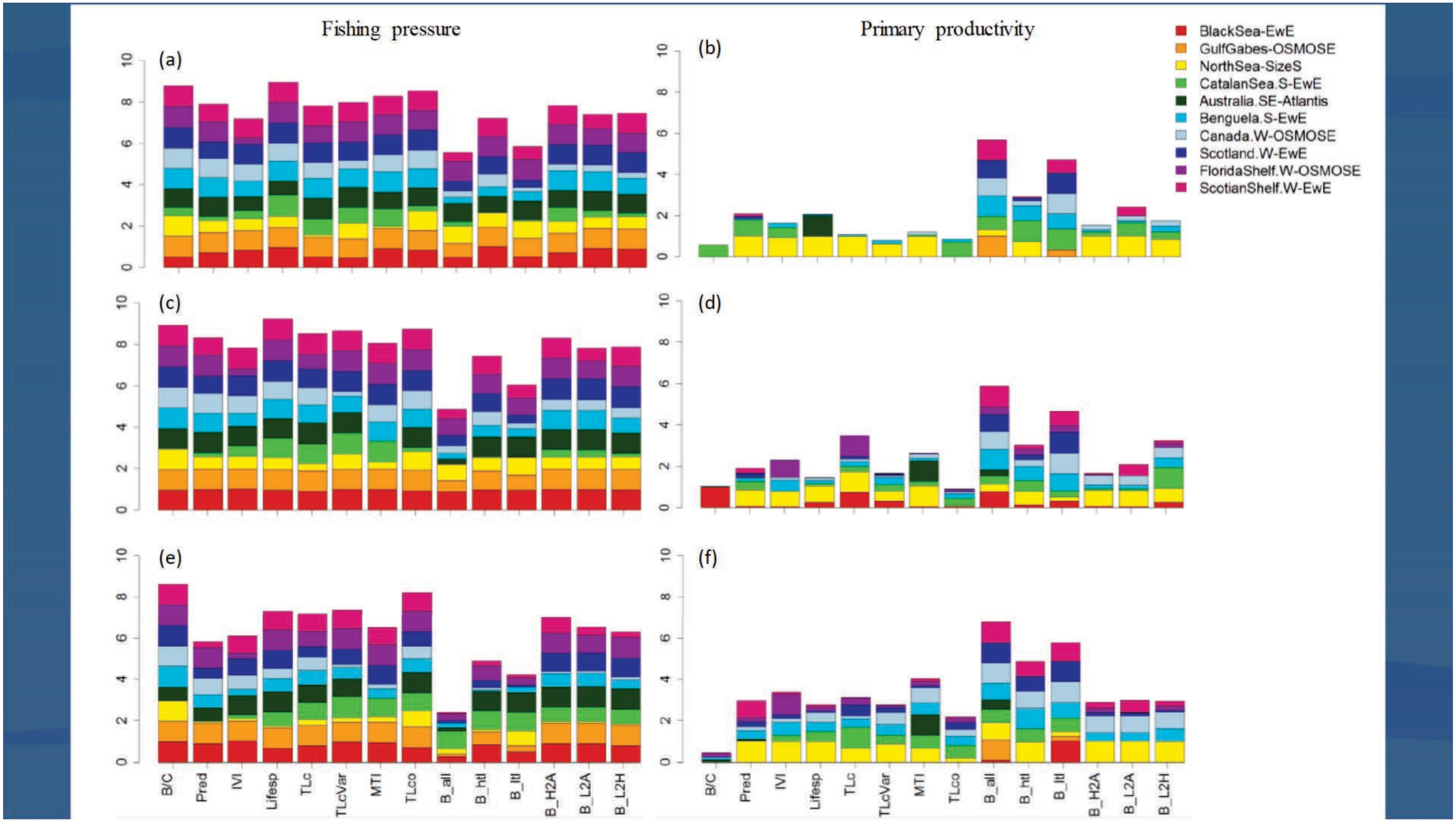
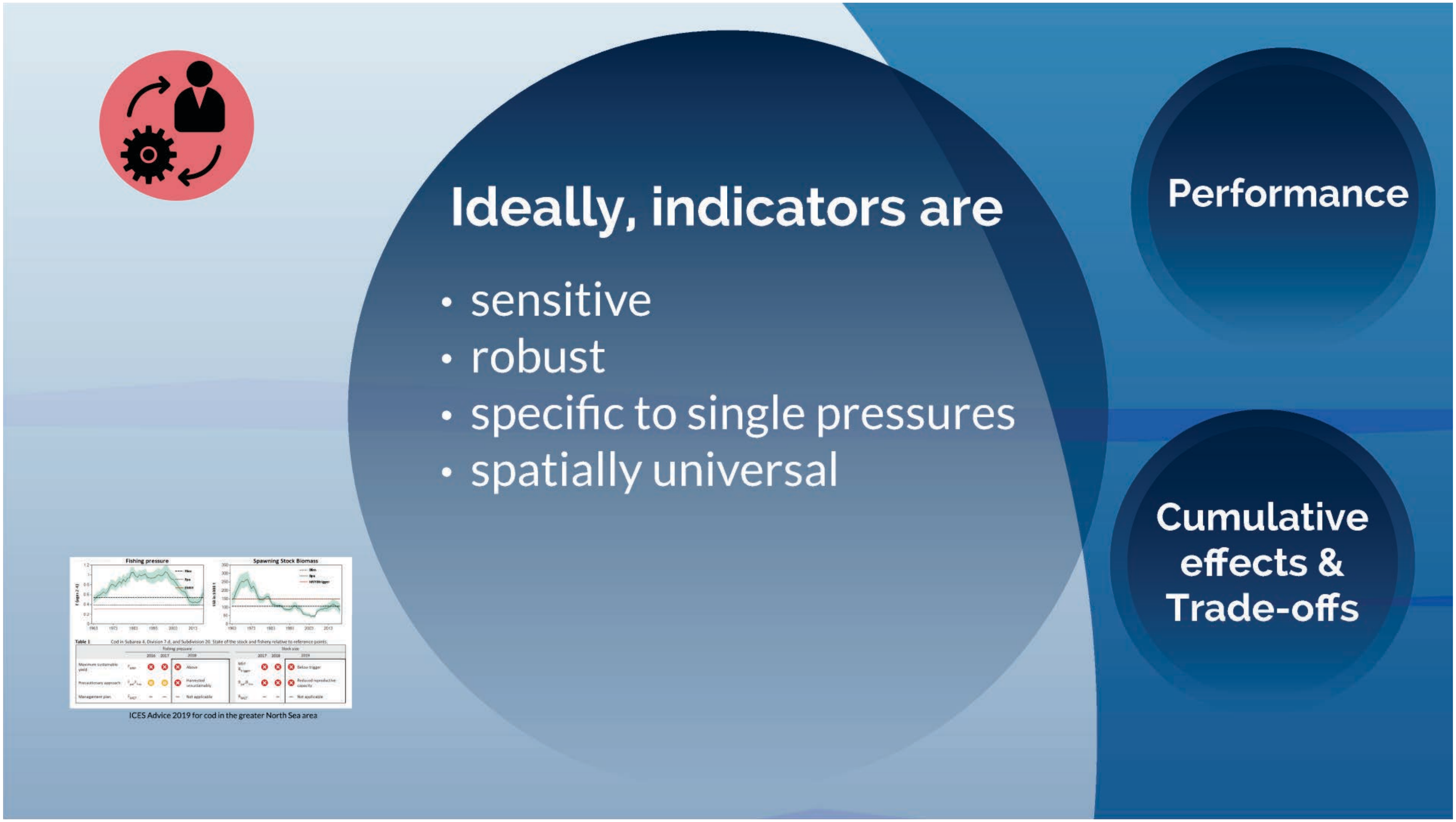


