# Disclosing the truth:
## Are models better than observations?

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# Disclosing the truth: are models better than observations?

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ABSTRACT: *All models are wrong, but some models are useful.* This aphorism is attributed to George Box (1976) about statistical models but is now used for scientific models in general. When presenting results from a marine simulation model, this effectively stops discussions on the quality of your model, as there is always another observation to mismatch, and thereby another confirmation why your model can not be trusted. It is common that observations are less challenged and are often viewed as a 'gold standard' for judging models, whereas proper interpretations and the true value of models are often overlooked. Models are not perfect, and there are many examples where models improperly are used to provide misleading answers with great confidence. But, to what extent does an observation represent the truth? The precision of the observational gear may be high, but what about representativeness? Isn't the interpretation of the observations just another model, but this time not coded in a computer language but formed by the individual observer? We submit that it would be more productive to initiate a process where the norm is that models and observations are joined to strengthen both. In the end neither is the goal, but only useful tools for disclosing truth. Biased views on either observational or modeling approaches would limit us from achieving this goal.

# Disclosing the **truth:**

## are **models** better than **observations?**

# Axioms of Algebra

**An *Axiom* is a mathematical statement that is assumed to be true. There are five basic axioms of algebra. The axioms are the reflexive axiom, symmetric axiom, transitive axiom, additive axiom and multiplicative axiom.**

***Reflexive Axiom:*** **A number is equal to itelf. (e.g a = a). This is the first axiom of equality. It follows Euclid's Common Notion One: "Things equal to the same thing are equal to each other."**

***Symmetric Axiom:*** **Numbers are symmetric around the equals sign. If a = b then b = a. This is the second axiom of equality It follows Euclid's Common Notion One: "Things equal to the same thing are equal to each other."**

***Transitive Axiom:*** **If a = b and b = c then a = c. This is the third axiom of equality. It follows Euclid's Common Notion One: "Things equal to the same thing are equal to each other."**

***Additive Axiom:*** **If a = b and c = d then a + c = b + d. If two quantities are equal and an equal amount is added to each, they are still equal.**

***Multiplicative Axiom:*** **If a=b and c = d then ac = bd. Since multiplication is just repeated addition, the multiplicative axiom follows from the additive axiom.**

*“Information is not knowledge.*
*Knowledge is not wisdom.*
*Wisdom is not truth………*

*Frank Zappa (Packard Goose)*

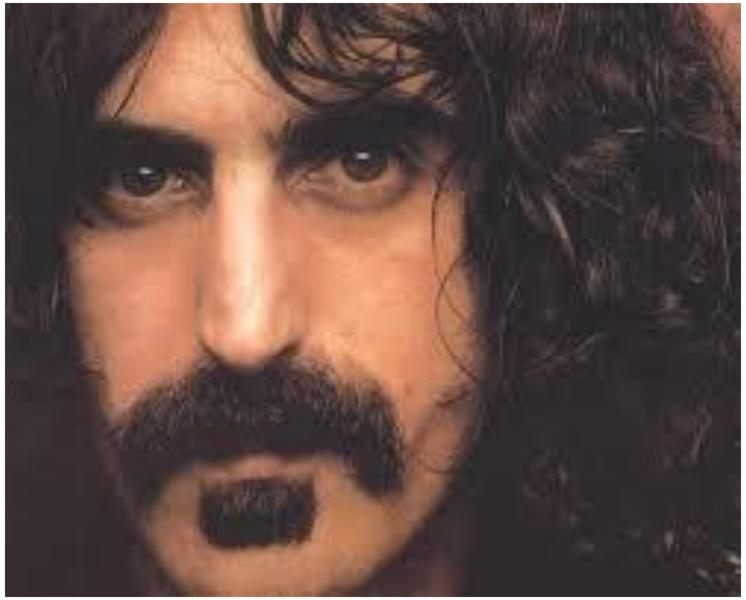


**Photo: Apostrophe (album cover)**


Photo: Getty Images/Comp: Liz Coulbourn)

picture: MatiasEnElMundo / Getty Images

# What is a model?

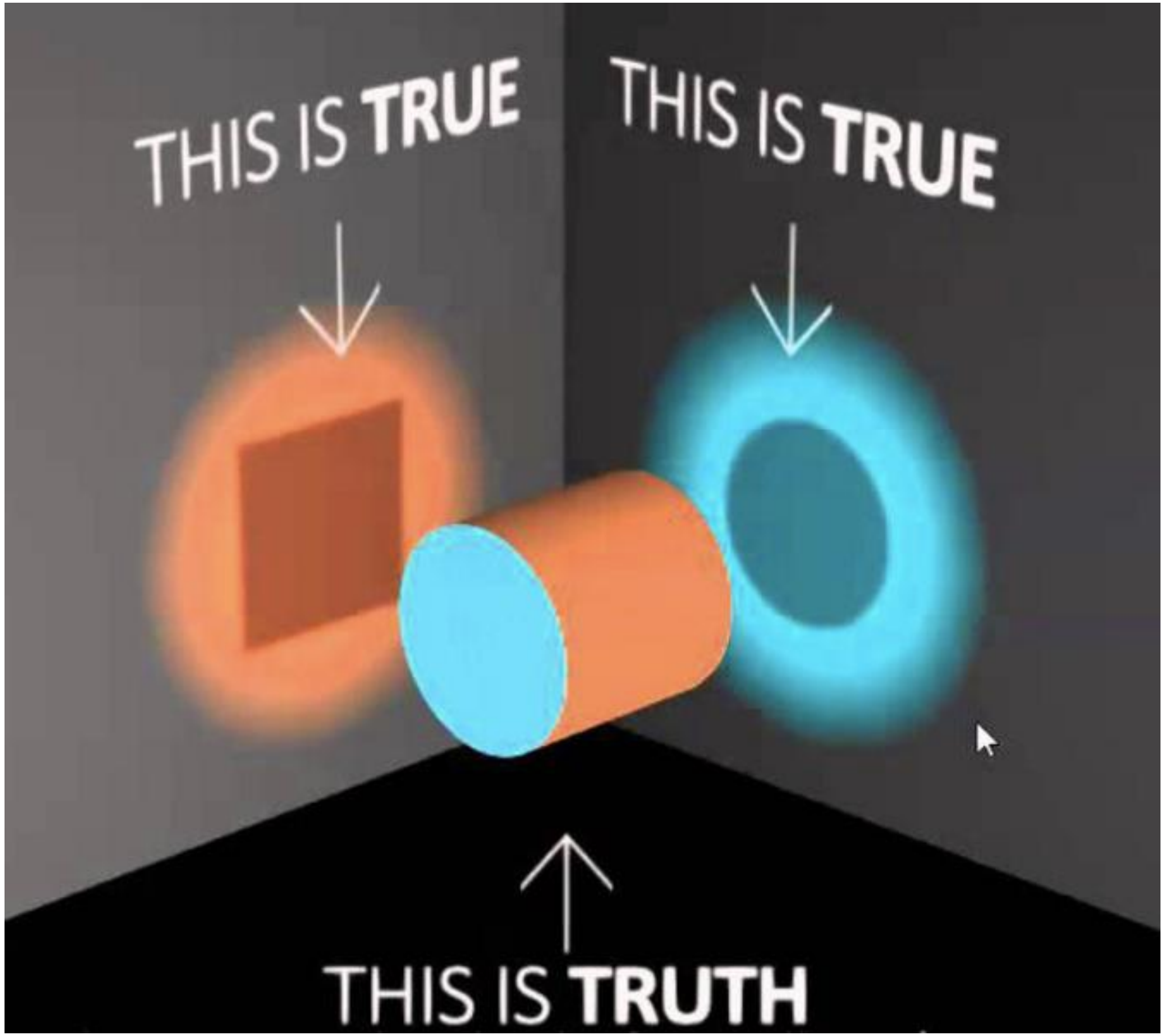
- a simplified representation of an idea, an object, a process or a system that is used to describe and explain a phenomenon
- Mechanistic marine ecosystem models (MMEMs): spatially resolved simulation models aiming to replicate a real marine ecosystem, using some sort of numerical time-stepping.
- MMEMs should be theoretical (based on a sound theory, enhance our process understanding) and ideally be able to predict the dynamics of a modelled ecosystem.
- MMEMs are *in-silico* observations in a virtual space
- MMEMs to test sensitivity and variability of state variables in what-if scenarios

