

# The development of integrated assessment tools – from HEAT over NEAT to WATERS

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NIVA-DK 10 years anniversary  
27 September 2024



UNIVERSITY OF  
GOTHENBURG

# Cumulative effects on marine ecosystems

- Eutrophication
- Harmful substances
- Food-web alteration
- Physical disturbance
- Habitat destruction
- Invasive species
- Climate change
- .....

GES4 SEAS

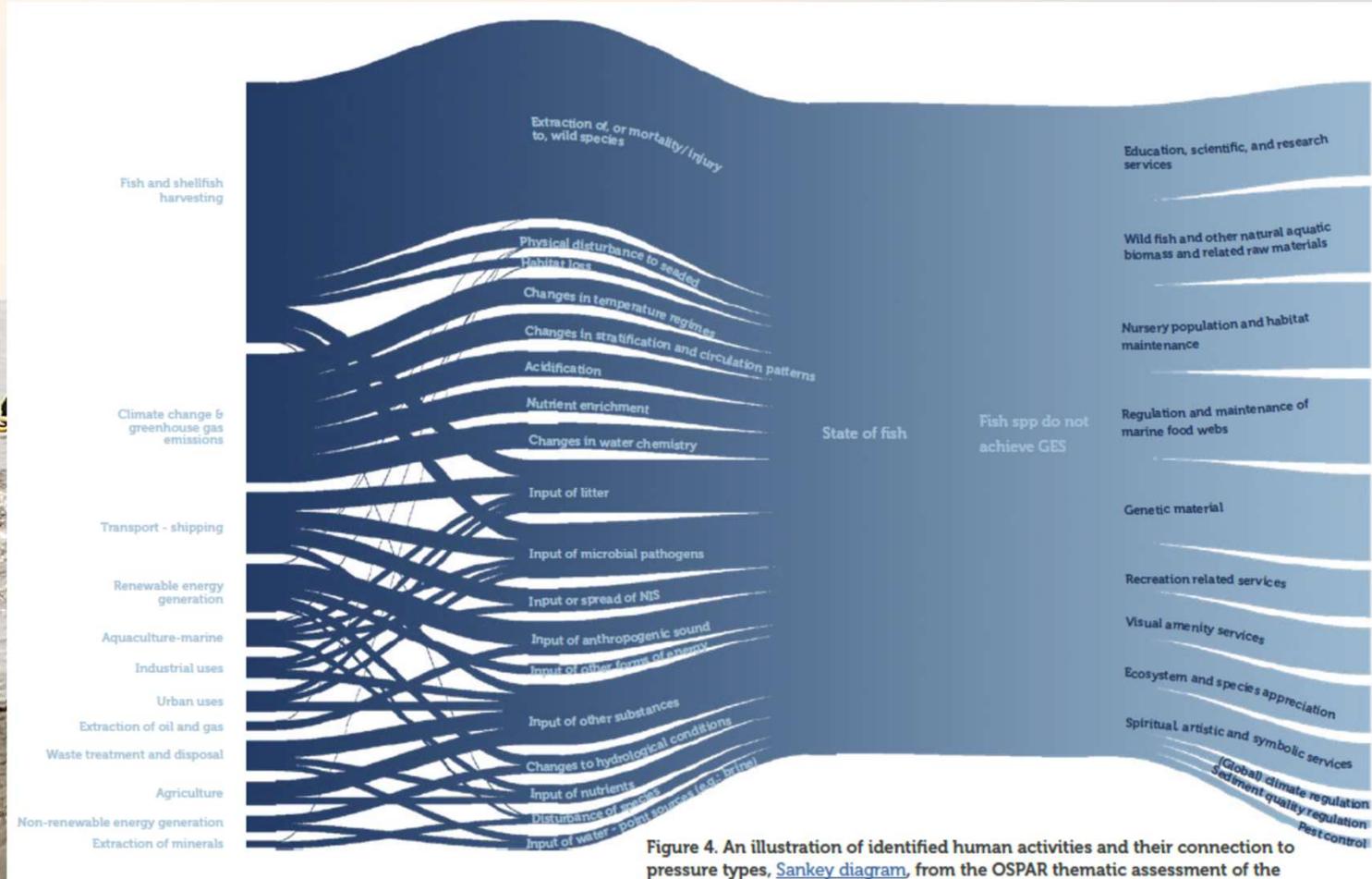
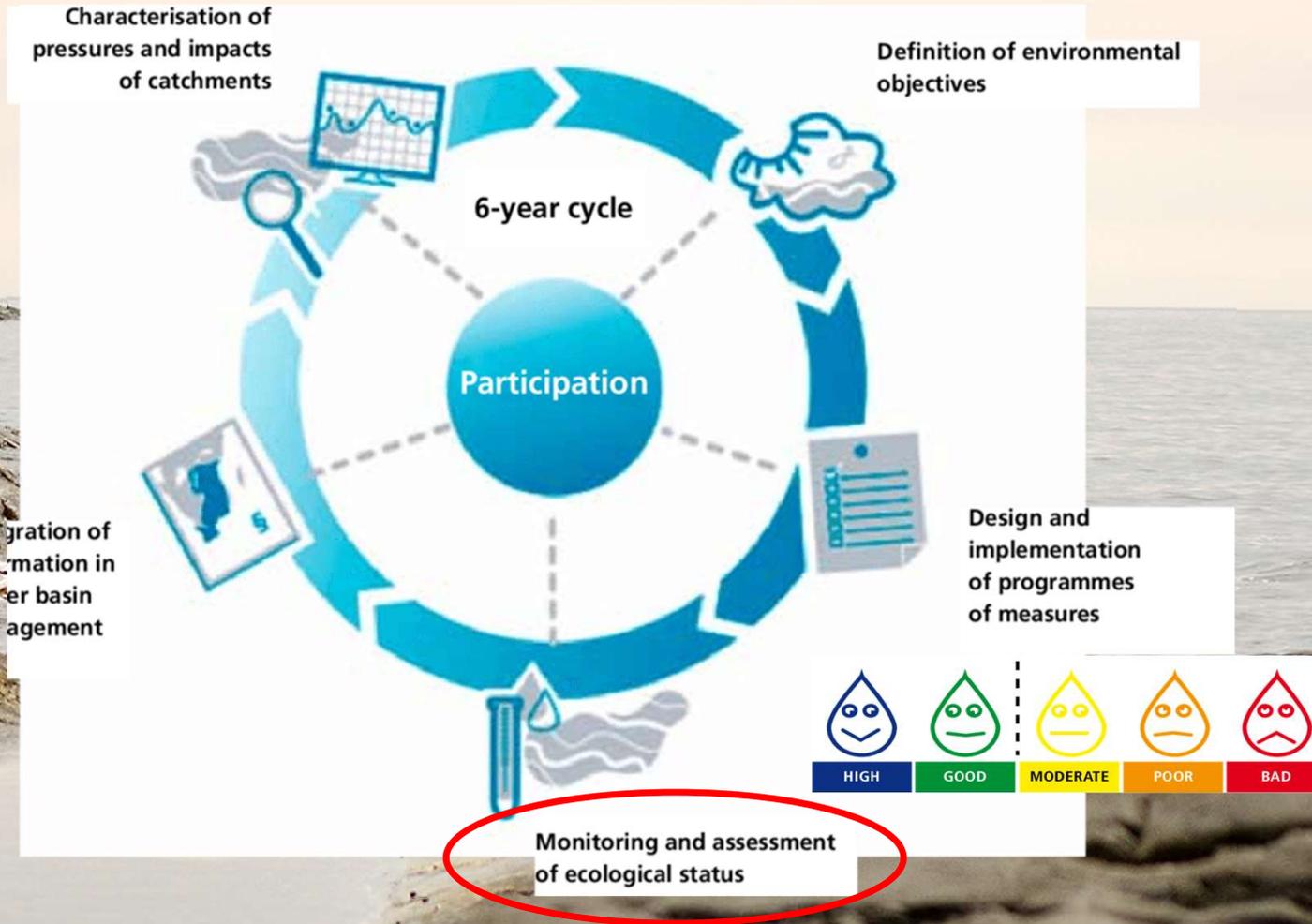


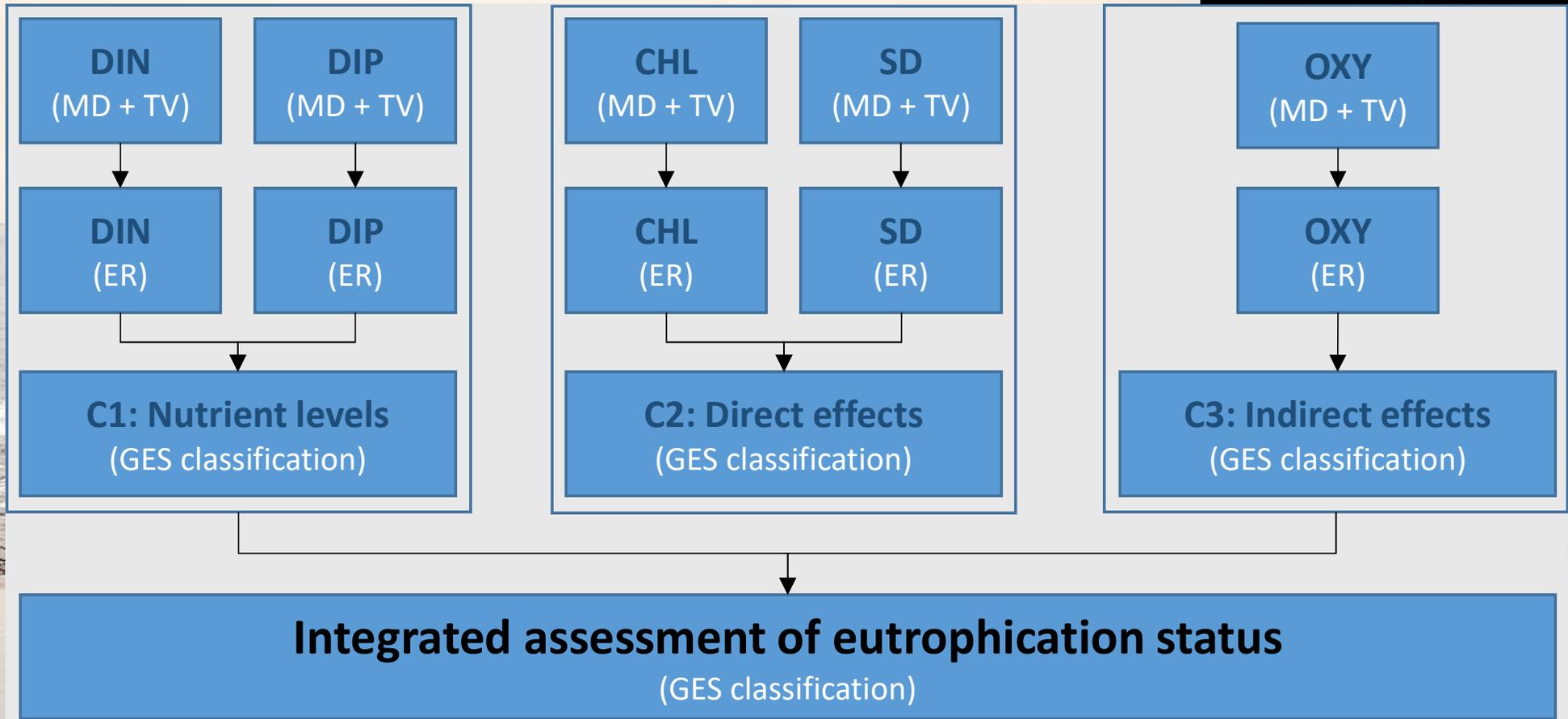
Figure 4. An illustration of identified human activities and their connection to pressure types, [Sankey diagram](#), from the OSPAR thematic assessment of the