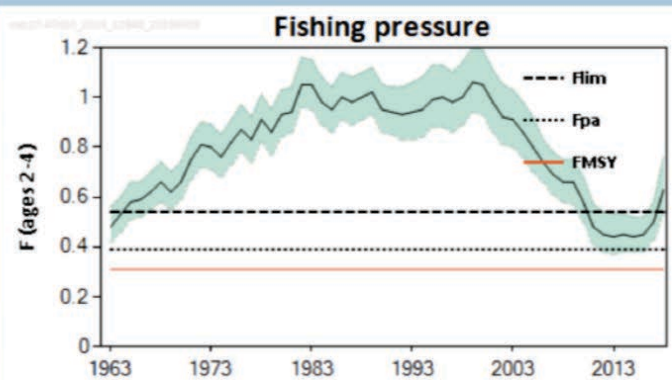
Fig. 1. Location of the ten marine ecosystems studied (BS = Black Sea, GoG = Gulf of Gabes, NS = North Sea, SCS = Southern Catalan Sea, SEA = Southeastern Australia, SB = Southern Benguela, WC = West coast of Canada, WS = Western Scotland, WFS = West Florida Shelf, and WSS = Western Scotian Shelf). Four ecosystem modelling frameworks were used to simulate the dynamics of these ten ecosystems: Ecopath with Ecosim (EwE), OSMOSE, Atlantis, and multispecies size-spectrum model (SS).



Fu et al. (2019, Ecol Ind)


Fishing pressure
Primary productivity
(a)
(b)
(c)
(d)
(e)
(f)
BlackSea-EwE
GulfGabes-OSMOSE
NorthSea-SizeS
CatalanSea.S-EwE
Australia.SE-Atlantis
Benguela.S-EwE
Canada.W-OSMOSE
Scotland.W-EwE
FloridaShelf.W-OSMOSE
ScotianShelf.W-EwE
B/C
Pred
IVI
Lifesp
TLc
TLcVar
MTI
TLco
B_all
B_htl
B_ltl
B_H2A
B_L2A
B_L2H


Ideally, indicators are
• sensitive
• robust
• specific to single pressures
• spatially universal
Performance
Cumulative effects & Trade-offs
ICES Advice 2019 for cod in the greater North Sea area



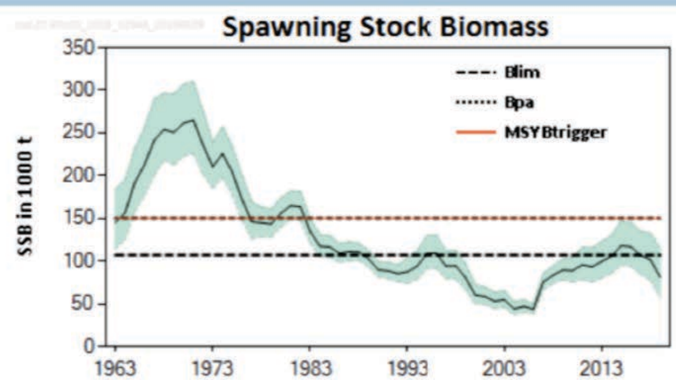


Table 1 Cod in Subarea 4, Division 7.d, and Subdivision 20. State of the stock and fishery relative to reference points.

		Fishing pressure				Stock size			
		2016	2017	2018		2017	2018	2019	
Maximum sustainable yield	F_{MSY}	⊗	⊗	⊗	Above	MSY $B_{trigger}$	⊗	⊗	⊗ Below trigger
Precautionary approach	F_{pa},F_{lim}	O	O	⊗	Harvested unsustainably	B_{pa},B_{lim}	⊗	⊗	⊗ Reduced reproductive capacity
Management plan	F_{MGT}	–	–	–	Not applicable	B_{MGT}	–	–	– Not applicable

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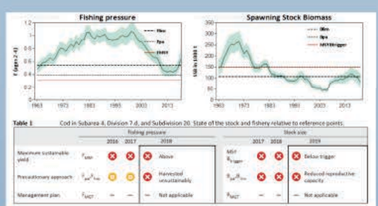
Ideally, indicators are

- sensitive
- robust
- specific to single pressures
- spatially universal



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Performance

Cumulative effects & Trade-offs

How to quantify indicator performance?