# What is an observation?

- a piece of information from a natural system either received through our senses or recorded using a scientific instrument
- Data and observations are not synonyms (but are often used as in marine science)
- Observations are often outputs of models in themselves
- observational setup’s prior conditions impacting the outcome of the sampling
- Observation + interpretation = model

«To which extent does an observation or a model represent the truth?»

«*Truth*» depends on the eye that see.



**Validation** of a computational model is the process of formulating and substantiating explicit claims about the applicability and accuracy of computational results, with reference to the intended purpose of the model as well as to the natural system it represents (Dee, 1995).

Both observation and models are approximations of the truth. Neither is perfect but are separated from truth by errors ($\varepsilon_o$ and $\varepsilon_m$) of fundamentally different origin. $\delta = 0$ does not imply that the error is zero, only that models and observations agree (Lynch *et al*., 2009).

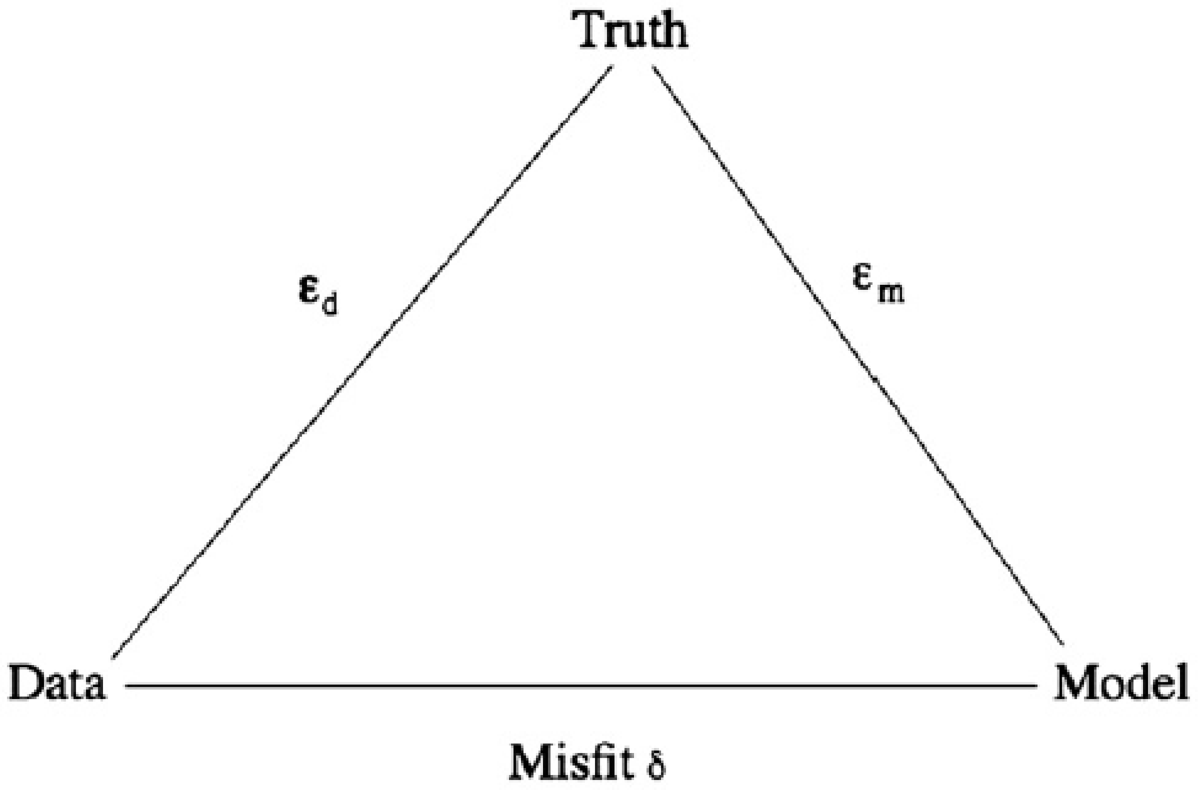
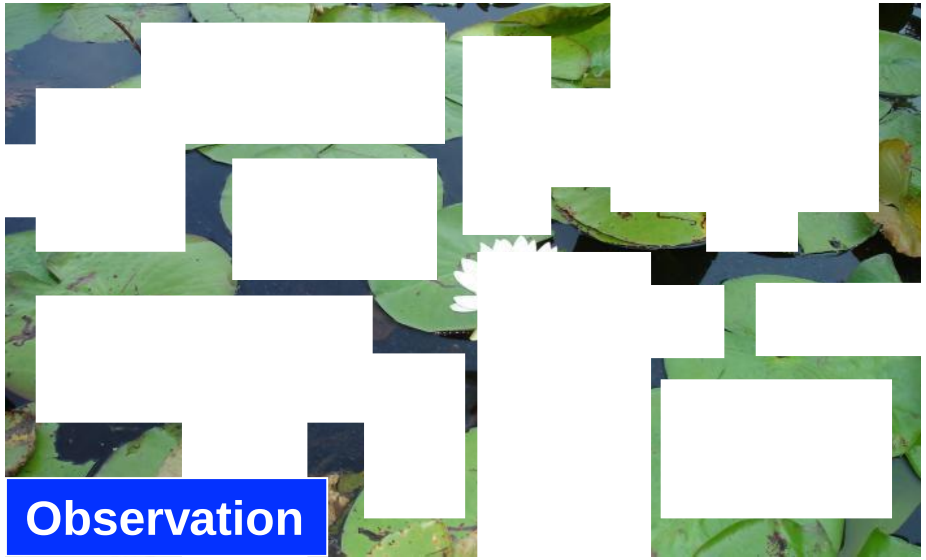