# Assessing the status of eutrophication

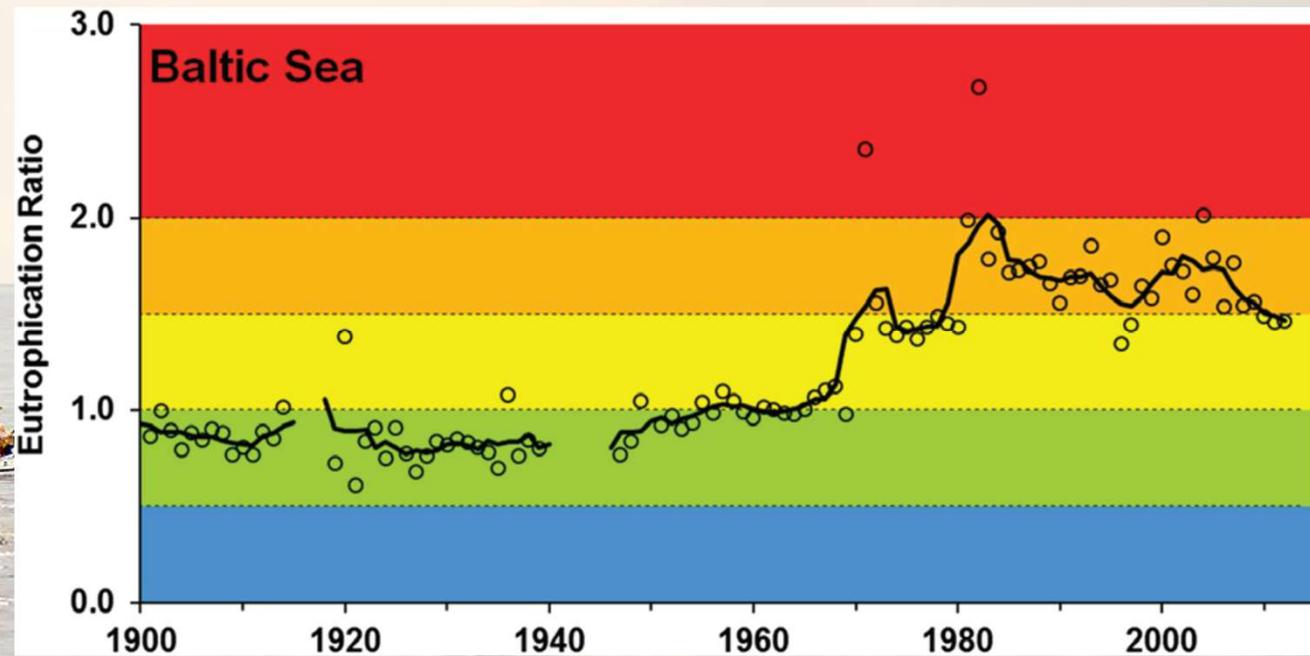
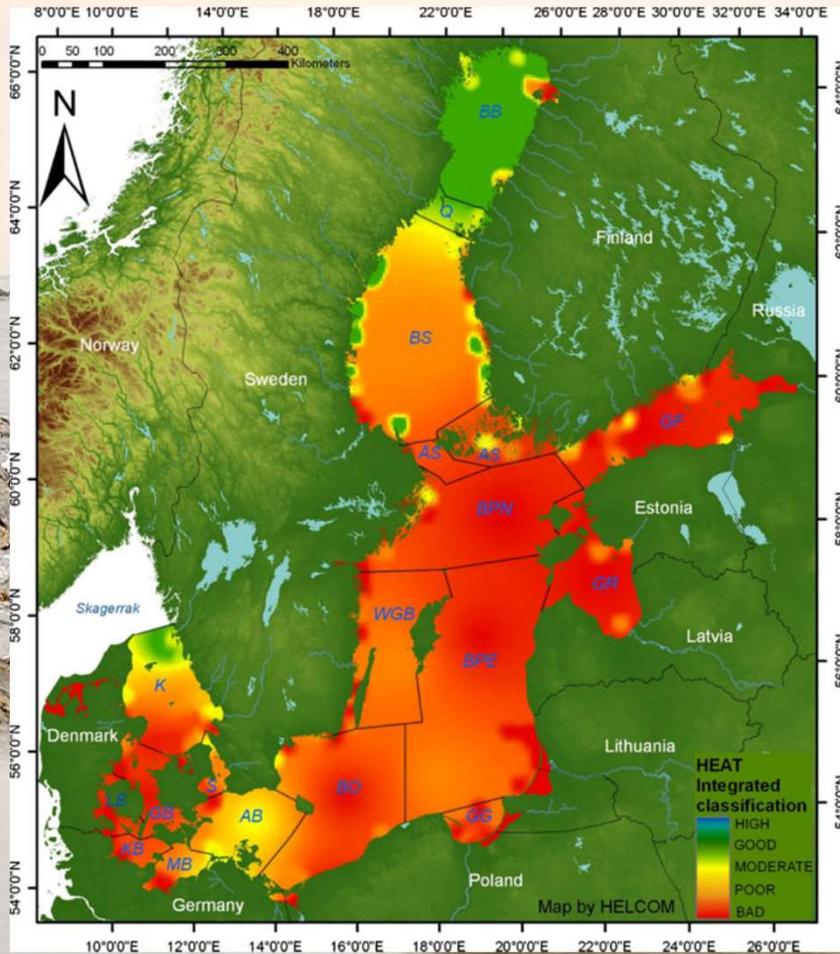




# The HEAT tool



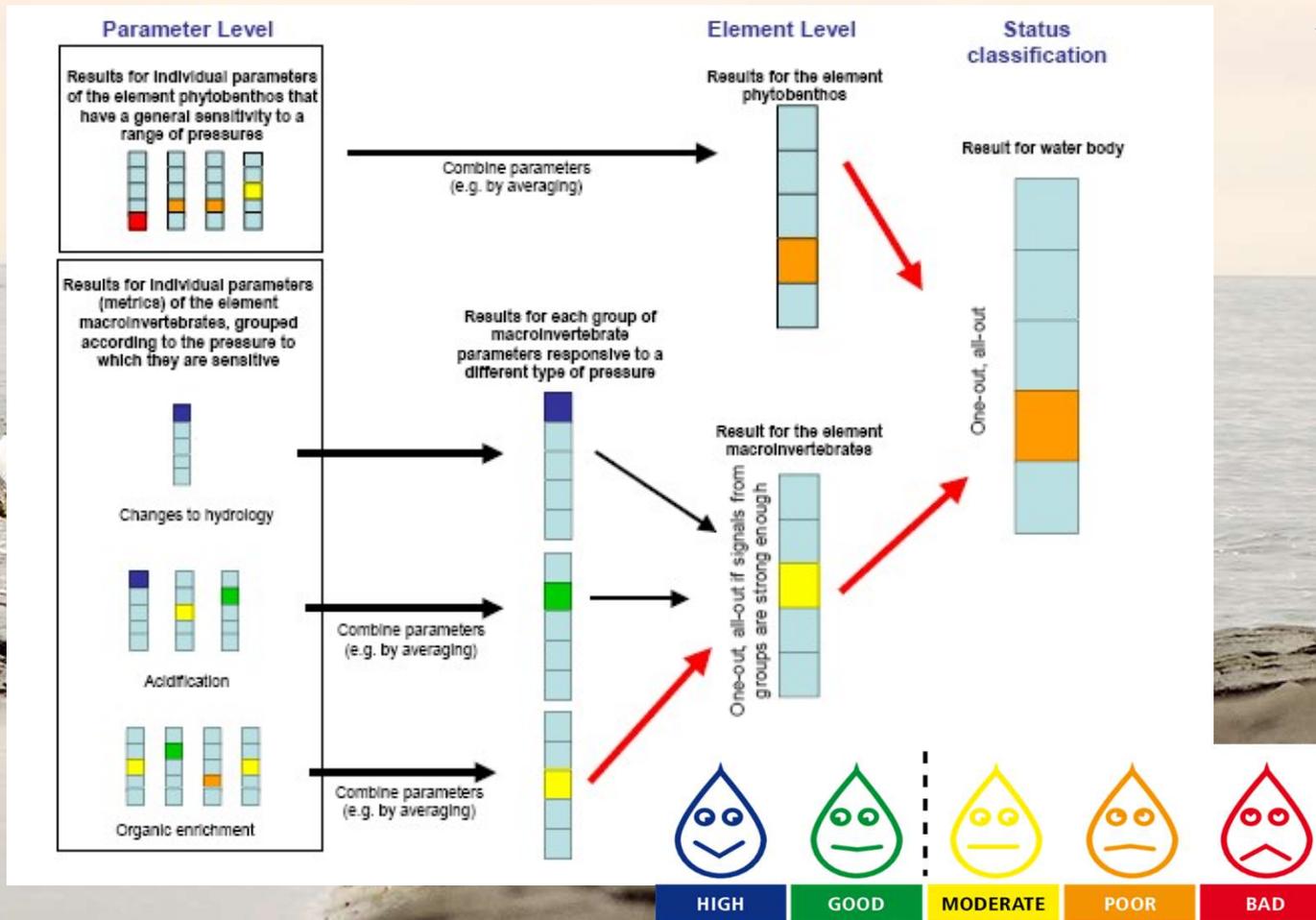
# Eutrophication status assessment in the Baltic Sea



## References:

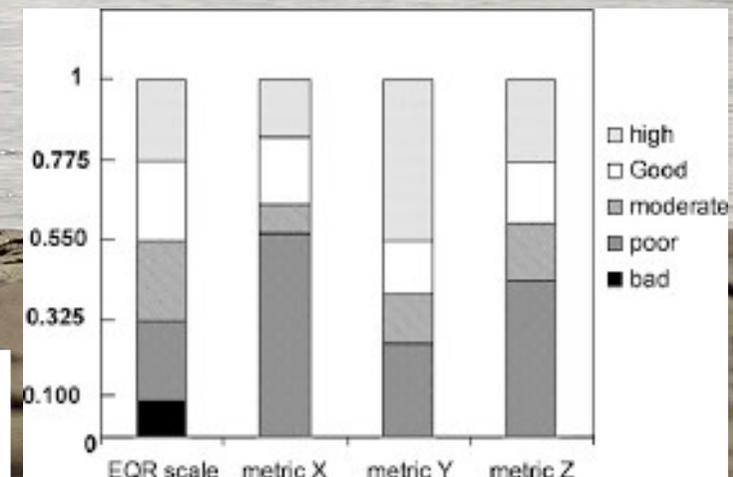
- Andersen *et al.* (2011) *Biogeochemistry* 106:137-156
- Andersen *et al.* (2017) *Biol. Rev.* 92:135-149.

# Ecological status assessment according to the European Water Framework Directive

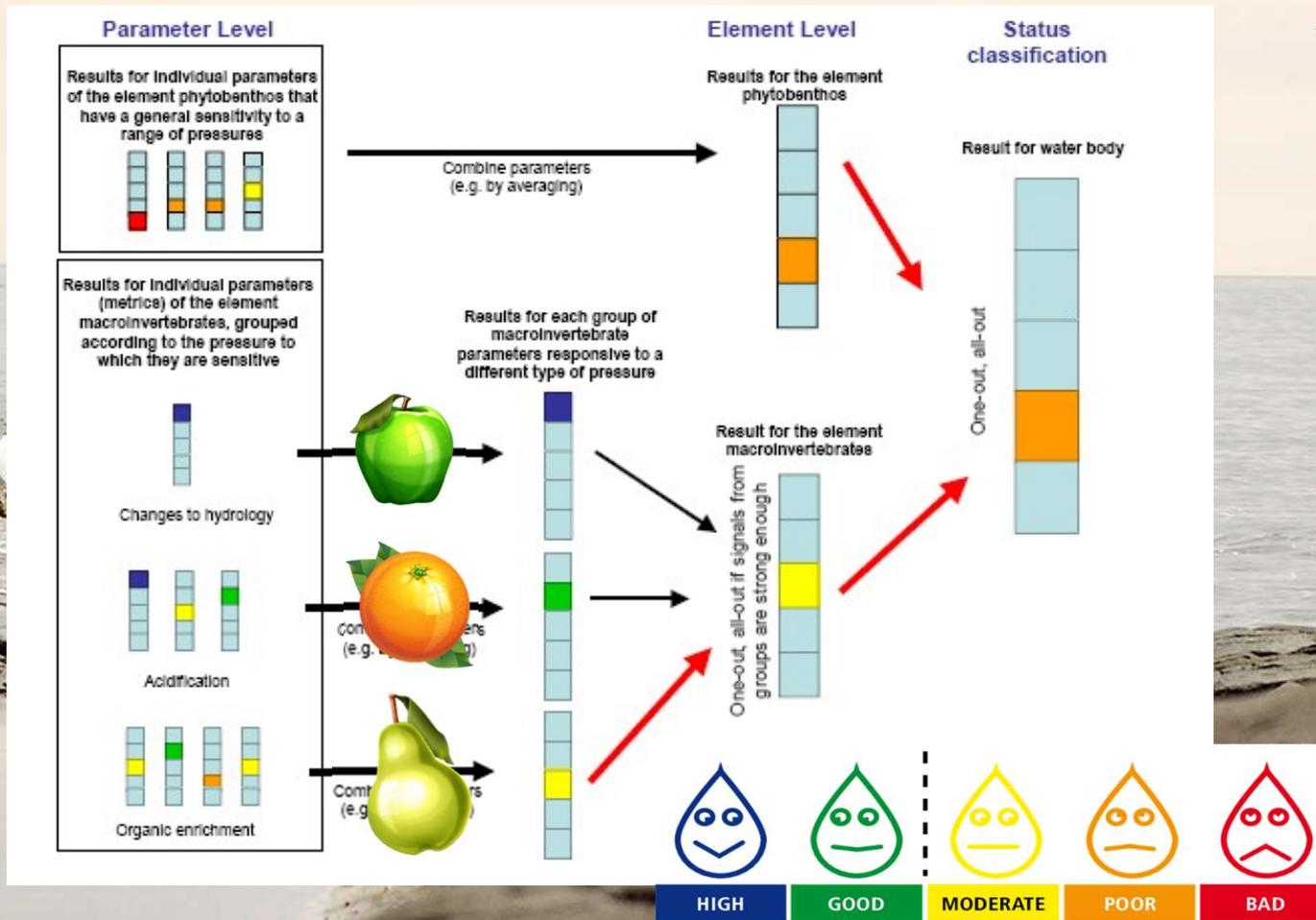


Within BQEs: metrics can be combined as seen appropriate

Between BQEs: 'one out-all out' principle

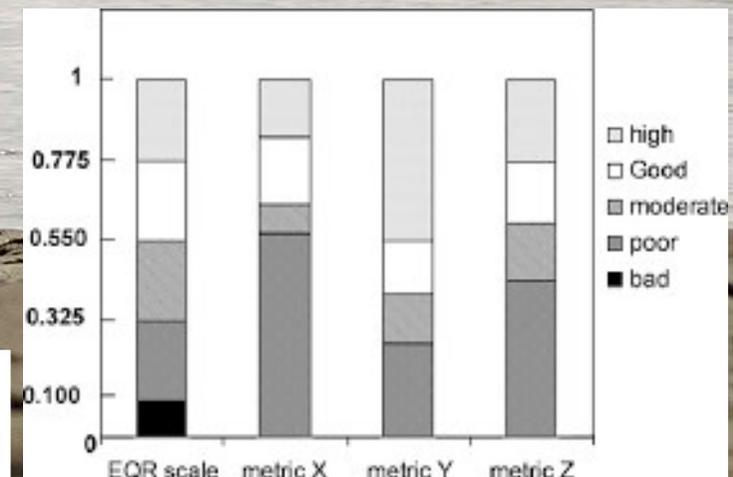


# Ecological status assessment according to the European Water Framework Directive



Within BQEs: metrics can be combined as seen appropriate

Between BQEs: 'one out-all out' principle



# Ecological status assessment according to the European Water Framework Directive

## Parameter Level

Results for individual parameters of the element phyto**ben**thos that have a general sensitivity to a range of pressures