Semi-quantitative approach

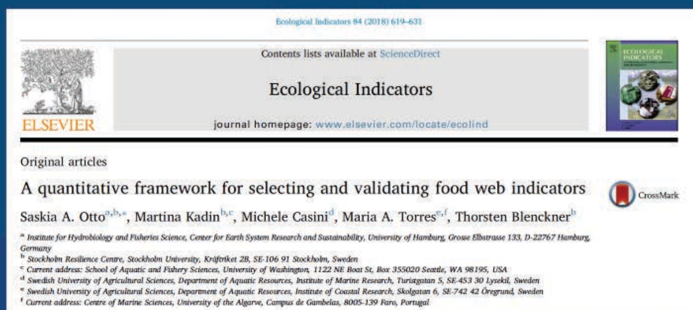
Aim: Objective, Transparent and Repeatable Assessment of Quality of Candidate Indicators	CANDIDATE INDICATORS ⇩
INDICATOR QUALITY CRITERIA (IQ)	**EVALUATION STEPS (ES)**
IQ1. Scientific basis	ES1 – ES5
IQ2. Ecosystem relevance	ES1 – ES5
IQ3. Responsiveness to pressure	ES1 – ES5
IQ4. Possibility to set targets within the indicator response	ES1 – ES5
IQ5. Precautionary capacity/early warning/anticipatory capability	ES1 – ES5
IQ6. Quality of sampling method: measurable, accurate and precise outputs	ES1 – ES5
IQ7. Cost-effective implementation	ES1 – ES5
IQ8. Part of an existing or current ongoing monitoring or data	ES1 – ES5
ES6. Sum of quality scores across IQs, per indicator	$\sum_{i=1}^{8} IQ_i$ (ES5)
Comparison of ES6 Scores For Candidate Indicators	⇩ SELECTION OF HIGHEST SCORING INDICATOR

FIGURE 1 | Overview of the elements in the IQ-ES framework for candidate indicator selection. Candidate indicators are tested on the basis of eight indicator quality criteria (IQ1–IQ8), each of which are evaluated and scored through five sequential steps (ES1–ES5). The final score for each candidate indicator is calculated across IQ1–IQ8 in evaluation step 6 (ES6). The comparison of the total quality score of candidate indicators is intended to provide an objective and transparent basis to inform indicator selection.

Queiros et al. (2016, FMAS)

How to quantify indicator performance?

Fully quantitative approach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Original articles

A quantitative framework for selecting and validating food web indicators

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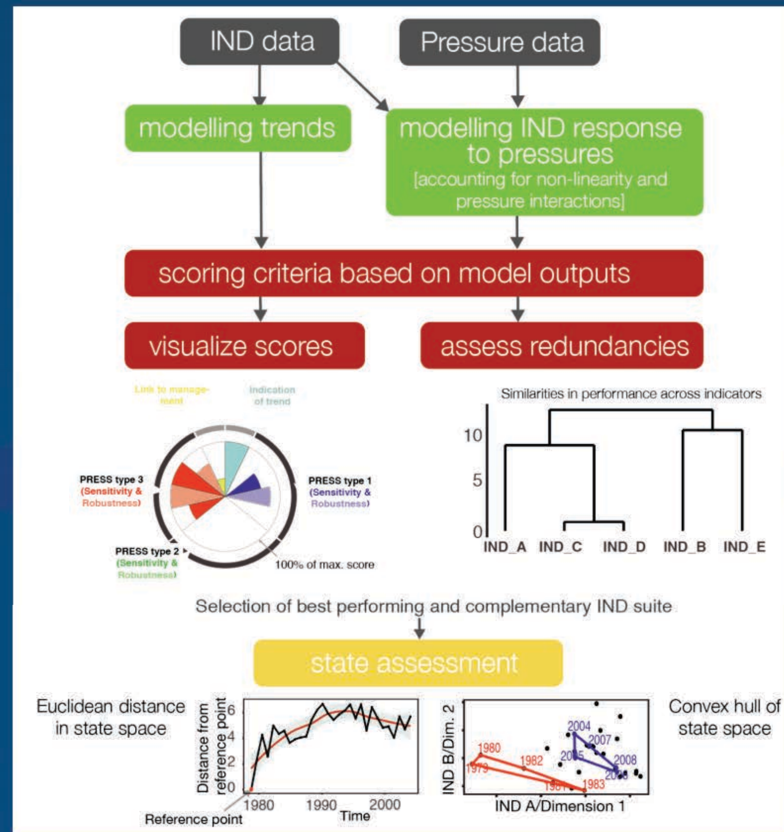
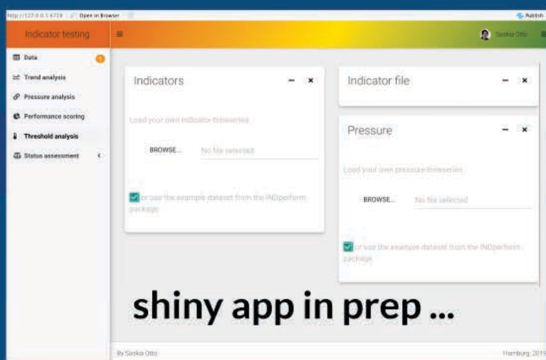
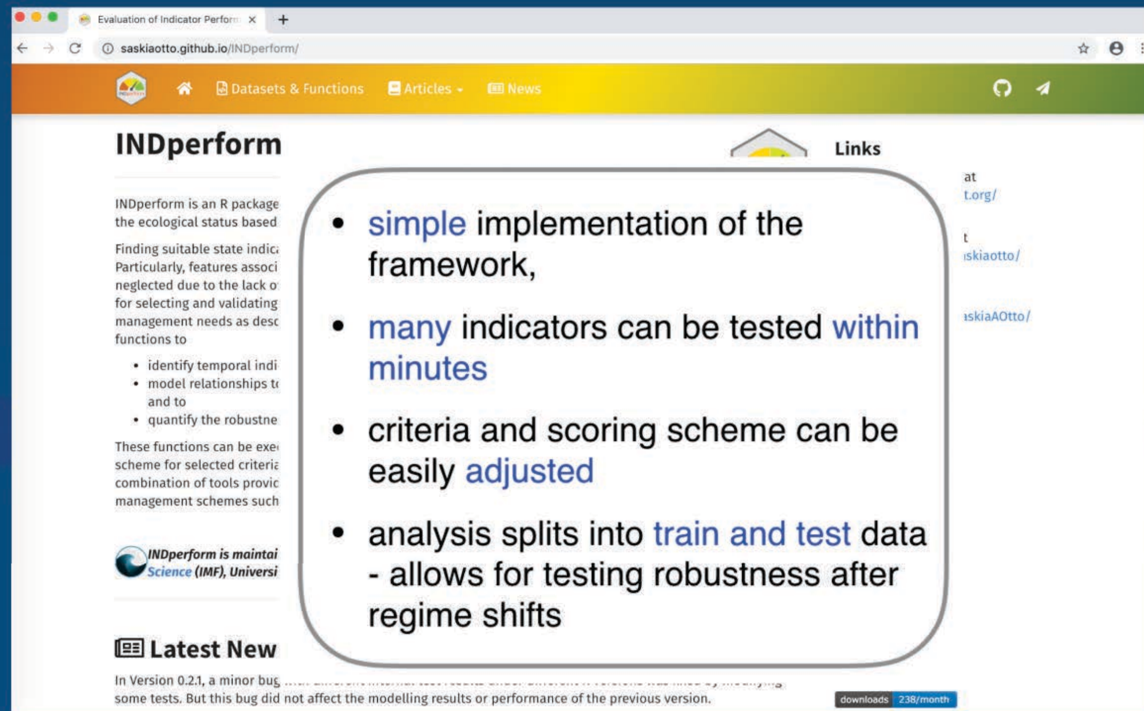