**Fig. 1.** Conceptual diagram of truth, Observed Data and Models Results, and associated departures from each other. Note the distinction between Error ($\varepsilon$) and Misfit ($\delta$). Refer to text for definitions.

**Figure: Lynch et al., 2009**


Incomplete access to a natural phenomenon where spatial and temporal resolution is a compromise


A basic spatial and temporal resolution, but incomplete representation of processes and components of a natural system

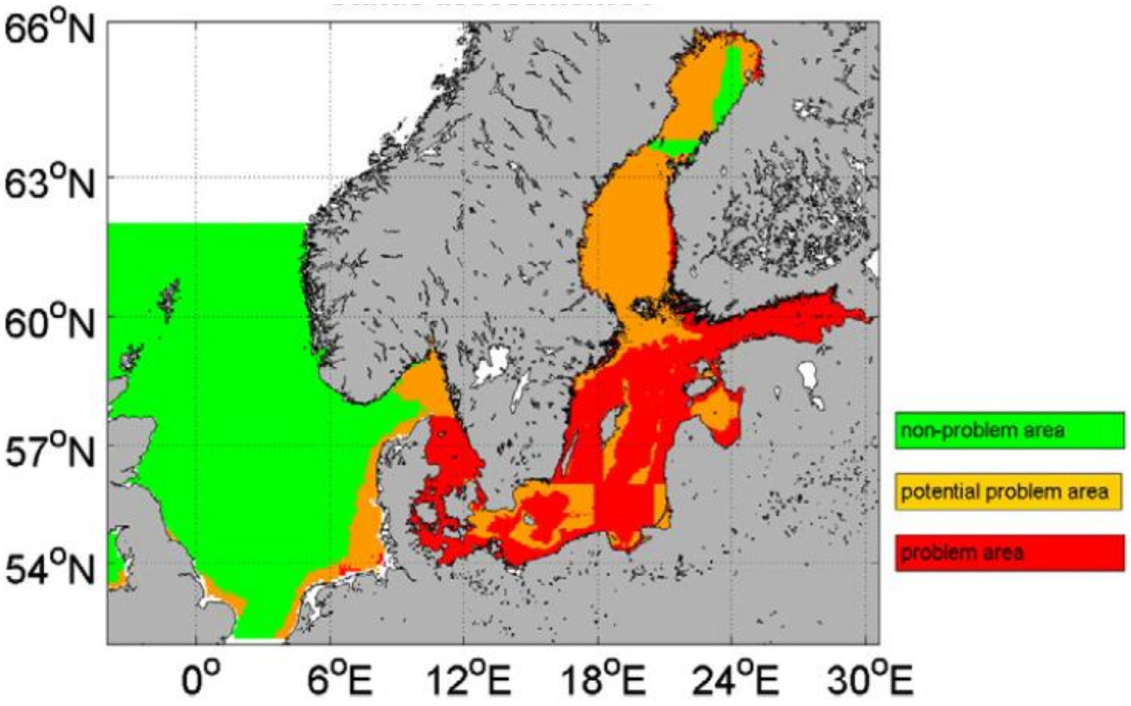
**Courtesy: R. Ji**

# Example 1

MMEMs can project into the future and tell about the past