Results for individual parameters (metrics) of the element macroinvertebrates, grouped according to the pressure to which they are sensitive

Changes to hydrology

Acidification

Organic enrichment

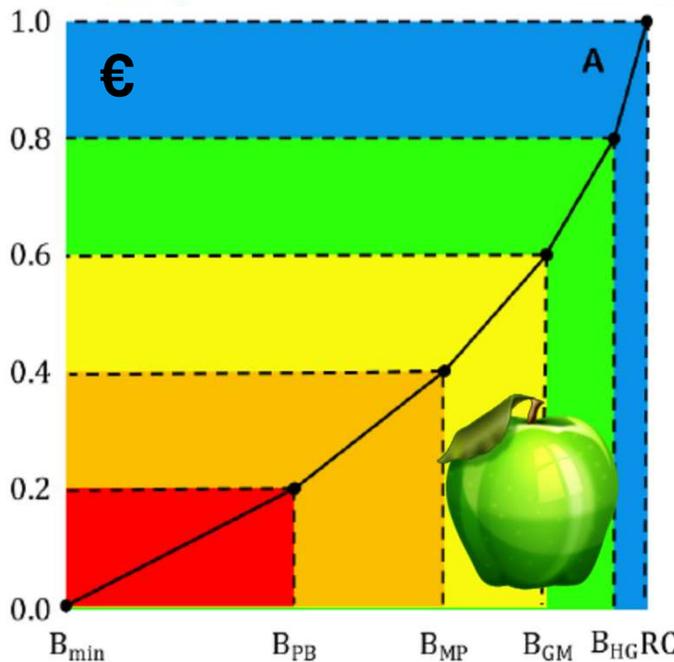
Combine parameters (e.g. by averaging)

## Element Level

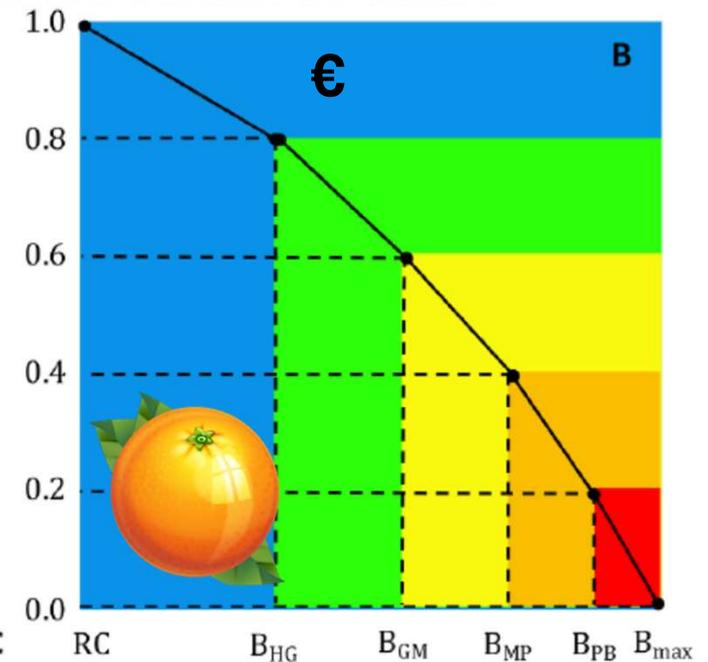
Results for the element phyto**ben**thos

## Status classification

Result for water body



Within BQEs: metrics can be combined as seen



Indicator scale

Carstensen et al. 2023, JEMA

# Uncertainty and confidence



# Confidence in ecological status assessment

Heuristic approaches

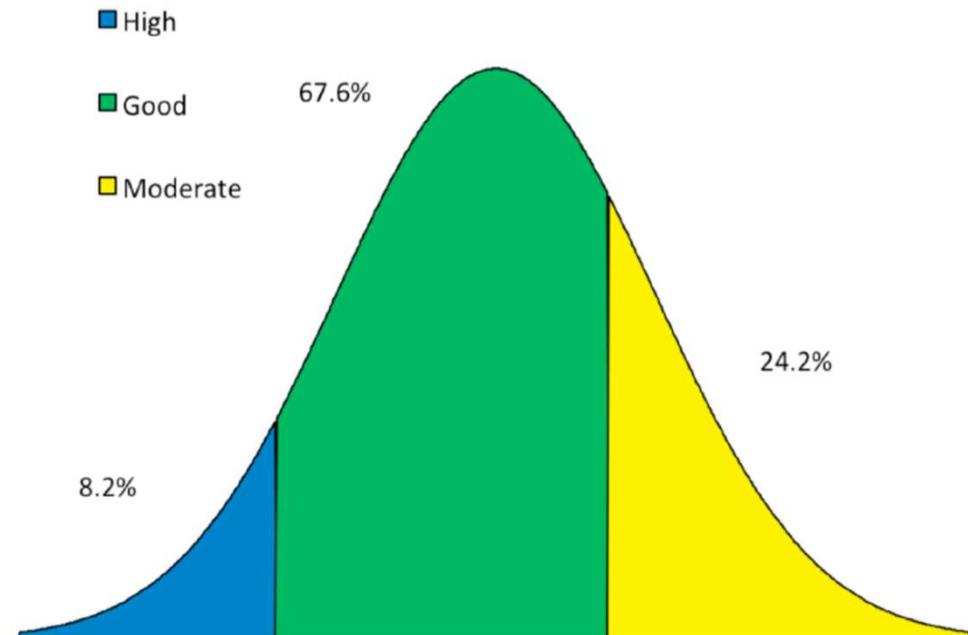


Approach founded in probabilistic theory

**Table 1**

Scoring matrix. A score of 3 indicates the best possible classification where a “High” quality rating has been assigned to RefCon, AcDev and to AcStat. A score of 9 indicates the worst possible classification, where all scores are rated “Low”. The indicator scores from 3 to 9 are converted to an indicator confidence rating ranging from 0 to 100%. The worst possible result is assigned a confidence score of 0% and the best possible score is equivalent to a confidence score of 100%. The confidence score for other combinations is arrived at by interpolating linearly.

Scores			$\Sigma$	Ind_conf
RefCon	AcDev	AcStat		
1	1	1	3	100%
1	1	2	4	83%
1	2	2	5	67%
2	2	2	6	50%
2	2	3	7	33%
2	3	3	8	17%
3	3	3	9	0%



# The transition from Excel to web-based tools

**The HELCOM Eutrophication Assessment Tool 3.0**

Sub-division/basin/water body/station:  please enter the name of assessment unit

Coordinates:  enter the coordinates in WGS 1984

**C1 Nutrient levels**

RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C1_EUT_sum	C1_EUT_status	C1_conf	C1_Weight
DN (Dec-Feb)		2.90	µM	+	H M L	3.75	H M L	1293	75 %	50%				
DIP (Dec-Feb)		0.25	µM	+	H M L	0.50	H M L	1992	75 %	50%				

**C2 Direct effects**

RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C2_EUT_sum	C2_EUT_status	C2_conf	C2_Weight	
Chlorophyll a (June-Sept)		1.65	µg/l	+	H M L	2.79	H M L	1692	75 %	50%	100%	1643	POOR	75 %	33%
Secchi depth (June-Sept)		7.10	m	-	H M L	5.50	H M L	1291	100 %	50%					

**C3 Indirect effects**

RefCon	AcDev	EUT_Target	Unit	Resp	EUT_T-score	EUT_status	EUT_S-score	EUT_Ratio	Ind_Conf	Weight	C3_EUT_sum	C3_EUT_status	C3_conf	C3_Weight
Oxygen debt		8.66	mg/l	+	H M L	10.54	H M L	1217	100 %	100%				

IMPORT data from XML

EXPORT data to XML

version 2009021



WATERS prototype Stockholm meeting v5.xlsm - Excel

ID	Waterbody	QE	QE Name	n	Status	Value	Bad	Poor	Mod	Good	High	<<Bad	<<Poor	<<Mod	<<Good	<<High
1	Inne Bråviken	1	Phytoplankton	2	0.532	Mod	0.0%	0.0%	80.0%	20.0%	0.0%	0.000	0.000	0.900	1.000	1.000
2	Inne Bråviken	2	SAV	2	0.493	Mod	0.0%	14.0%	84.0%	2.0%	0.0%	0.000	0.140	0.980	1.000	1.000
3	Inne Bråviken	3	Benthic Fauna	1	0.626	Good	14.0%	7.0%	14.0%	65.0%	0.0%	0.140	0.210	0.350	1.000	1.000
4	Inne Bråviken	4	Fish	2	0.372	Poor	0.0%	94.0%	6.0%	0.0%	0.0%	0.000	0.940	1.000	1.000	1.000
5	Inne Bråviken	5	Supporting elements	2	0.371	Poor	0.0%	71.0%	29.0%	0.0%	0.0%	0.000	0.710	1.000	1.000	1.000
6	Inne Slåtbaken	1	Phytoplankton	2	0.380	Poor	0.0%	77.0%	23.0%	0.0%	0.0%	0.000	0.770	1.000	1.000	1.000
7	Inne Slåtbaken	2	SAV	2	0.478	Mod	0.0%	13.0%	85.0%	2.0%	0.0%	0.000	0.130	0.980	1.000	1.000
8	Inne Slåtbaken	3	Benthic Fauna	1	0.800	Bad	72.0%	8.0%	10.0%	10.0%	0.0%	0.720	0.800	0.900	1.000	1.000
9	Inne Slåtbaken	4	Fish	2	0.304	Poor	0.0%	91.0%	9.0%	0.0%	0.0%	0.000	0.910	1.000	1.000	1.000
10	Inne Slåtbaken	5	Supporting elements	2	0.293	Poor	0.0%	100.0%	0.0%	0.0%	0.0%	0.000	1.000	1.000	1.000	1.000
11	Kaggebofjärden	1	Phytoplankton	2	0.462	Mod	0.0%	3.0%	96.0%	1.0%	0.0%	0.000	0.030	0.990	1.000	1.000
12	Kaggebofjärden	2	SAV	2	0.603	Good	0.0%	1.0%	48.0%	51.0%	0.0%	0.000	0.010	0.470	1.000	1.000
13	Kaggebofjärden	3	Benthic Fauna	1	0.532	Mod	19.0%	11.0%	27.0%	43.0%	0.0%	0.190	0.300	0.570	1.000	1.000
14	Kaggebofjärden	4	Fish	2	0.816	High	0.0%	0.0%	0.0%	27.0%	73.0%	0.000	0.000	0.000	0.270	1.000
15	Kaggebofjärden	5	Supporting elements	2	0.336	Poor	0.0%	93.0%	7.0%	0.0%	0.0%	0.000	0.930	1.000	1.000	1.000
16	Yttre Bråviken	1	Phytoplankton	2	0.524	Mod	0.0%	0.0%	87.0%	12.0%	1.0%	0.000	0.000	0.870	0.990	1.000
17	Yttre Bråviken	2	SAV	2	0.751	Good	0.0%	0.0%	6.0%	88.0%	12.0%	0.000	0.000	0.000	0.880	1.000
18	Yttre Bråviken	3	Benthic Fauna	1	0.677	Good	1.0%	1.0%	4.0%	92.0%	2.0%	0.010	0.020	0.060	0.980	1.000
19	Yttre Bråviken	4	Fish	2	0.307	Poor	0.0%	74.0%	18.0%	8.0%	0.0%	0.000	0.740	0.920	1.000	1.000
20	Yttre Bråviken	5	Supporting elements	2	0.473	Mod	0.0%	7.0%	84.0%	9.0%	0.0%	0.000	0.070	0.910	1.000	1.000
21	Trännöfjärden	1	Phytoplankton	2	0.472	Mod	0.0%	0.0%	98.0%	2.0%	0.0%	0.000	0.000	0.980	1.000	1.000
22	Trännöfjärden	2	SAV	2	0.672	Good	0.0%	0.0%	6.0%	93.0%	1.0%	0.000	0.000	0.060	0.990	1.000
23	Trännöfjärden	3	Benthic Fauna	1	0.148	Bad	57.0%	17.0%	18.0%	8.0%	0.0%	0.570	0.740	0.920	1.000	1.000
24	Trännöfjärden	4	Fish	2	0.744	Good	0.0%	0.0%	0.0%	95.0%	5.0%	0.000	0.000	0.000	0.950	1.000
25	Trännöfjärden	5	Supporting elements	2	0.322	Poor	0.0%	98.0%	2.0%	0.0%	0.0%	0.000	0.980	1.000	1.000	1.000
26	Lindödjupet	1	Phytoplankton	2	0.447	Mod	0.0%	8.0%	91.0%	1.0%	0.0%	0.000	0.080	0.990	1.000	1.000
27	Lindödjupet	2	SAV	2	0.710	Good	0.0%	0.0%	5.0%	89.0%	6.0%	0.000	0.000	0.050	0.940	1.000
28	Lindödjupet	3	Benthic Fauna	1	0.546	Mod	19.0%	6.0%	29.0%	46.0%	0.0%	0.190	0.250	0.540	1.000	1.000
29	Lindödjupet	4	Fish	2	0.749	Good	0.0%	0.0%	3.0%	73.0%	24.0%	0.000	0.000	0.030	0.760	1.000
30	Lindödjupet	5	Supporting elements	2	0.348	Poor	0.0%	87.0%	13.0%	0.0%	0.0%	0.000	0.870	1.000	1.000	1.000
31	Kärrfjärden	1	Phytoplankton	2	0.445	Mod	0.0%	10.0%	90.0%	0.0%	0.0%	0.000	0.100	1.000	1.000	1.000
32	Kärrfjärden	2	SAV	2	0.810	High	0.0%	0.0%	0.0%	37.0%	63.0%	0.000	0.000	0.000	0.370	1.000
33	Kärrfjärden	3	Benthic Fauna	1	0.603	Good	11.0%	9.0%	27.0%	53.0%	0.0%	0.110	0.200	0.470	1.000	1.000
34	Kärrfjärden	4	Fish	2	0.750	Good	0.0%	0.0%	0.0%	98.0%	2.0%	0.000	0.000	0.000	0.980	1.000