How to quantify indicator performance?

→ INDperform





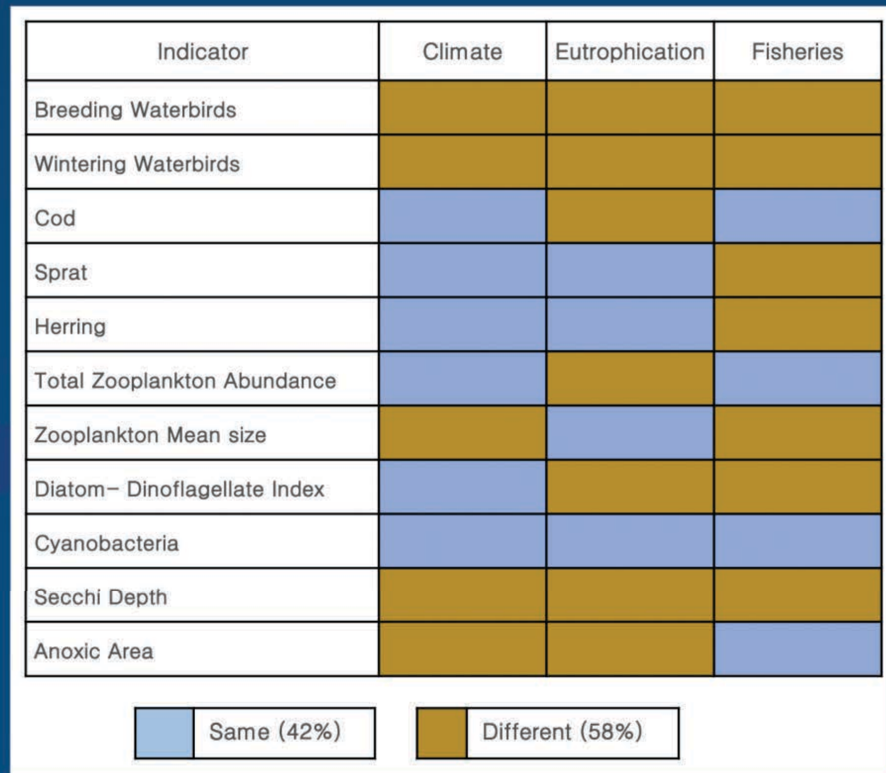
- simple implementation of the framework,
- many indicators can be tested within minutes
- criteria and scoring scheme can be easily adjusted
- analysis splits into train and test data - allows for testing robustness after regime shifts