# Eutrophication assessment (OSPAR), present and future climate

**Control (1970-2000)**




**A1B (2070-2100)**

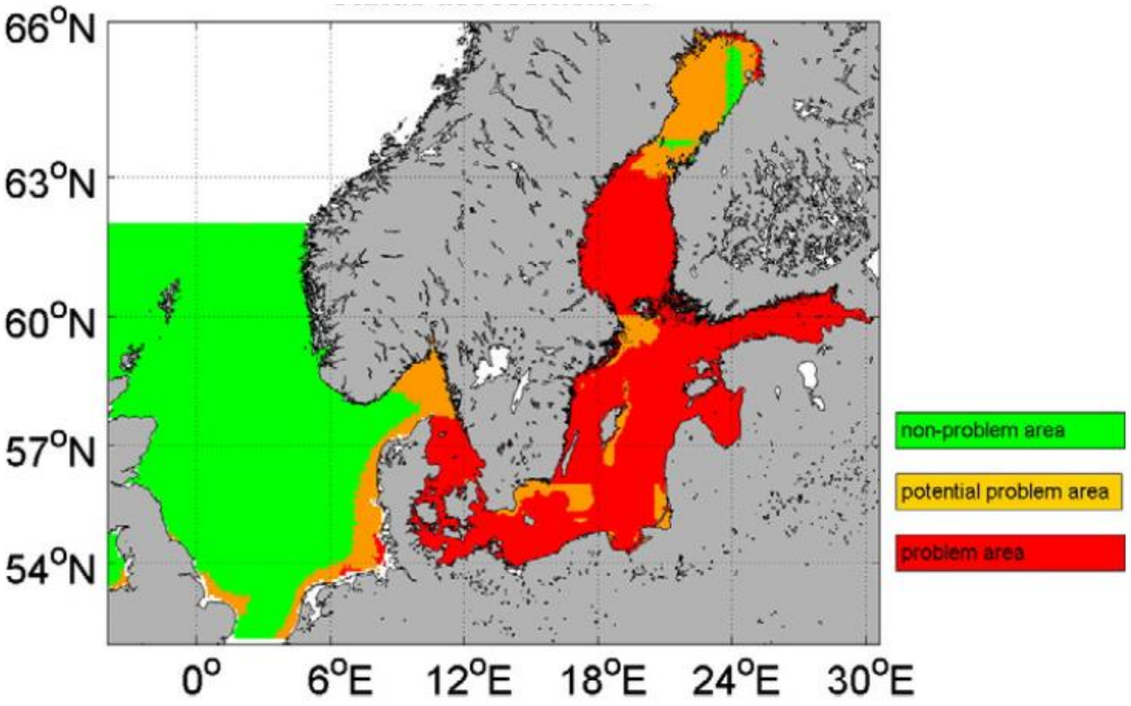
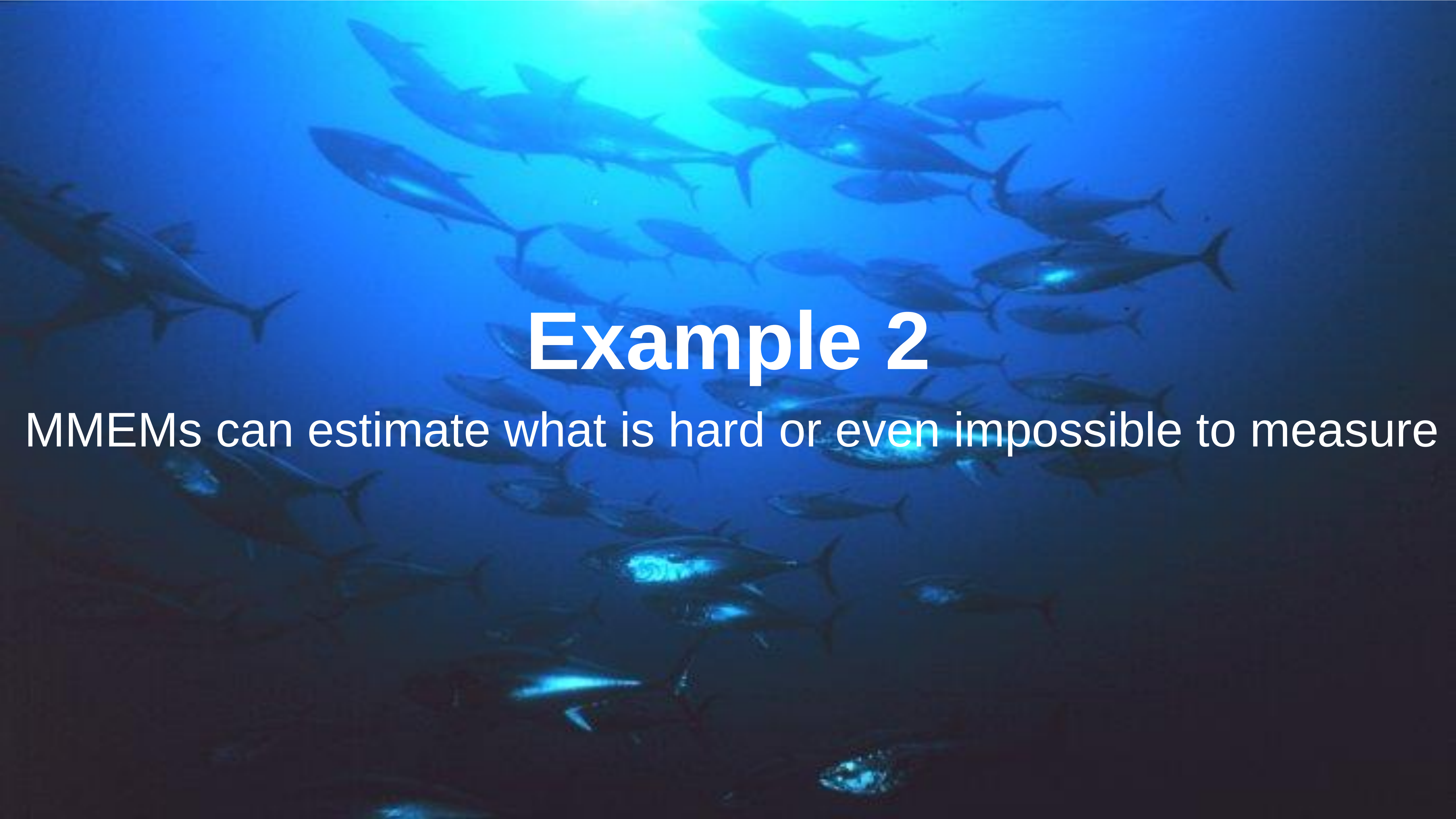



*Table A 2. Integration of Categorised Assessment Parameters*

| | Category I Degree of nutrient enrichment | Category II Direct effects | | Category III and IV Indirect effects/ other possible effects | Classification |
|---|---|---|---|---|---|
| a | + | + | and/or | + | problem area |
| b | - | + | and/or | + | problem area |
| C | + | - | | - | potential problem area |
| D | - | - | | - | non-problem area |