# The transition from Excel to web-based tools

**The HELCOM Eutrophication Assessment Tool 3.0**

Sub-division/basin/water body/station: ... please enter the name of assessment unit

C1: Nutrient levels

RefCon	AcDev	EUT_Target	Unit
		2.90	µM
		0.25	µM

C2: Direct effects

RefCon	AcDev	EUT_Target	Unit
		1.65	µg/l
		7.10	m

C3: Indirect effects

RefCon	AcDev	EUT_Target	Unit
		8.66	mg/l

IMPORT data from XML

EXPORT data to XML

version 2010031

**DEVOTool - DEVOTES WP3 indicator catalogue**

all indicators

Indicator name: Abundance of bioengineering species

Code: AZTI-JGR 279

Identification

Original name: density of structure-forming species

Contributor code: AZTI-JGR 279

RSC affiliation: UHULL-KM 183

Last modification: 14.12.2013 12:49:54

Description

Indicator description: Abundance of bioengineering species measured as number, cover or density per spatial unit

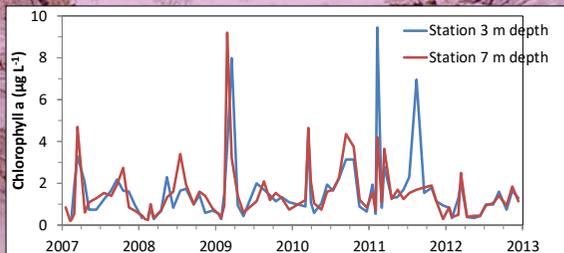
Data requirements: Abundance and cover data

Collection method: Costs

Location	Indicator	Value	Quality	Metric 1	Metric 2	Metric 3	Metric 4	Metric 5	Metric 6	Metric 7	Metric 8	Metric 9	Metric 10
5 Trännöfjärden	4 Fish	2 @ 0.744	Good	0.0%	0.0%	0.0%	95.0%	5.0%	0.000	0.000	0.000	0.950	1.000
5 Trännöfjärden	5 Supporting elements	2 @ 0.322	Poor	0.0%	98.0%	2.0%	0.0%	0.0%	0.000	0.980	1.000	1.000	1.000
6 Lindödjupet	1 Phytoplankton	2 @ 0.447	Mod	0.0%	8.0%	91.0%	1.0%	0.0%	0.000	0.080	0.990	1.000	1.000
6 Lindödjupet	2 SAV	2 @ 0.710	Good	0.0%	0.0%	5.0%	89.0%	6.0%	0.000	0.000	0.050	0.940	1.000
6 Lindödjupet	3 Benthic Fauna	1 @ 0.546	Mod	19.0%	6.0%	29.0%	46.0%	0.0%	0.190	0.250	0.540	1.000	1.000
6 Lindödjupet	4 Fish	2 @ 0.749	Good	0.0%	0.0%	3.0%	73.0%	24.0%	0.000	0.000	0.030	0.760	1.000
6 Lindödjupet	5 Supporting elements	2 @ 0.348	Poor	0.0%	87.0%	13.0%	0.0%	0.0%	0.000	0.870	1.000	1.000	1.000
7 Kärrfjärden	1 Phytoplankton	2 @ 0.445	Mod	0.0%	10.0%	90.0%	0.0%	0.0%	0.000	0.100	1.000	1.000	1.000
7 Kärrfjärden	2 SAV	2 @ 0.810	High	0.0%	0.0%	0.0%	37.0%	63.0%	0.000	0.000	0.000	0.370	1.000
7 Kärrfjärden	3 Benthic Fauna	1 @ 0.603	Good	11.0%	9.0%	27.0%	53.0%	0.0%	0.110	0.200	0.470	1.000	1.000
7 Kärrfjärden	4 Fish	2 @ 0.750	Good	0.0%	0.0%	0.0%	98.0%	2.0%	0.000	0.000	0.000	0.980	1.000

# The transition from Excel to web-based tools

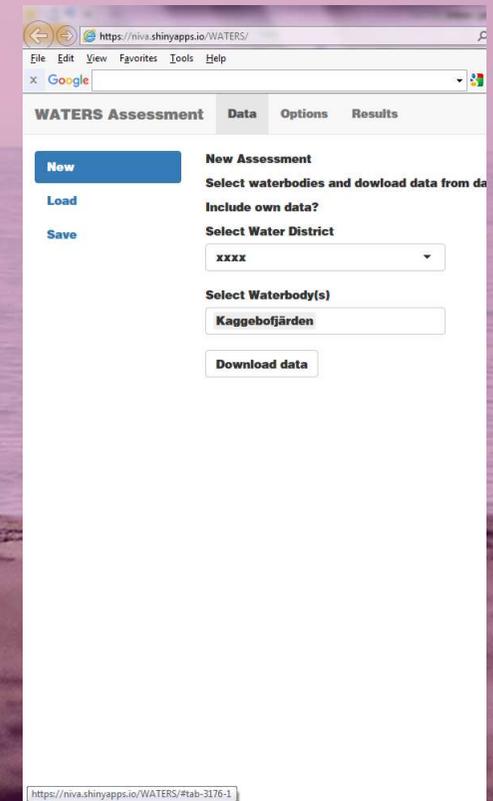
## Övervaknings-databas



## R-package för indikatorberäkning



## Sammanvägningsverktyg



# An online tool for the user making the WFD status assessment

- Downloading data from national hosts (SLU, SMHI)
- Configuration files for boundaries, uncertainty library, water bodies, default indicators, other parameters
- Interactive selection of indicators

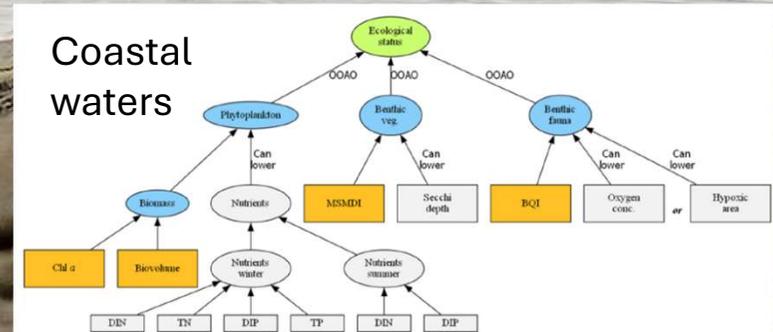
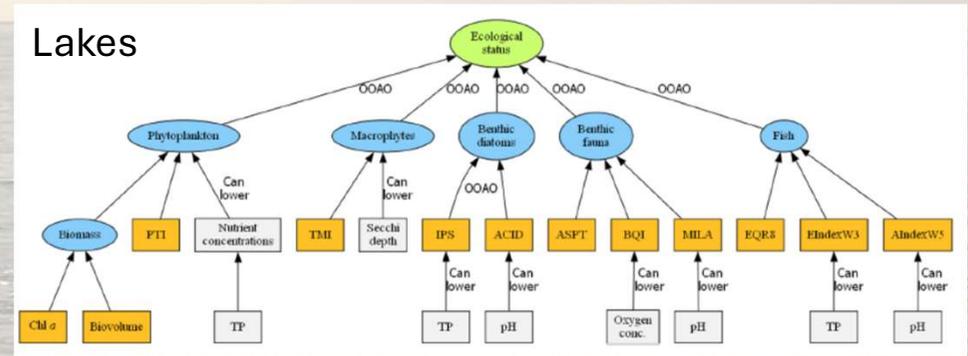
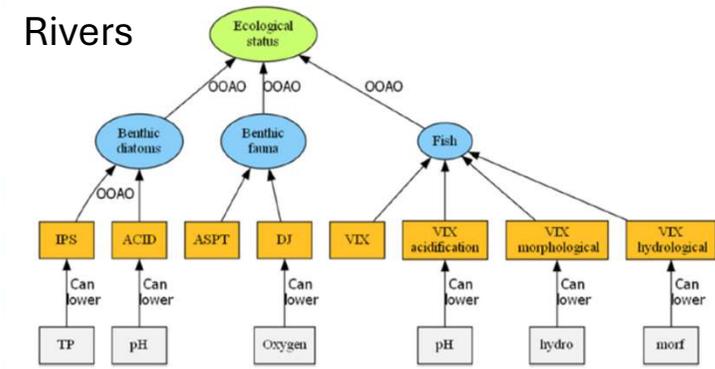
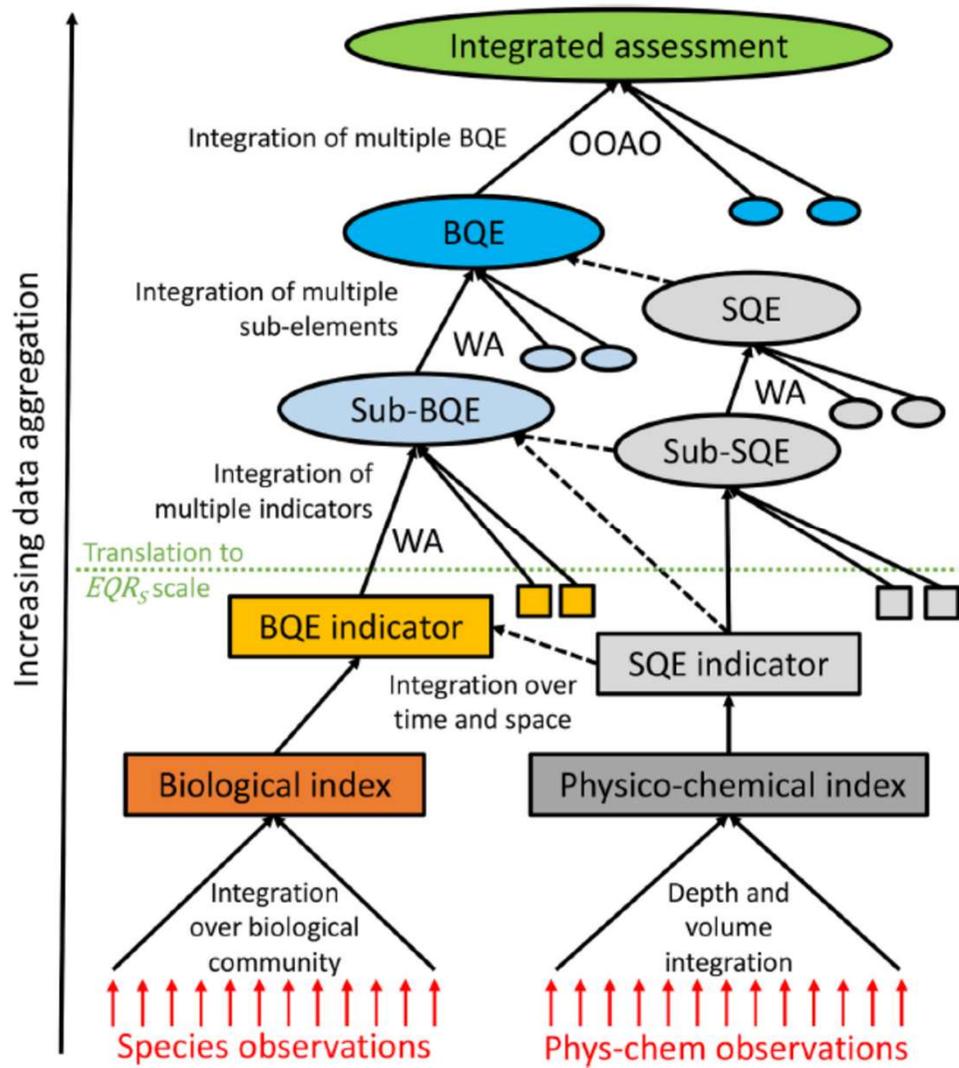
The screenshot displays the WATERS web application interface. The top navigation bar includes 'WATERS', 'Waterbodies', 'Get Indicators', 'Get Status', and 'Download'. The main content area is divided into several sections:

- WB:** WA46670058 - Gullmars centralbassån
- Period:** 2019-2024
- WA46670058 - Gullmars centralbassån [2019-2024] - Aggregation**: A tree diagram showing the hierarchy of indicators. The root is 'Ecological Status', which branches into 'Phytoplankton' and 'Benthic fauna'. 'Phytoplankton' further branches into 'Biomass' and 'Nutrients'. 'Benthic fauna' branches into 'BQI' and 'Oxygen'. 'BQI' branches into 'BQI (>20m)' and 'Hypoxic Area (%)'. 'Oxygen' branches into 'Oxygen Conc.' and 'Secchi depth'. 'Nutrients' branches into 'Nutrients Winter' and 'Nutrients Summer'. 'Nutrients Winter' branches into 'DIN Winter', 'TN Winter', 'DIP Winter', and 'TP Winter'. 'Nutrients Summer' branches into 'TN Summer' and 'TP Summer'.
- WA46670058 - Gullmars centralbassån [2019-2024] - Indicator Results**: A table showing the results for various indicators.