https://saskiaotto.github.io/INDperform/

Additional measure of robustness

Running analysis for 2 time periods, e.g. before and after ecosystem shifts

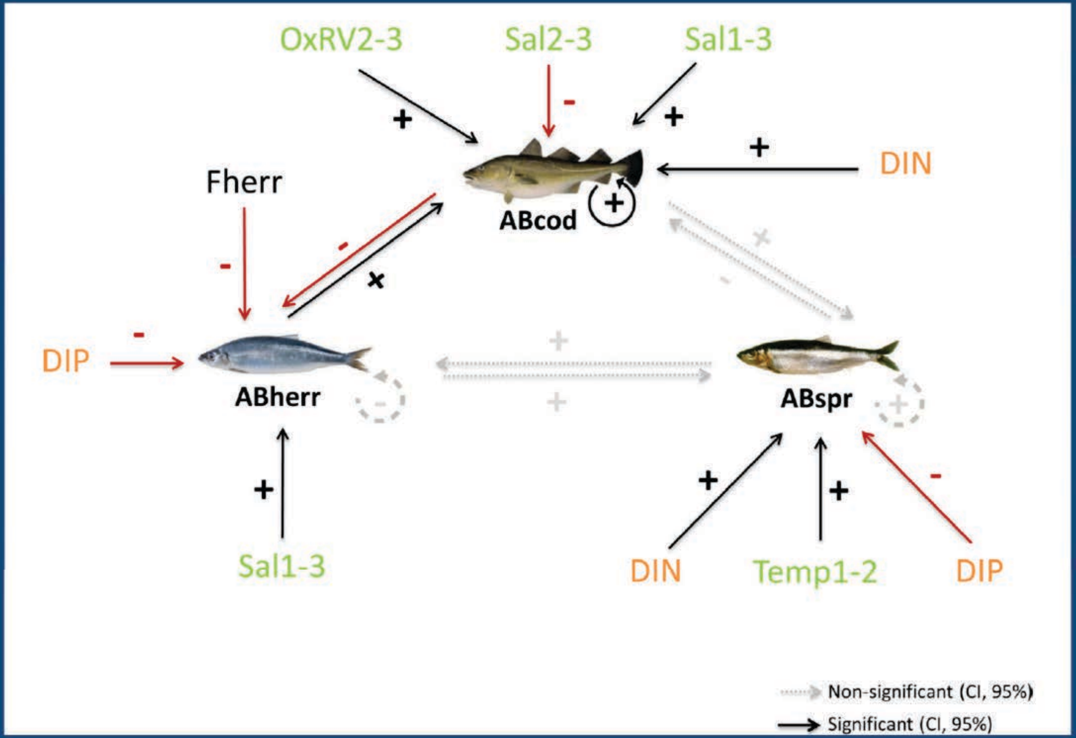
- Baltic example:



Heidrich et al. (*in prep.*)

Multiple direct & indirect effects

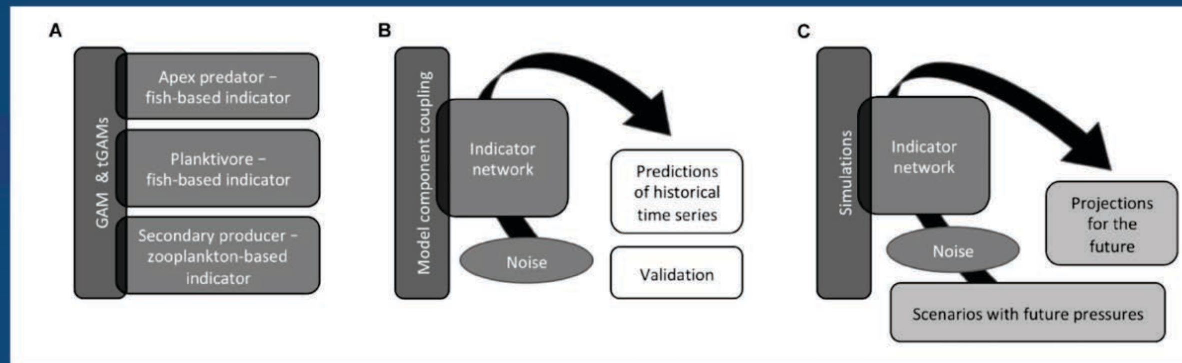
Bi-trophic food web model based on Multivariate Autoregressive Model (MAR)



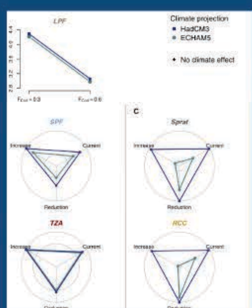
Torres et al. (2017, Ecol Ind)

Multiple direct & indirect effects

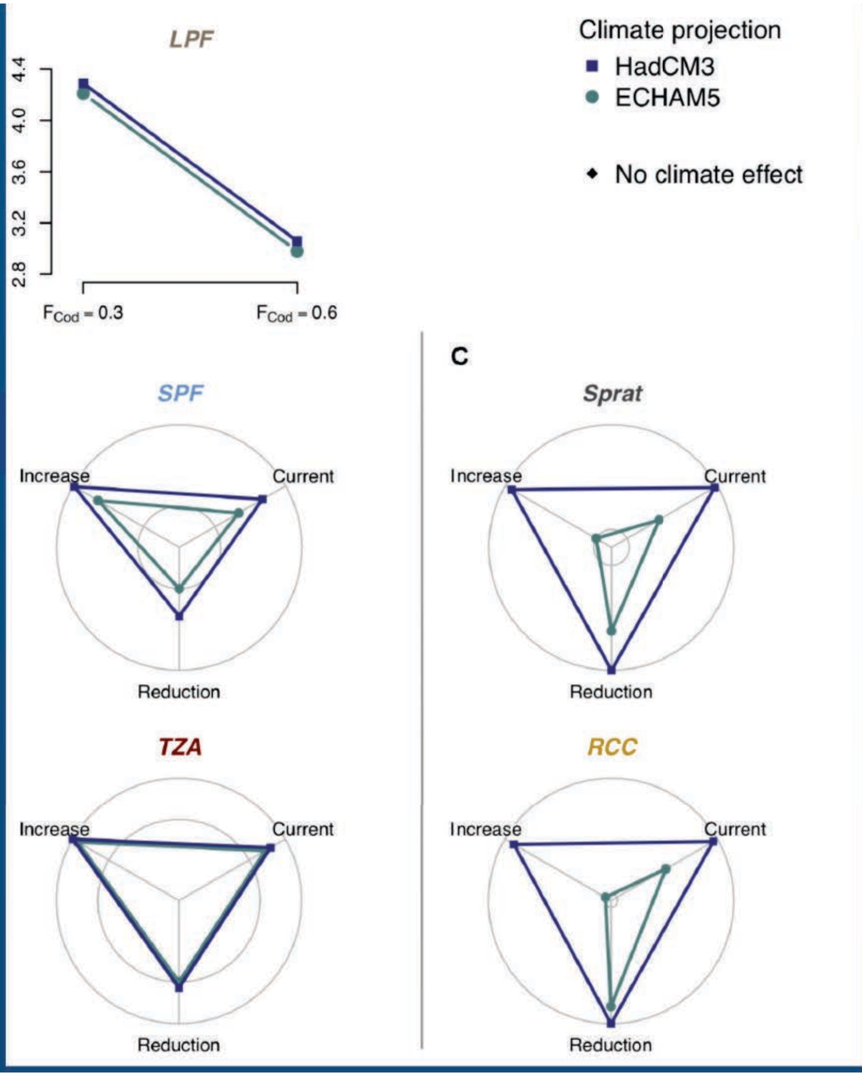
Tri-trophic food web model based on coupled GAMs/TGAMs