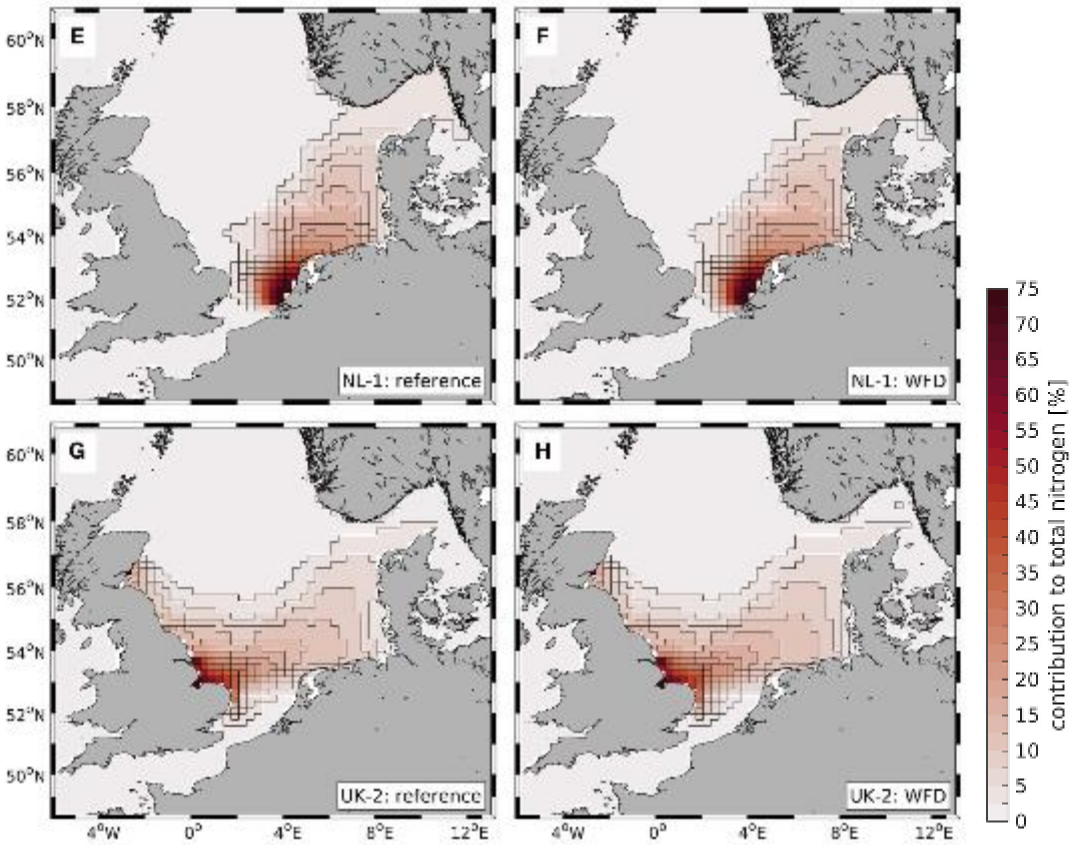
**Assessment from:**
**Winter nutrients,**
**chlorophyll,**
**oxygen**