Indicator	EQR	Mean	Unit	RefCondAvg	pGES	Classes
Ecological Status	0.670				0.707	
> Phytoplankton	0.738				1.000	
>> Biomass	0.938				1.000	
>>> Chlorophyll a	0.875	1.496	µg/l	1.900	0.979	
>>> Biovolume	1.000	0.027	mm3/l	1.350	1.000	
>> Nutrients	0.773				0.998	
>>> Nutrients Winter	0.943				1.000	
>>>> Dissolved Inorganic Nitrogen Winter	1.000	7.815	µmol/l	6.000	1.000	
>>>> Total Nitrogen Winter	1.000	19.108	µmol/l	19.000	0.999	
>>>> Dissolved Inorganic Phosphorus Winter	1.000	0.427	µmol/l	0.500	1.000	
>>>> Total Phosphorus Winter	0.773	0.857	µmol/l	0.700	0.705	

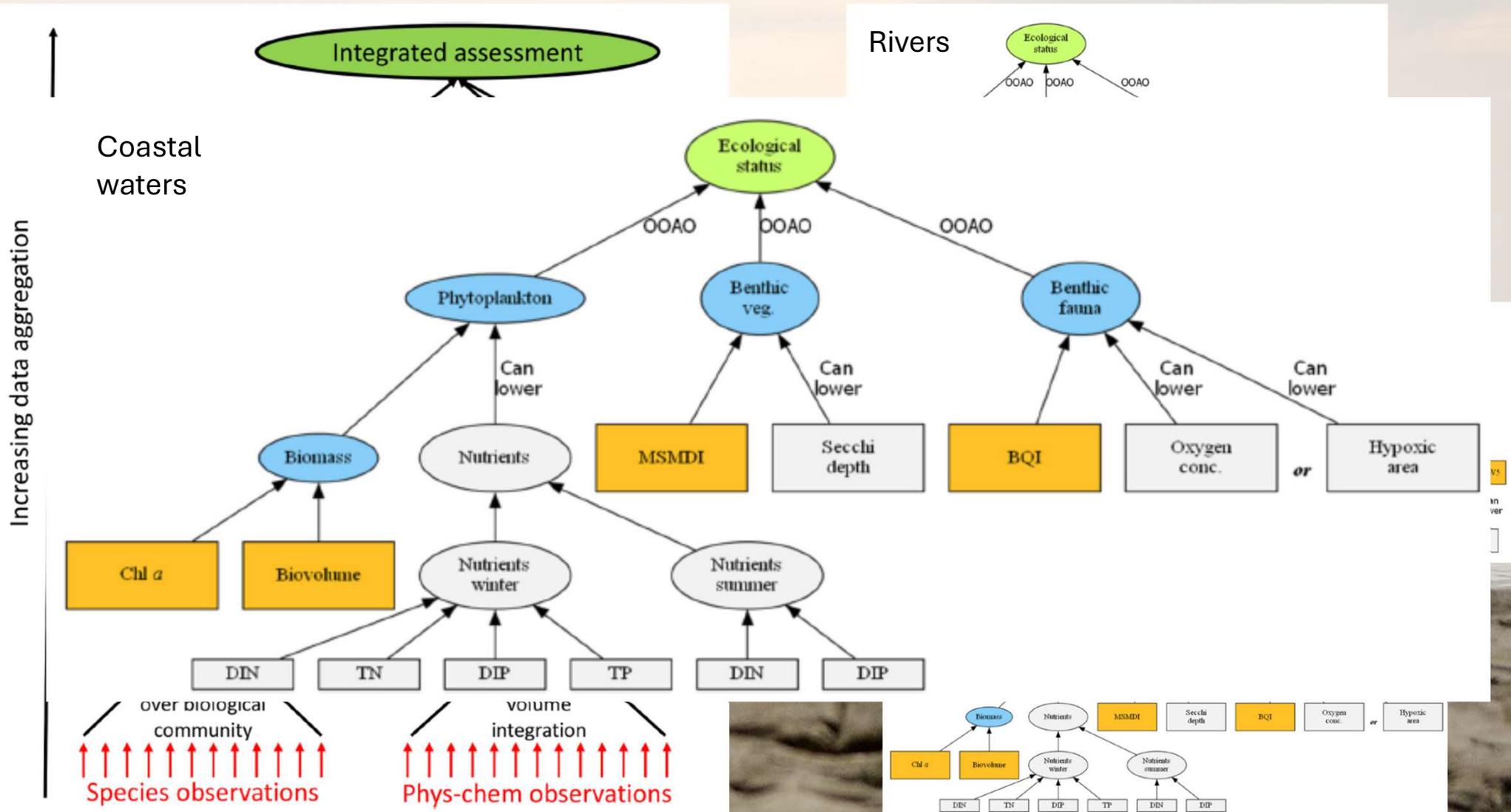
# From observations to ecological status

Carstensen et al. 2023, JEMA

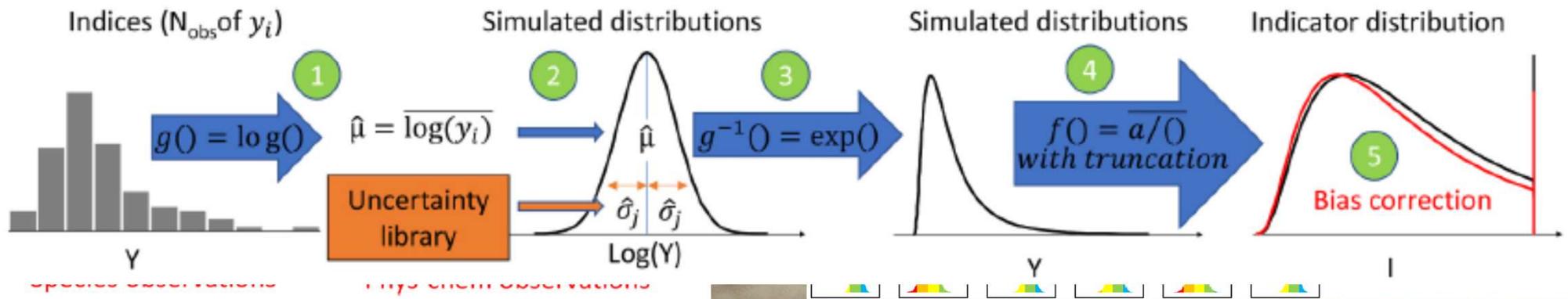
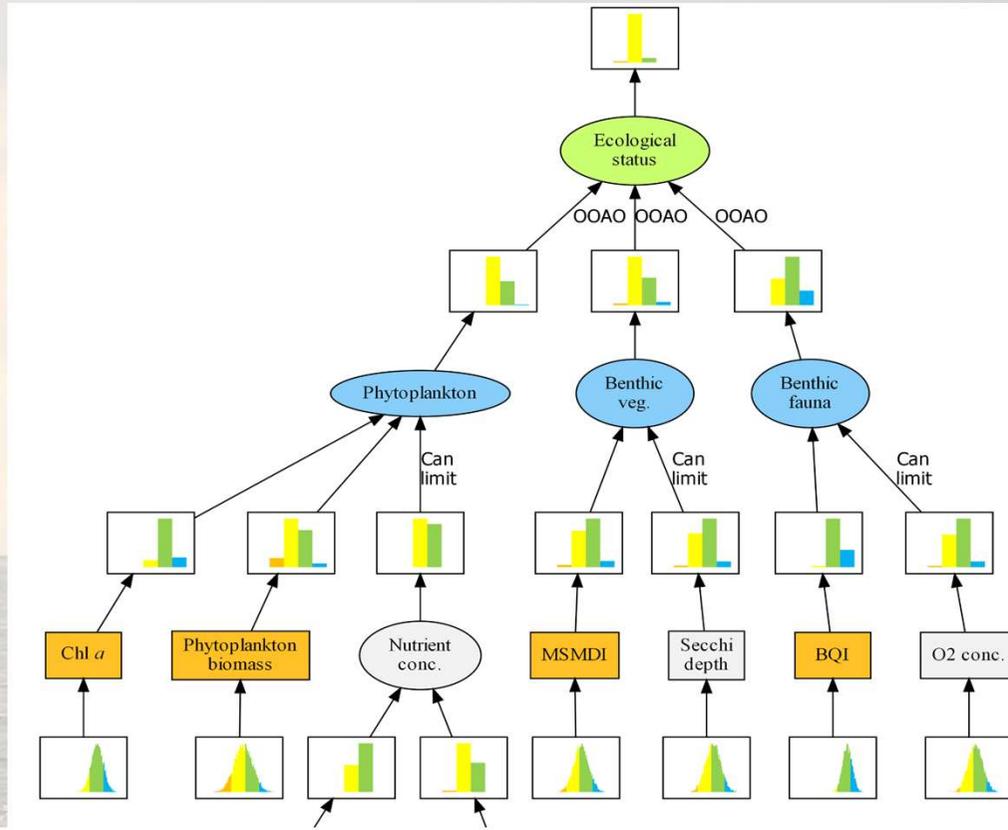
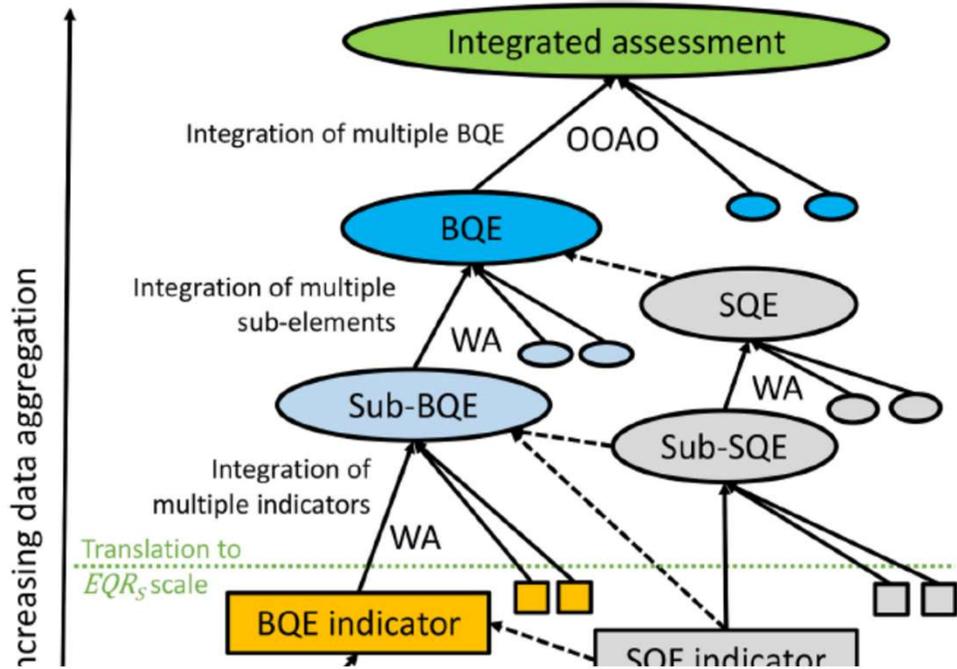