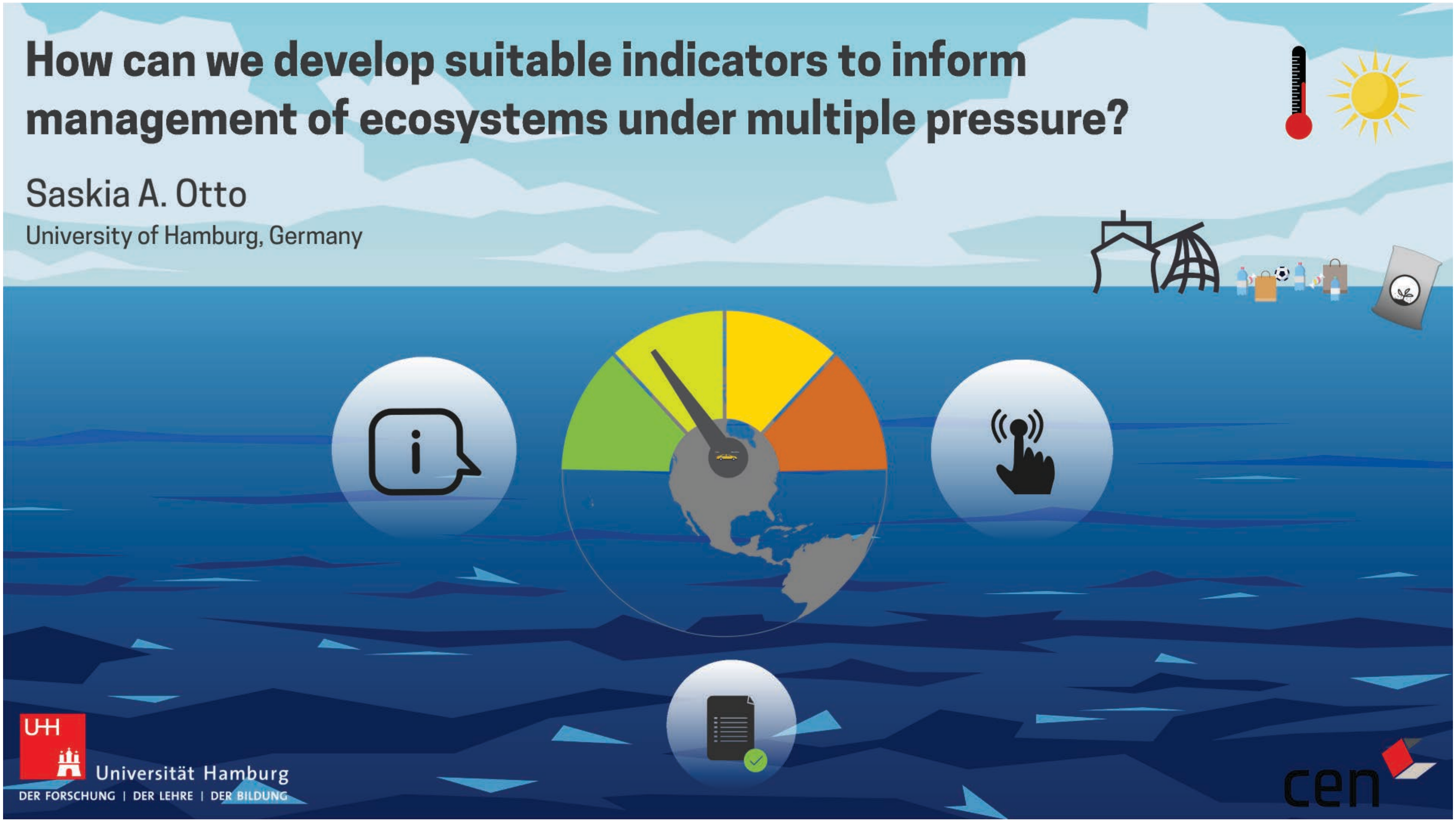
Kadin et al. (2019, FMAS)