**(Skogen et al., 2014)**

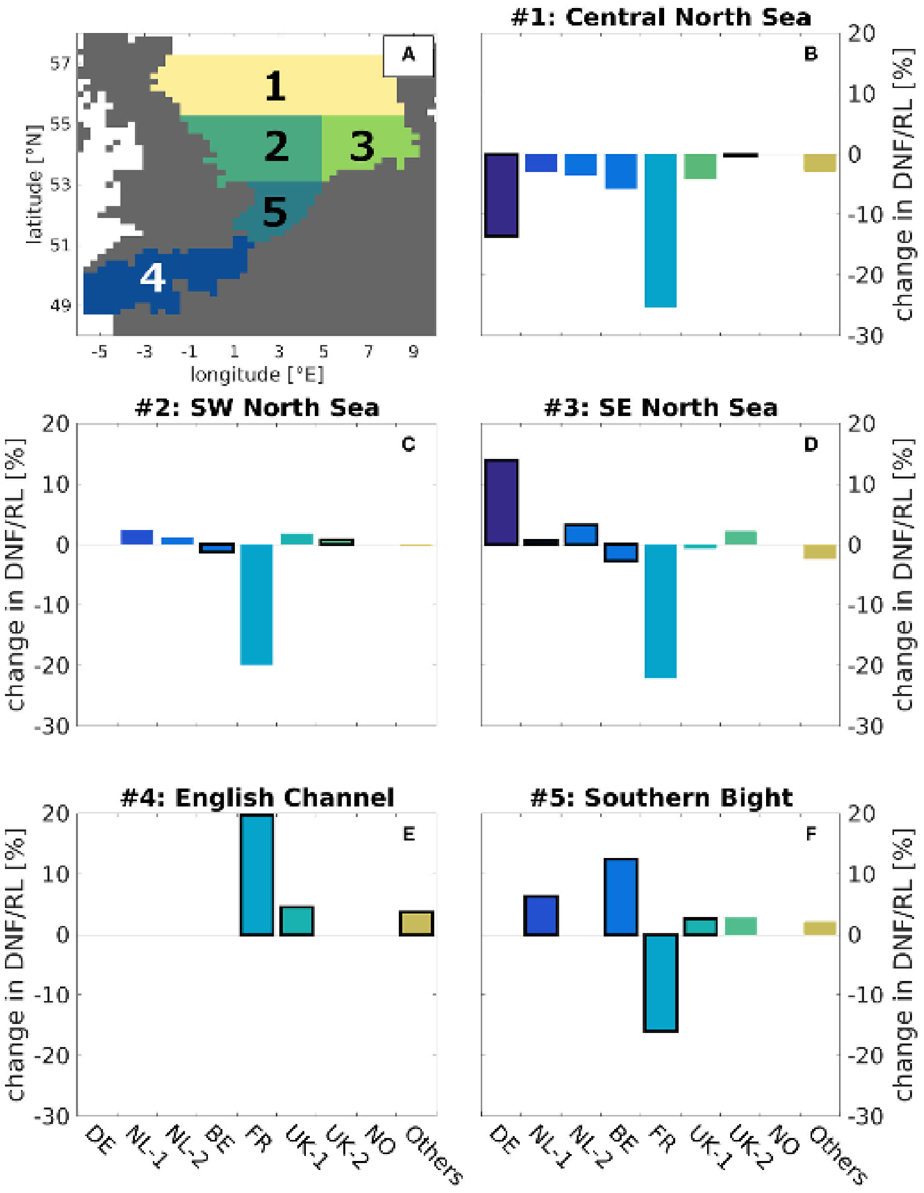


# Example 2

MMEMs can estimate what is hard or even impossible to measure

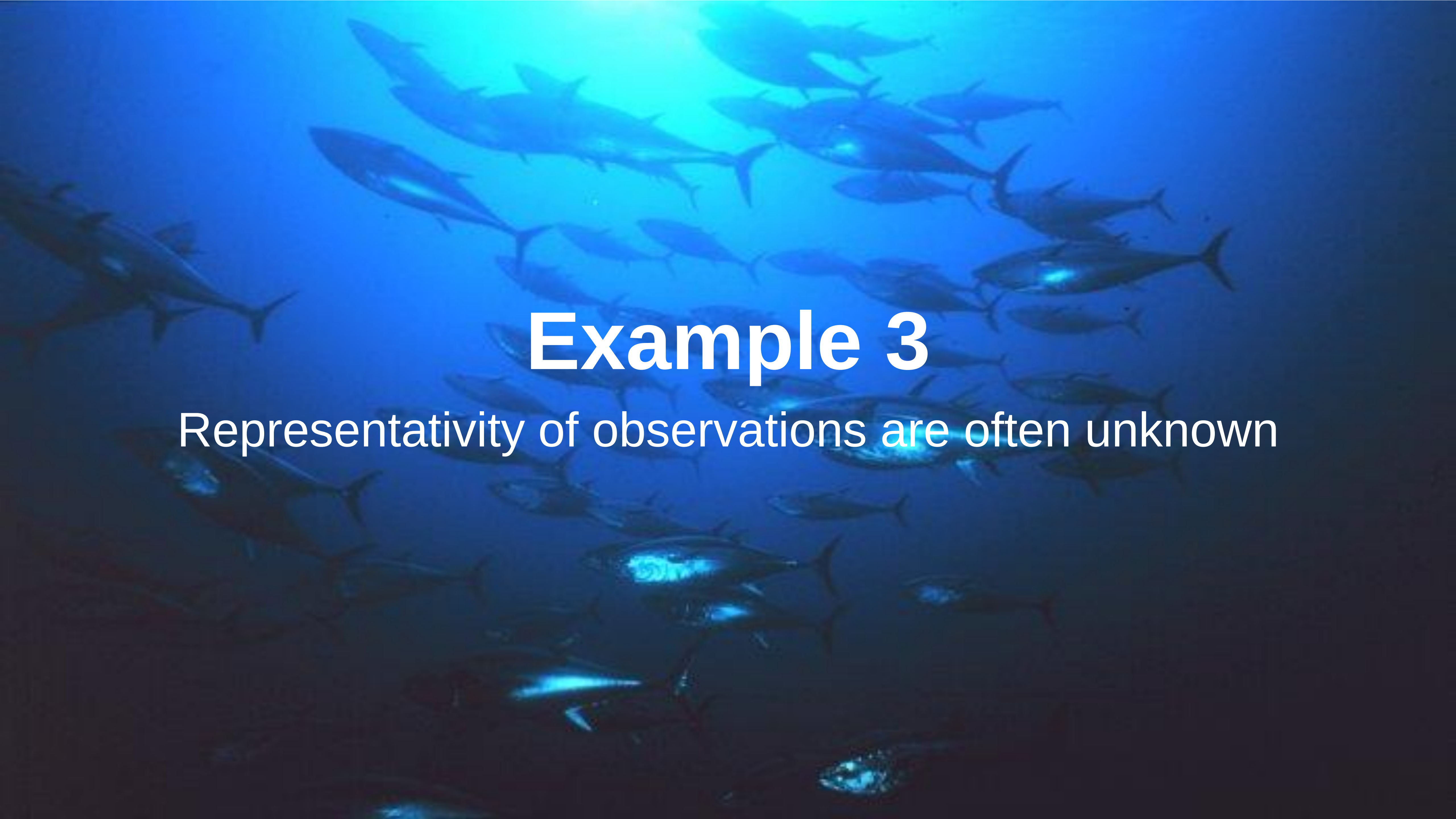



Relative contributions to TN by selected river source groups for (left) the reference simulation and (right) the WFD reduction scenario during 2006–2014




H.-J. Lenhart, F. Große
*Frontiers in Marine Science* (2018)

Relative change in source-specific benthic denitrification between reference(=2006-2014) and a WFD reduction scenario