# From observations to ecological status

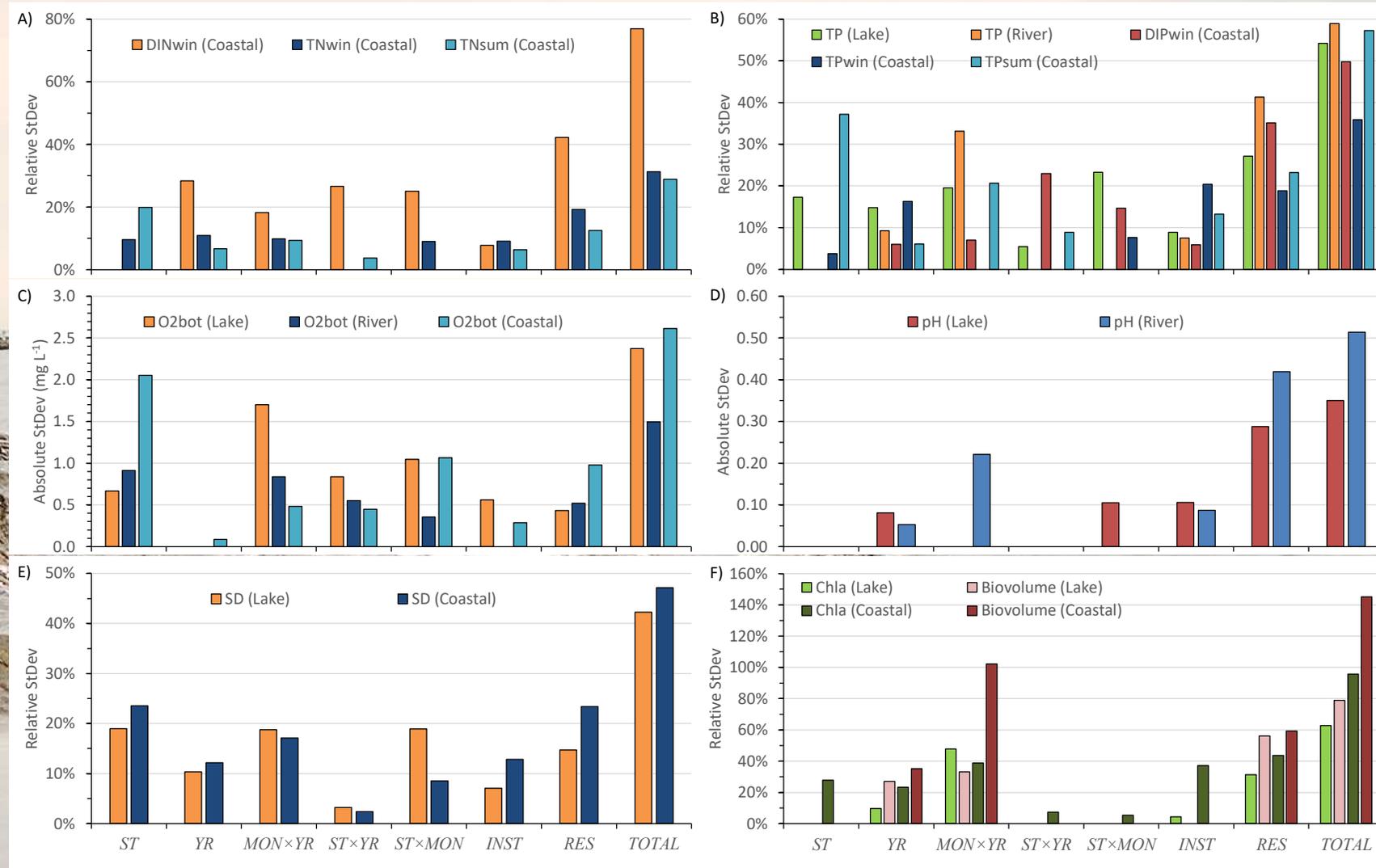
Carstensen et al. 2023, JEMA



# Confidence assessment

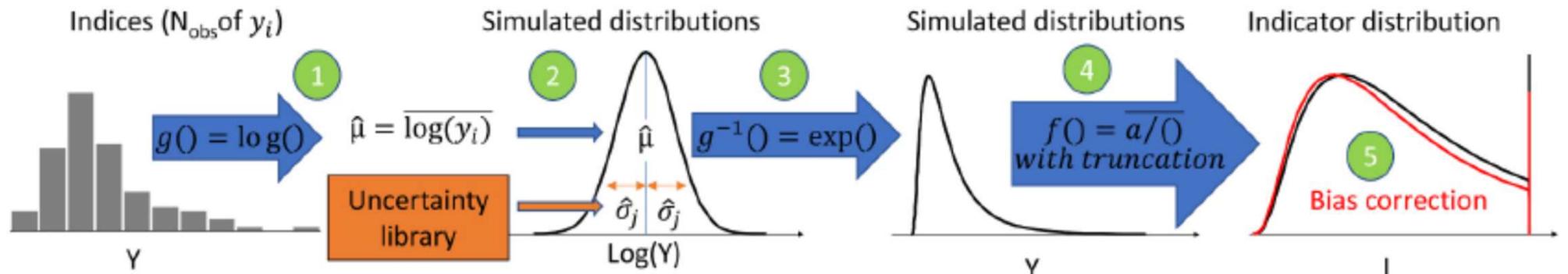
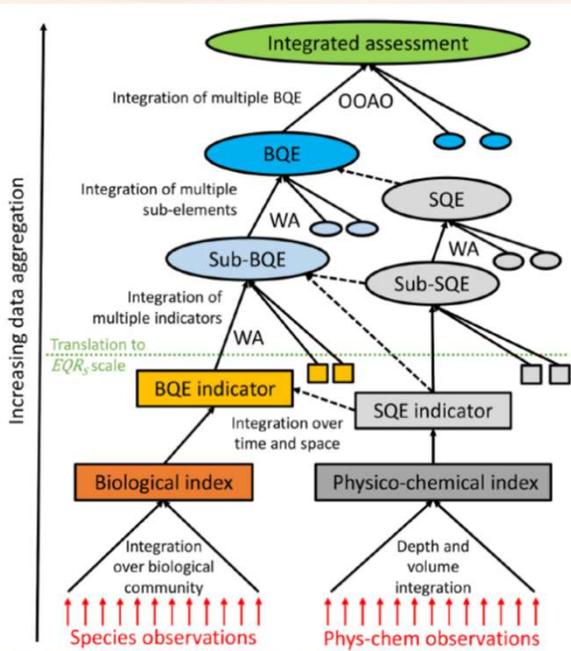
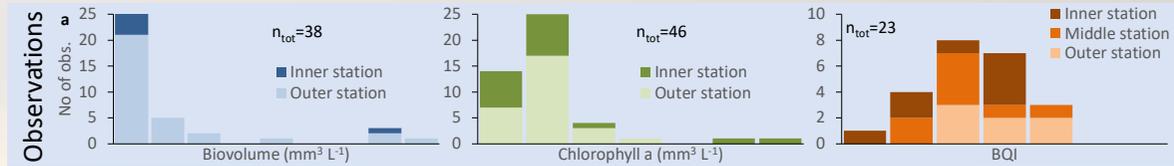


# Getting the errors right: Uncertainty library

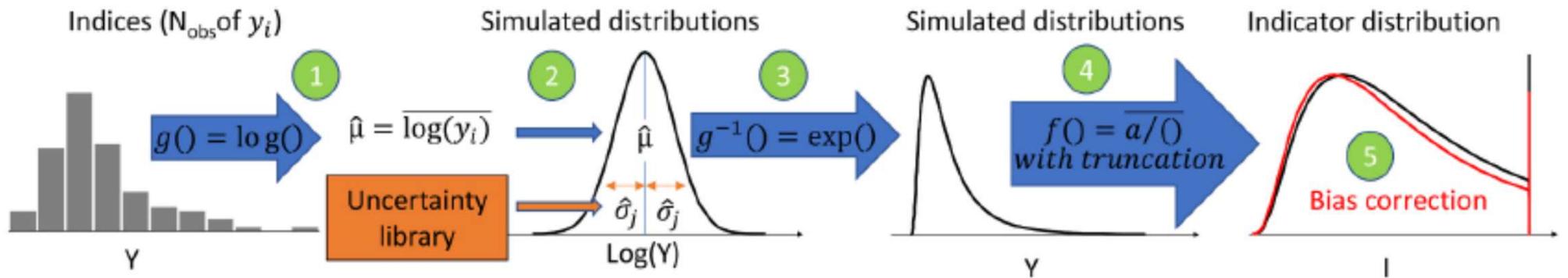
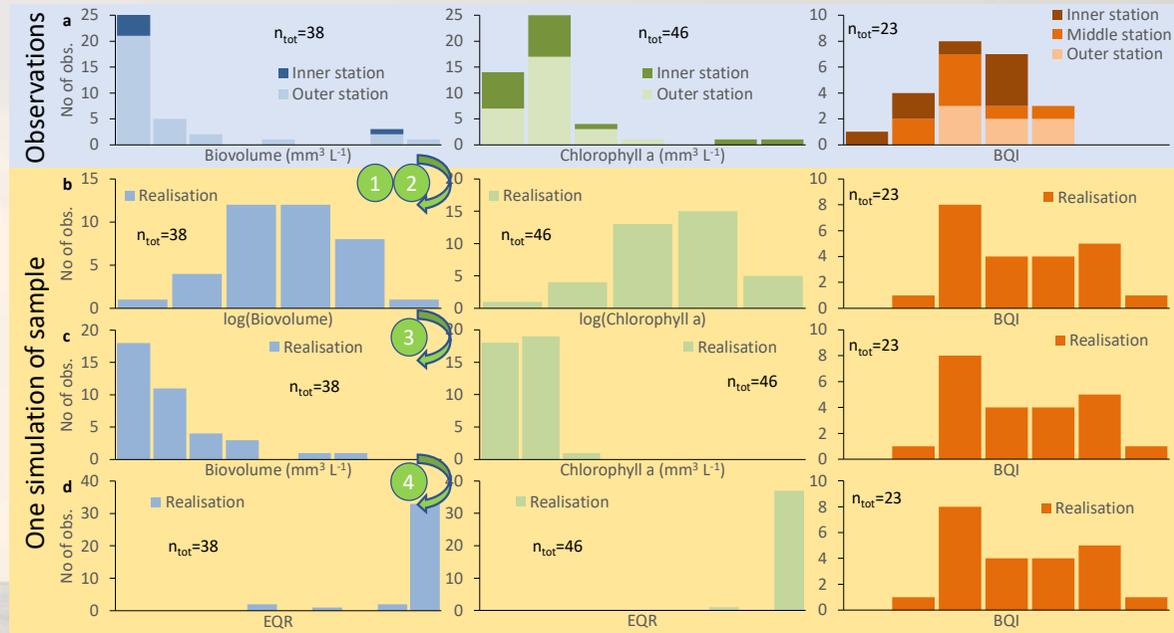
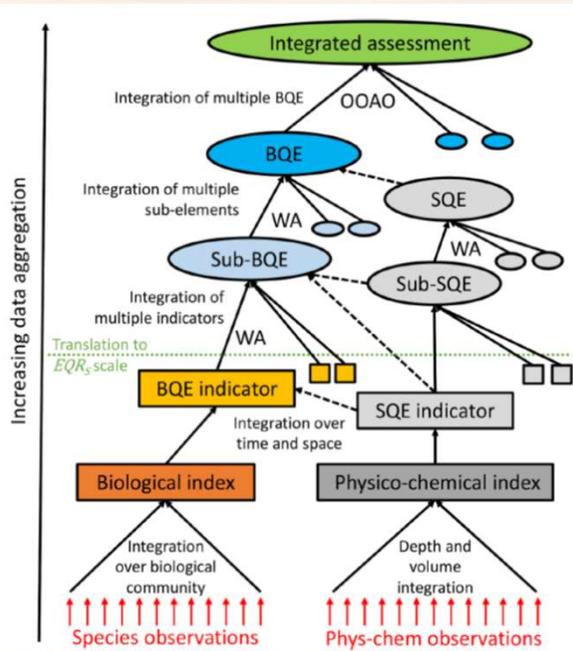


- Incorrect partitioning of error sources underestimates total uncertainty
- Sampling distribution in time, space and across institutions influence indicator uncertainty