Findings call for adaptive target setting under climate change



Findings call for adaptive target setting under climate change


How can we develop suitable indicators to inform management of ecosystems under multiple pressure?
Saskia A. Otto
University of Hamburg, Germany
Universität Hamburg
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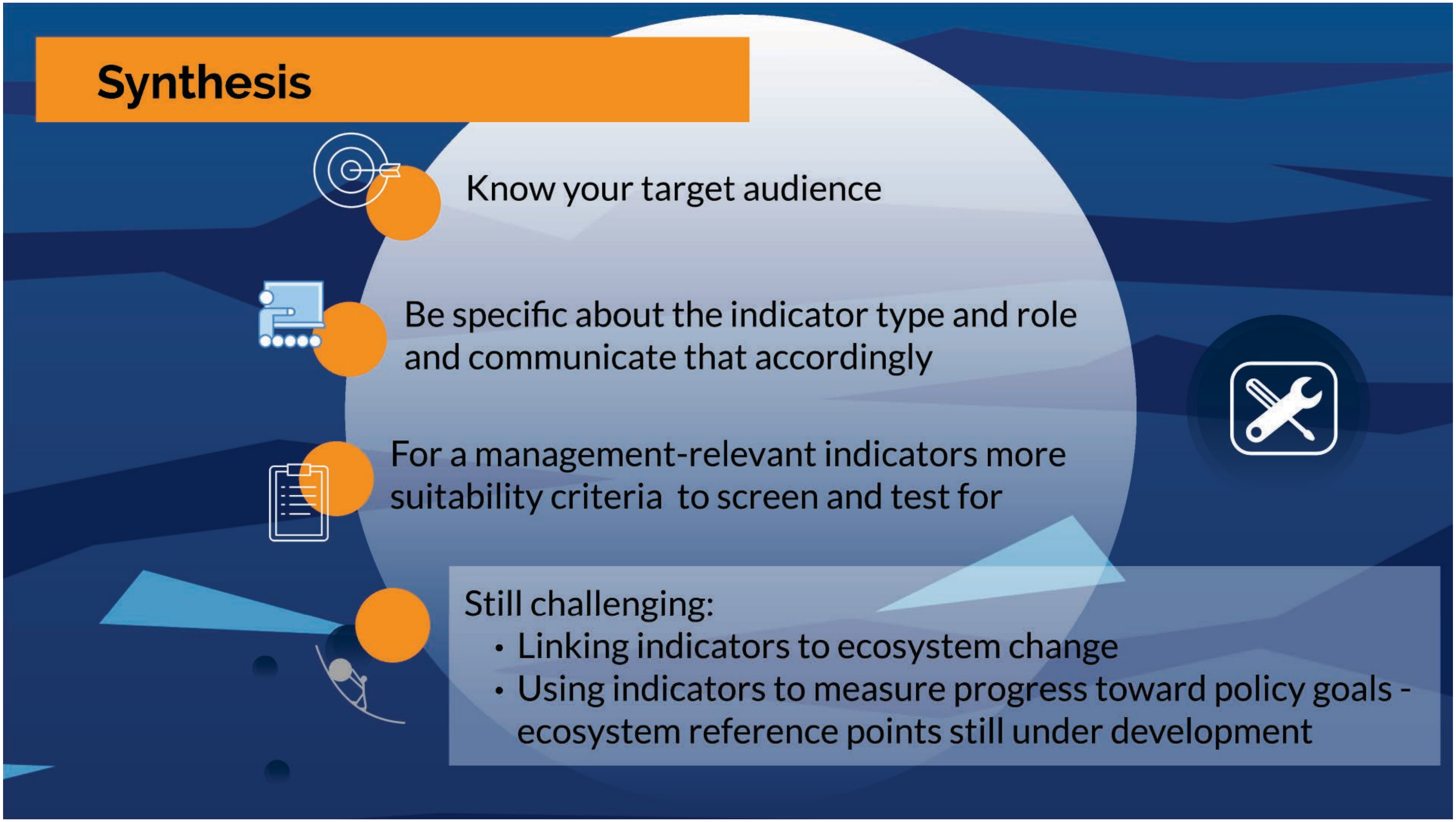
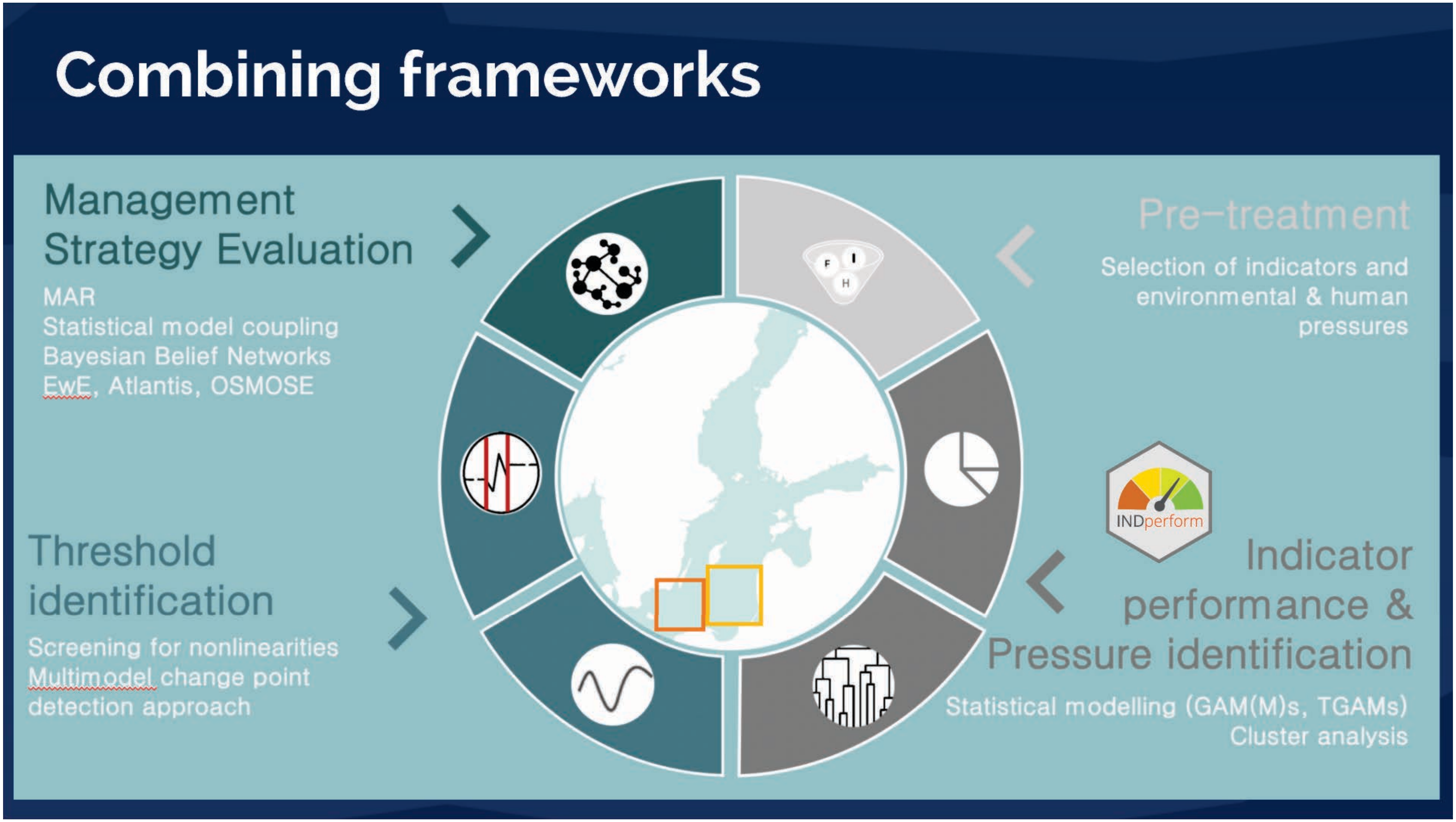