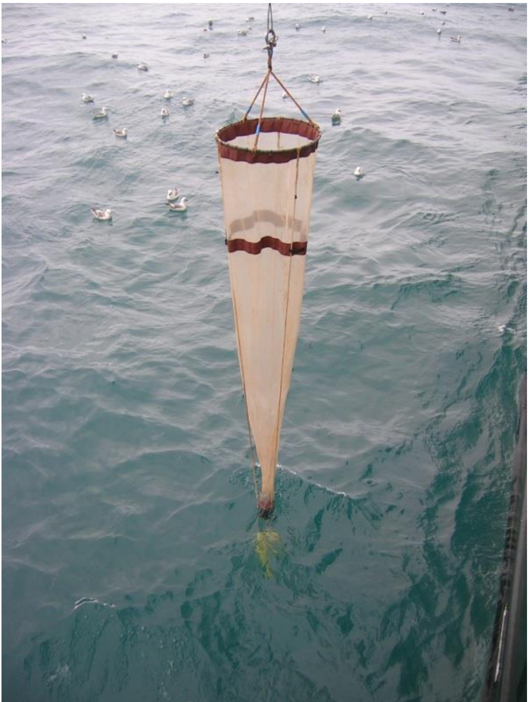


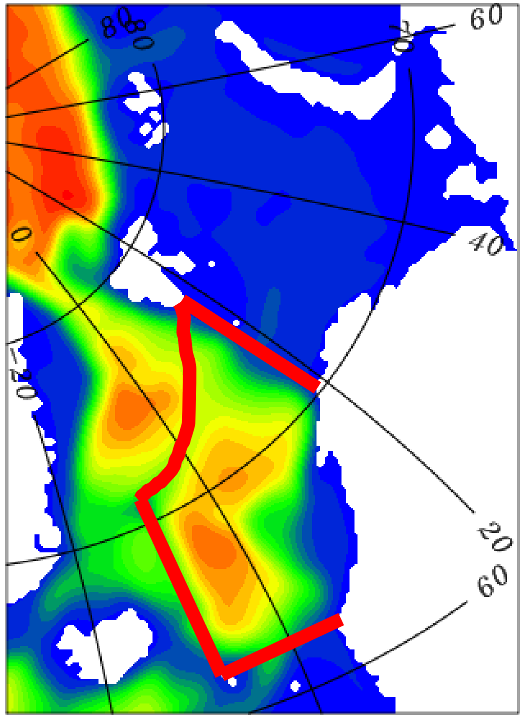
# Example 3

Representativity of observations are often unknown

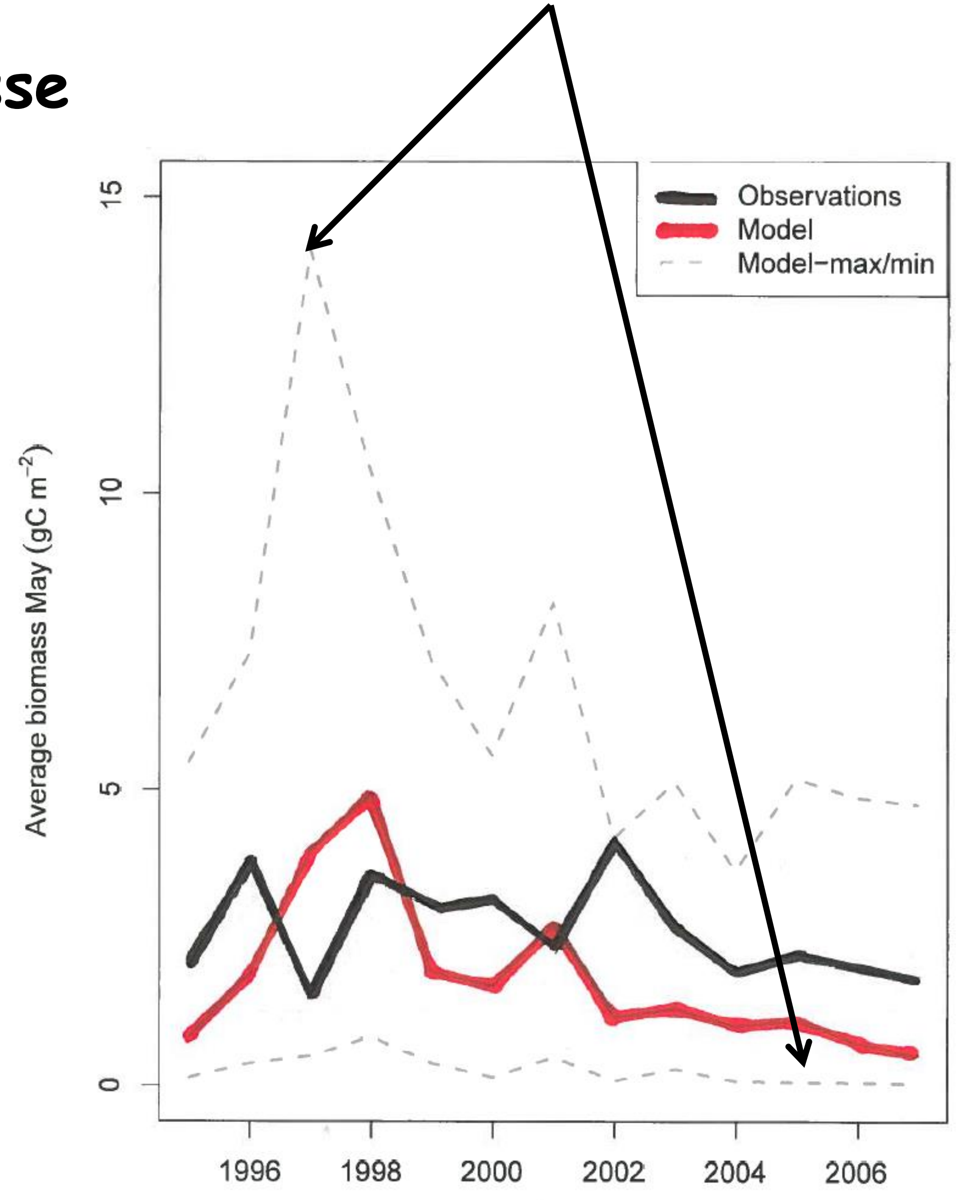
# Norwegian Sea mean May zooplankton biomasse

- model lower than observations
- decreasing trend in both
- always possible to get a perfect fit between model and observations…..