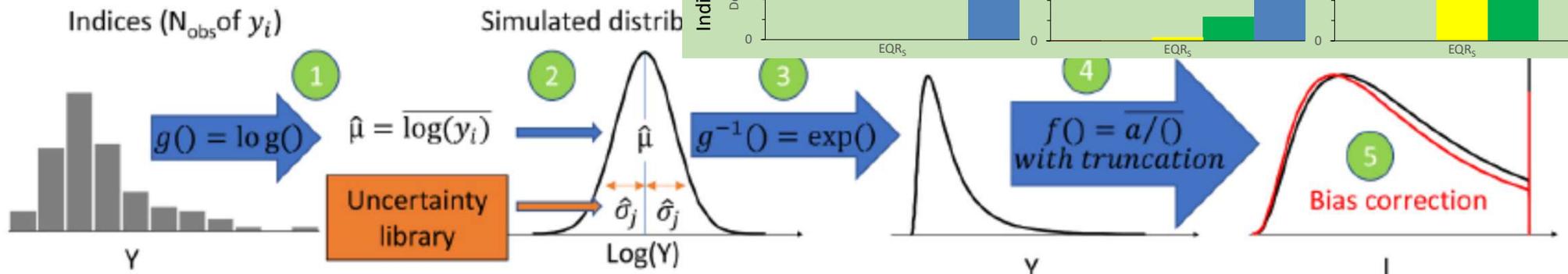
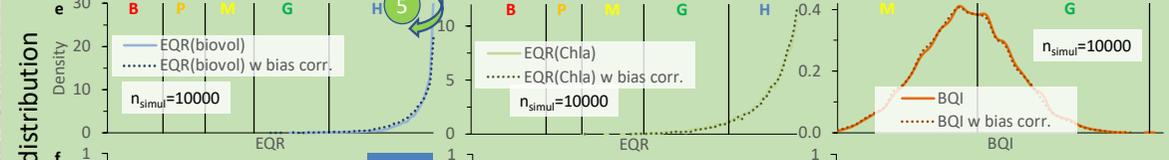
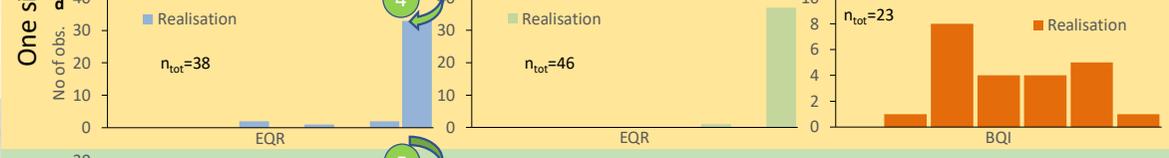
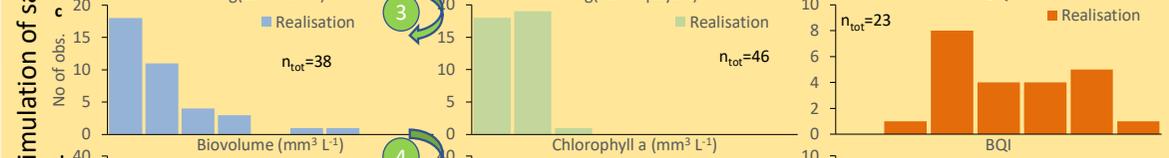
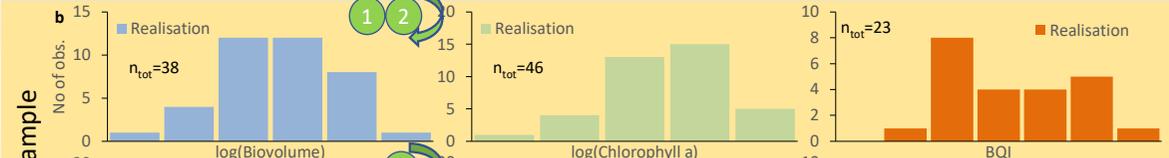
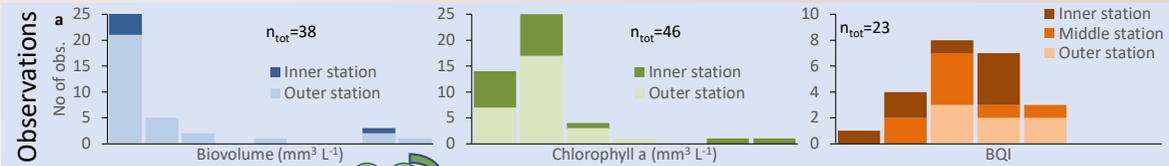
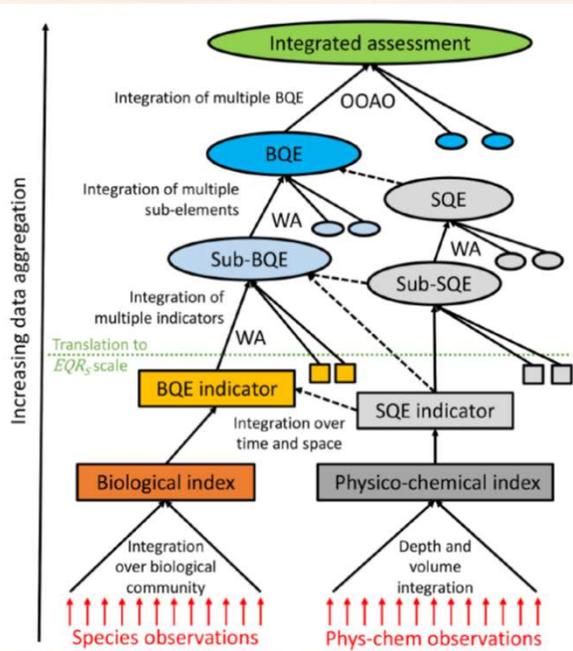
# How does it work in practice?



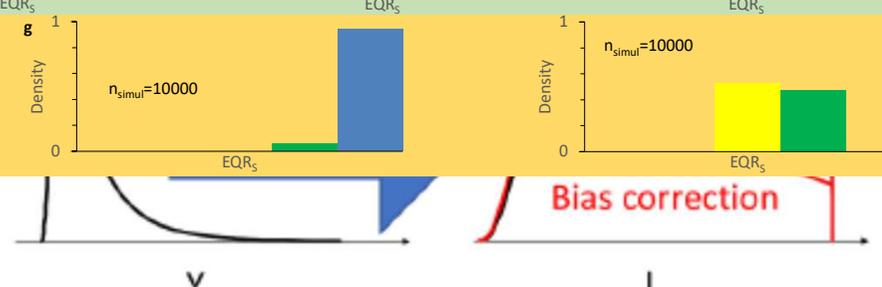
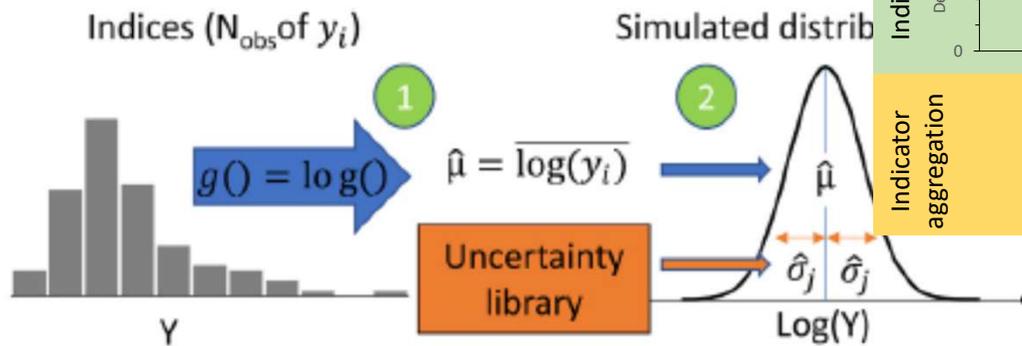
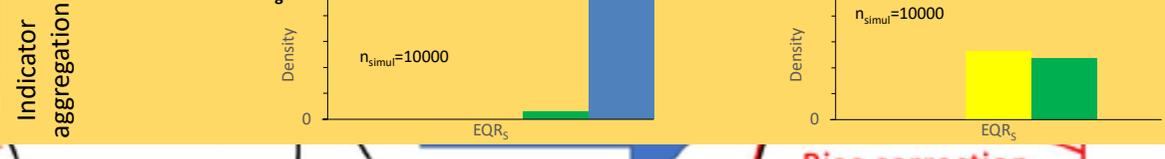
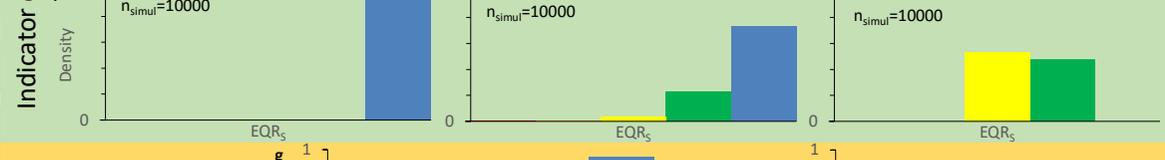
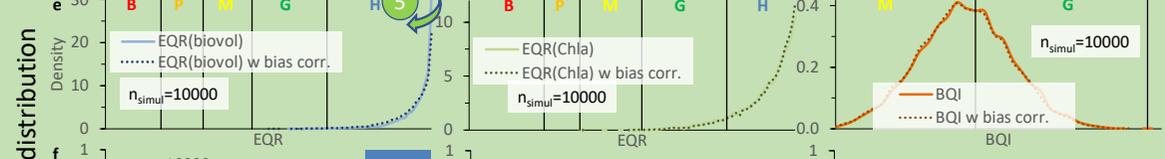
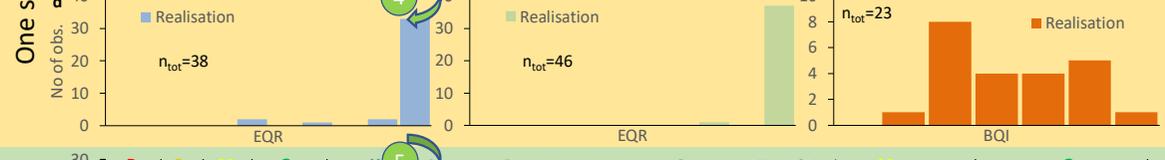
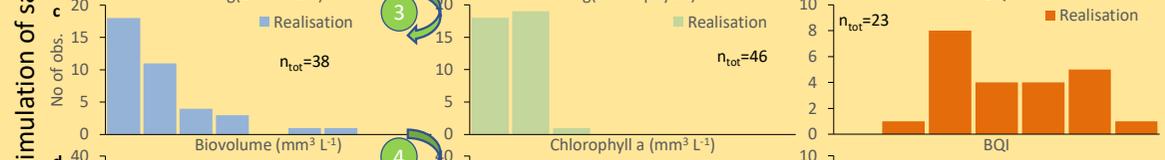
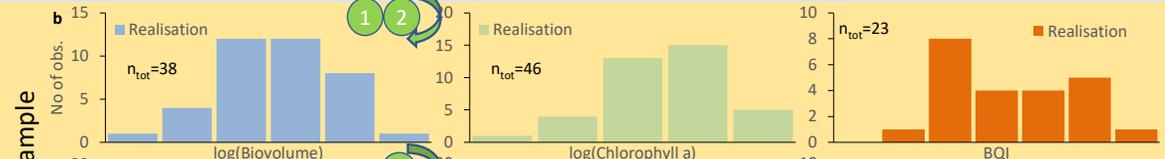
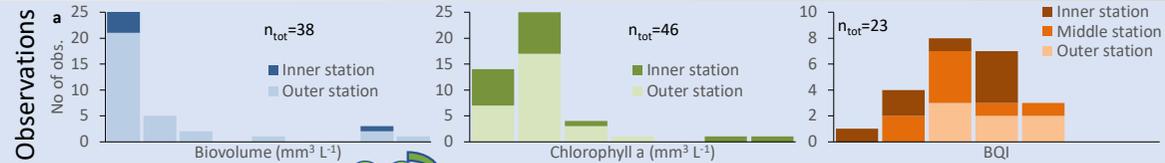
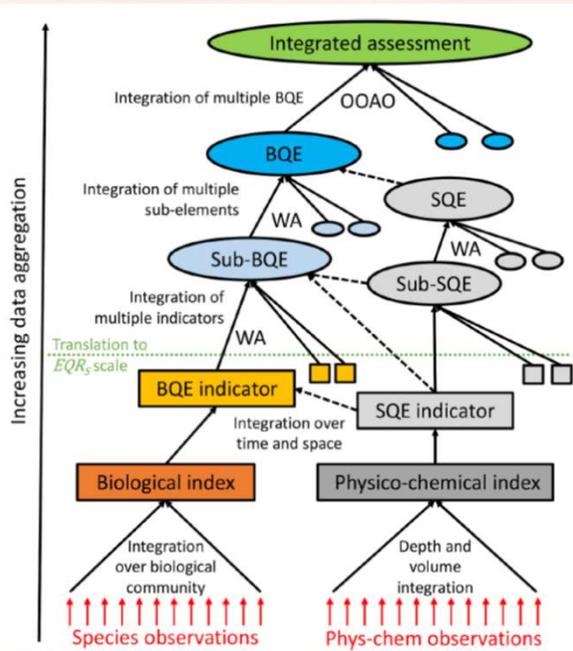
# How does it work in practice?



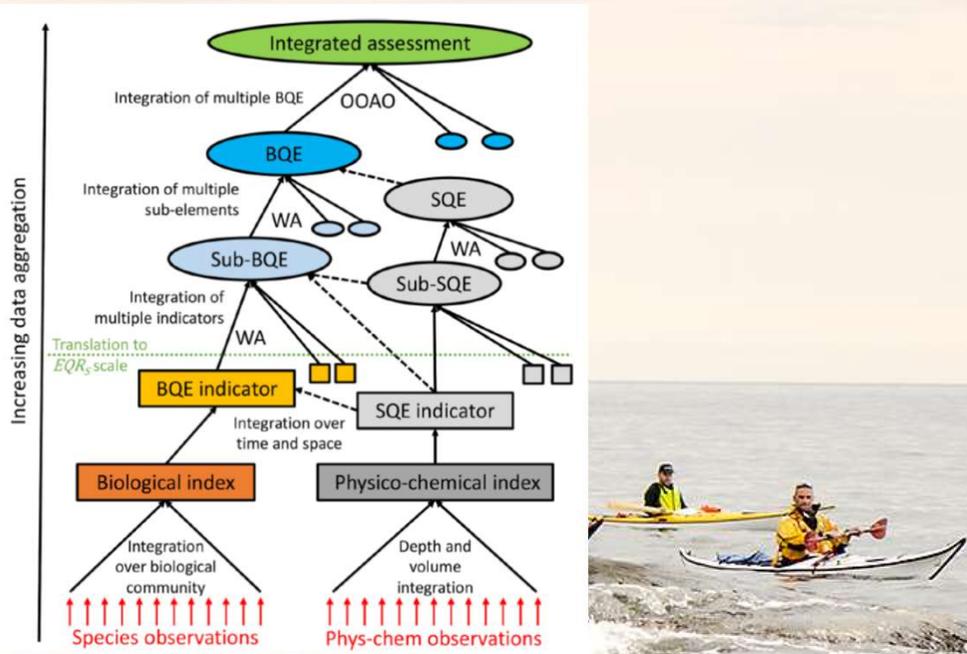
# How does it work in practice?