Synthesis
Know your target audience
Be specific about the indicator type and role and communicate that accordingly
For a management-relevant indicators more suitability criteria to screen and test for
Still challenging:
• Linking indicators to ecosystem change
• Using indicators to measure progress toward policy goals - ecosystem reference points still under development


Combining frameworks
Management Strategy Evaluation
MAR
Statistical model coupling
Bayesian Belief Networks
EwE, Atlantis, OSMOSE
Pre-treatment
Selection of indicators and environmental & human pressures
F I H
Threshold identification
Screening for nonlinearities
Multimodel change point detection approach
INDperform
Indicator performance & Pressure identification
Statistical modelling (GAM(M)s, TGAMs)
Cluster analysis


Thanks to
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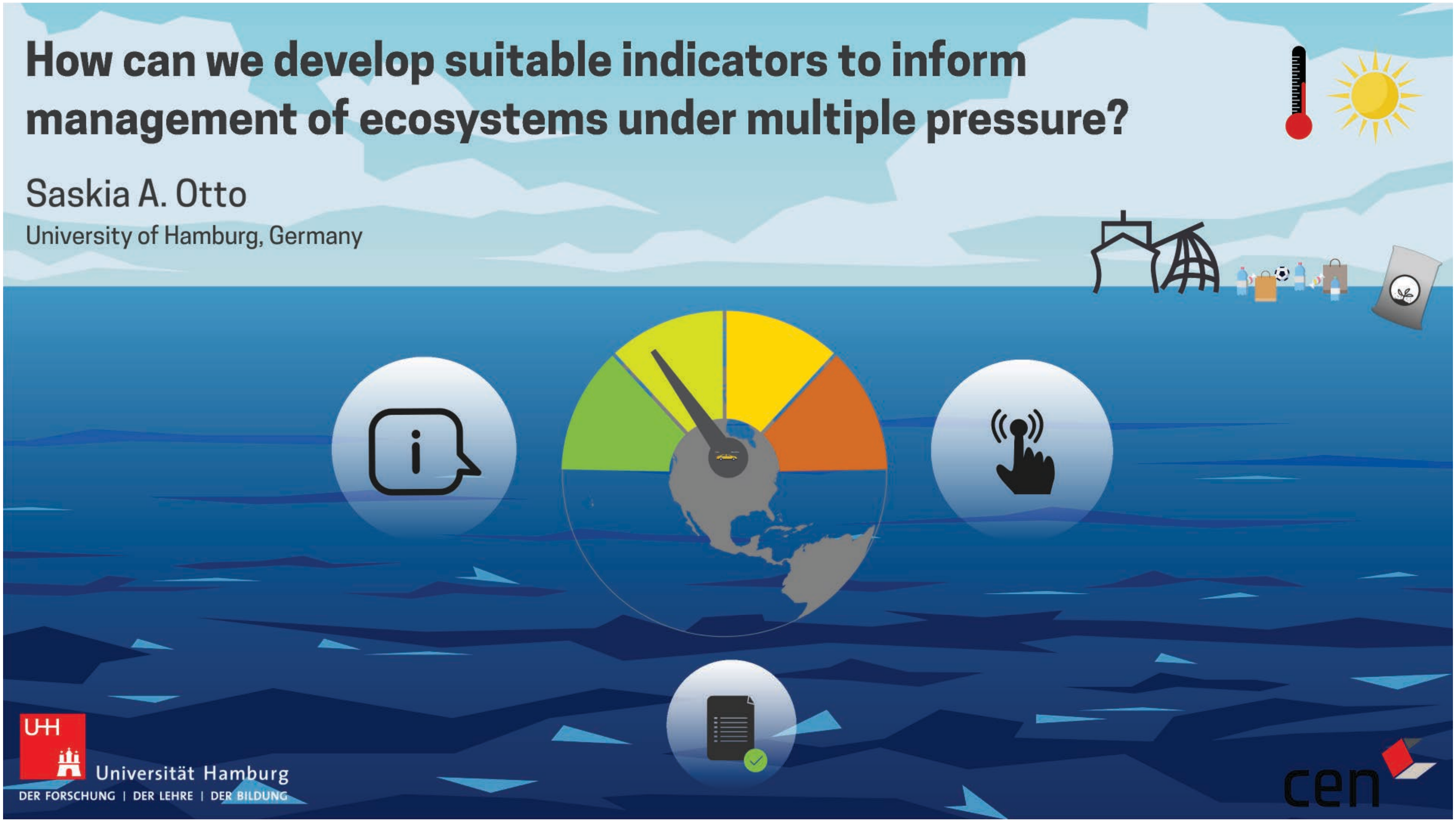
• INDperform coding team: Réné Plonus, Steffen Funk, Alexander Keth (UHAM)
BLUEWEBS
NATUR VÅRDS VERKET
SWEDISH ENVIRONMENTAL PROTECTION AGENCY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