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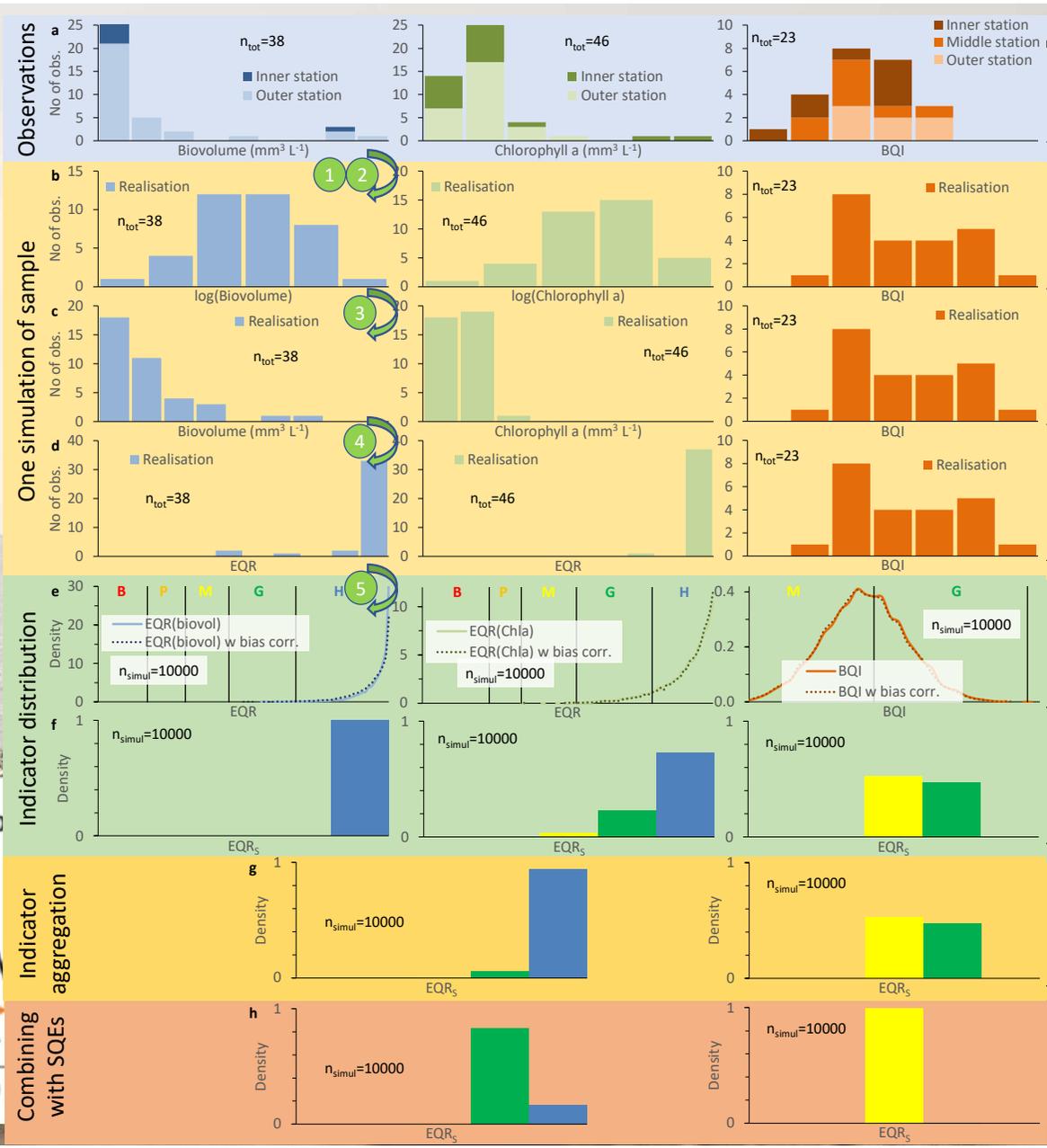
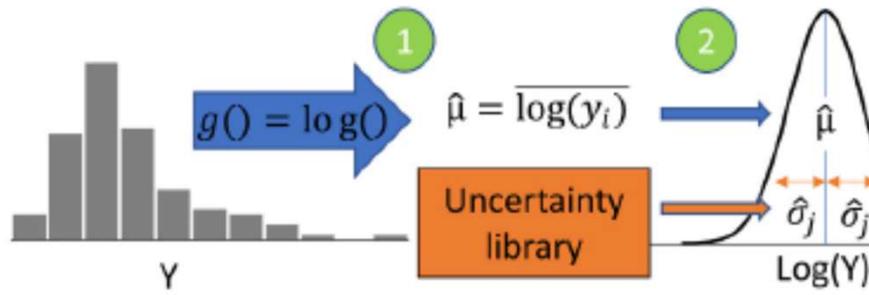


# How does it work in practice?

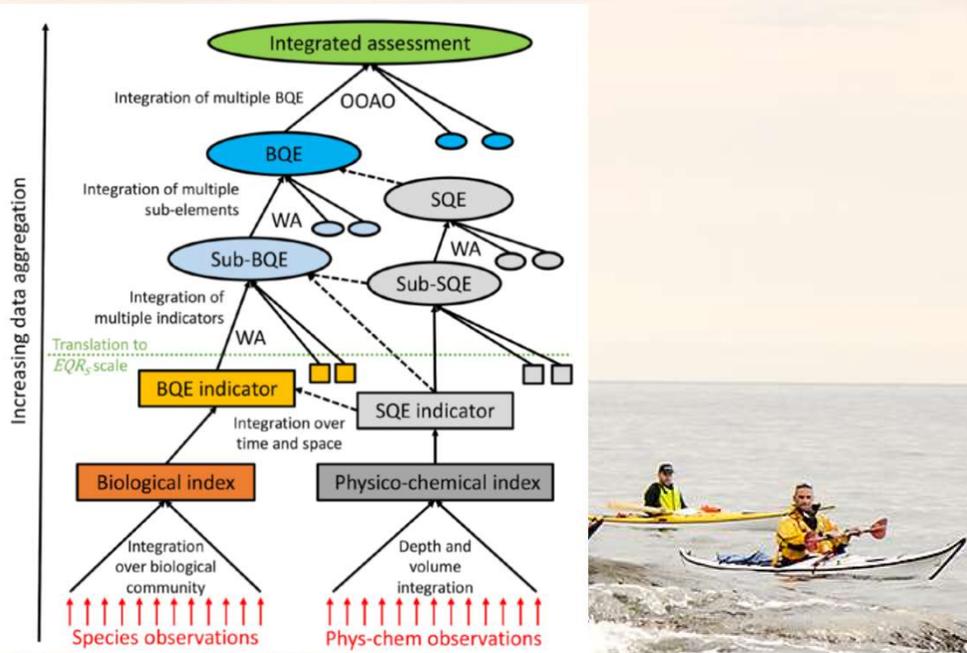


Indices ( $N_{obs}$  of  $y_i$ )

Simulated distrib

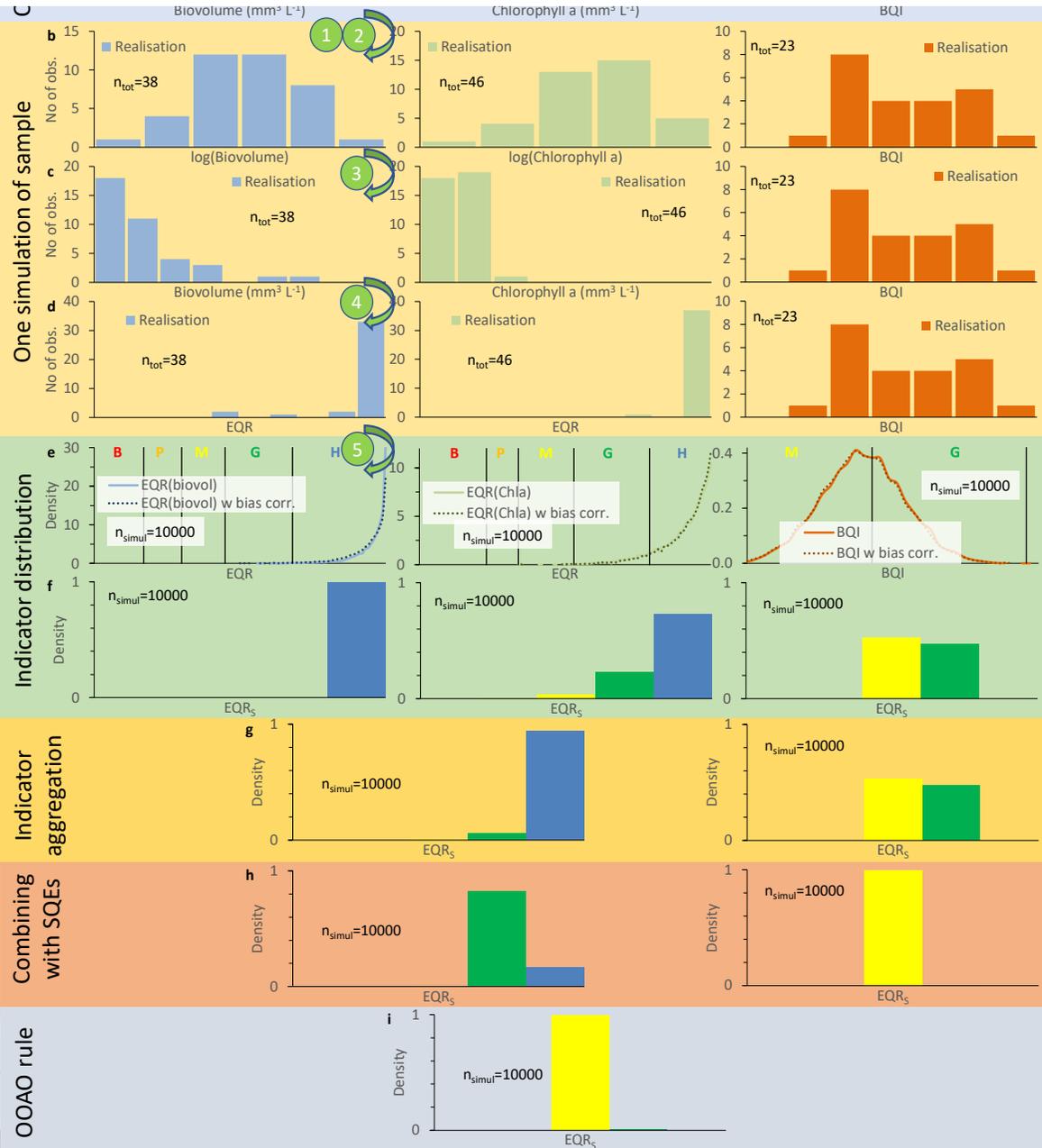
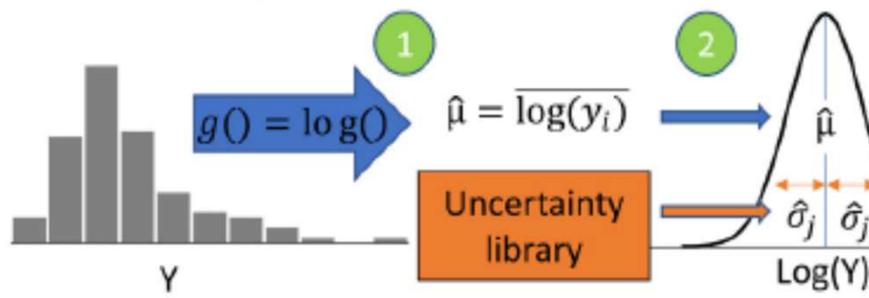


# How does it work in practice?



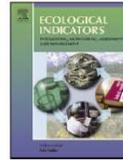
Indices ( $N_{obs}$  of  $y_i$ )

Simulated distrib



# Conclusions

- Integrated assessment systems have developed over time
  - Better integration of metrics
  - Incorporation of a probabilistic uncertainty framework
- Combining diverse indicators can be done through a standardized EQR-transformation
- Integrated assessment should consider indicator distributions (and not just values) to be able to assess the confidence
- Confidence and uncertainty assessment can be parameters through a general uncertainty framework and library
- This framework can handle all possible aggregation schemes through Monte Carlo simulations
- Such frameworks should be developed as web-applications for the user



## Confidence in ecological indicators: A framework for quantifying uncertainty components from monitoring data

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<sup>b</sup> Department of Biology and Environmental Science, Gothenburg University, SE-45296 Strömstad, Sweden



### Original Articles

## Getting the errors right: The importance of partitioning sources of uncertainty for ecological indicators

Jacob Carstensen<sup>a,\*</sup>, Ciarán J. Murray<sup>b</sup>, Mats Lindegarth<sup>c</sup>

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### Research article

## Mixing apples and oranges: Assessing ecological status and its confidence from multiple and diverse indicators

Jacob Carstensen<sup>a,\*</sup>, Ciaran Murray<sup>b</sup>, Mats Lindegarth<sup>c,d</sup>

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