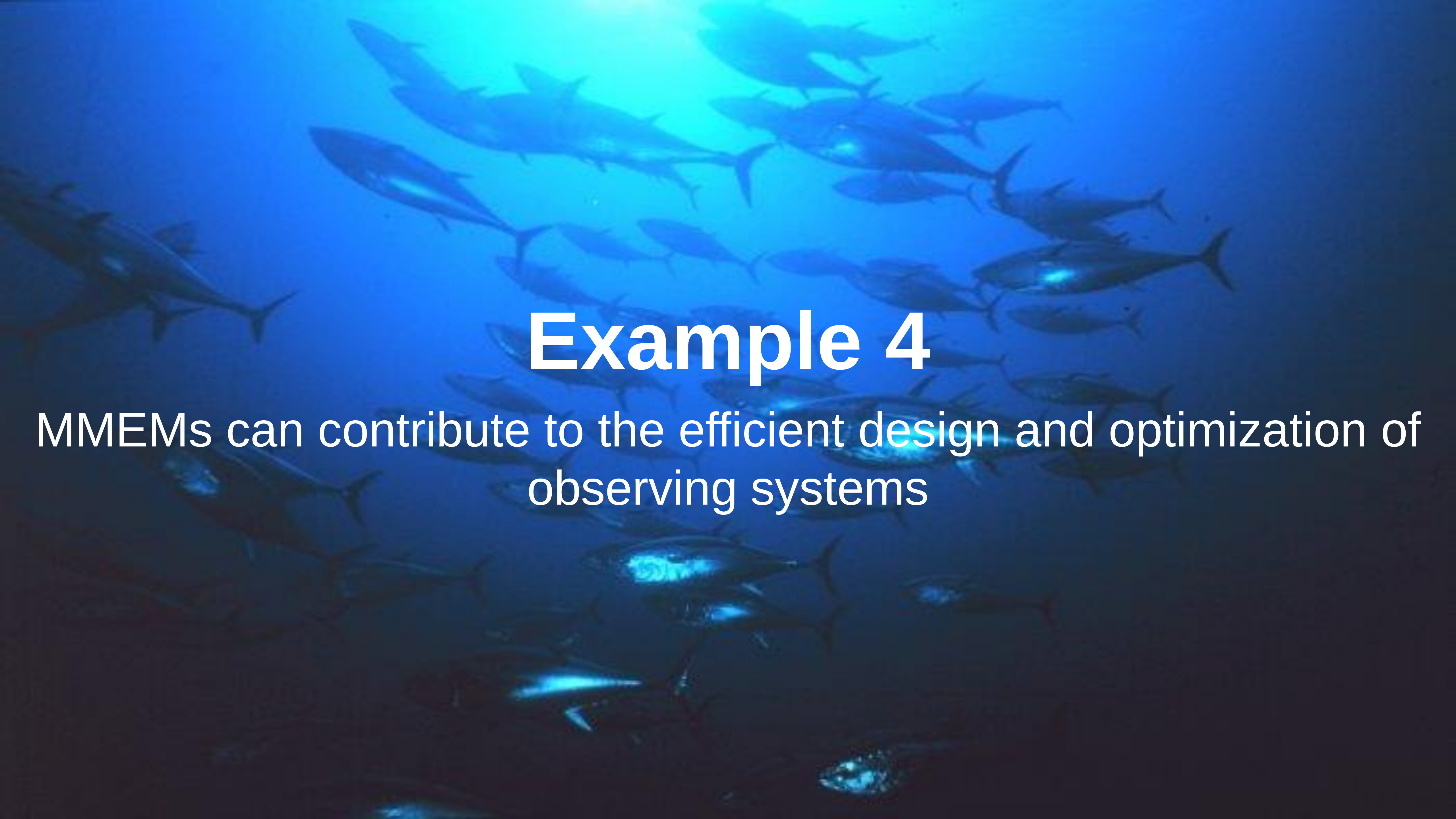





**Max/min ± 10 days & 2 grid points**




**Skogen, IMR, unpublished data**



# Example 4

MMEMs can contribute to the efficient design and optimization of observing systems

# Example 3: Survey design (mackerel and herring)

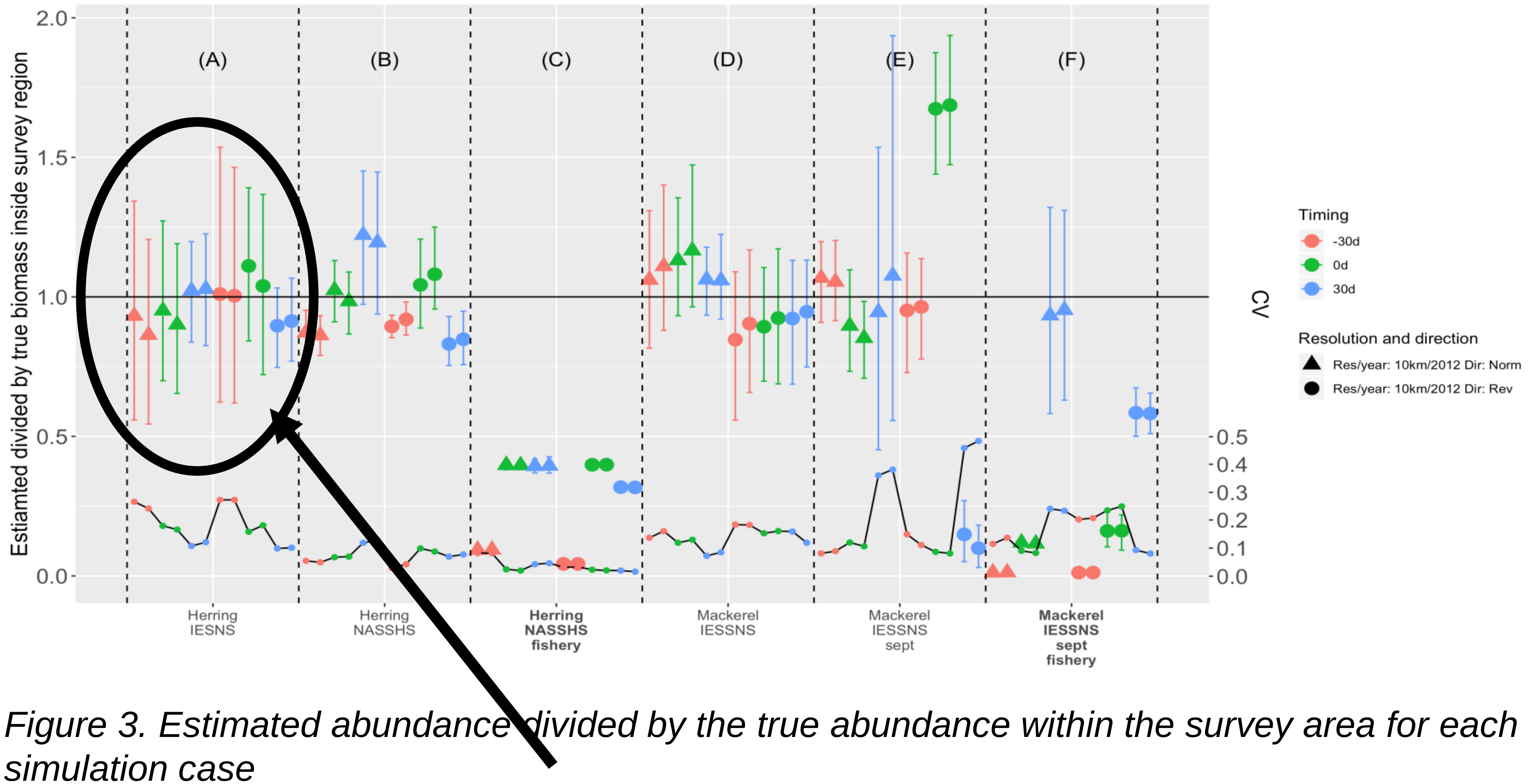



*Figure 3. Estimated abundance divided by the true abundance within the survey area for each simulation case*

**Stable estimate but large uncertainty**

**Holmin et al., 2020**

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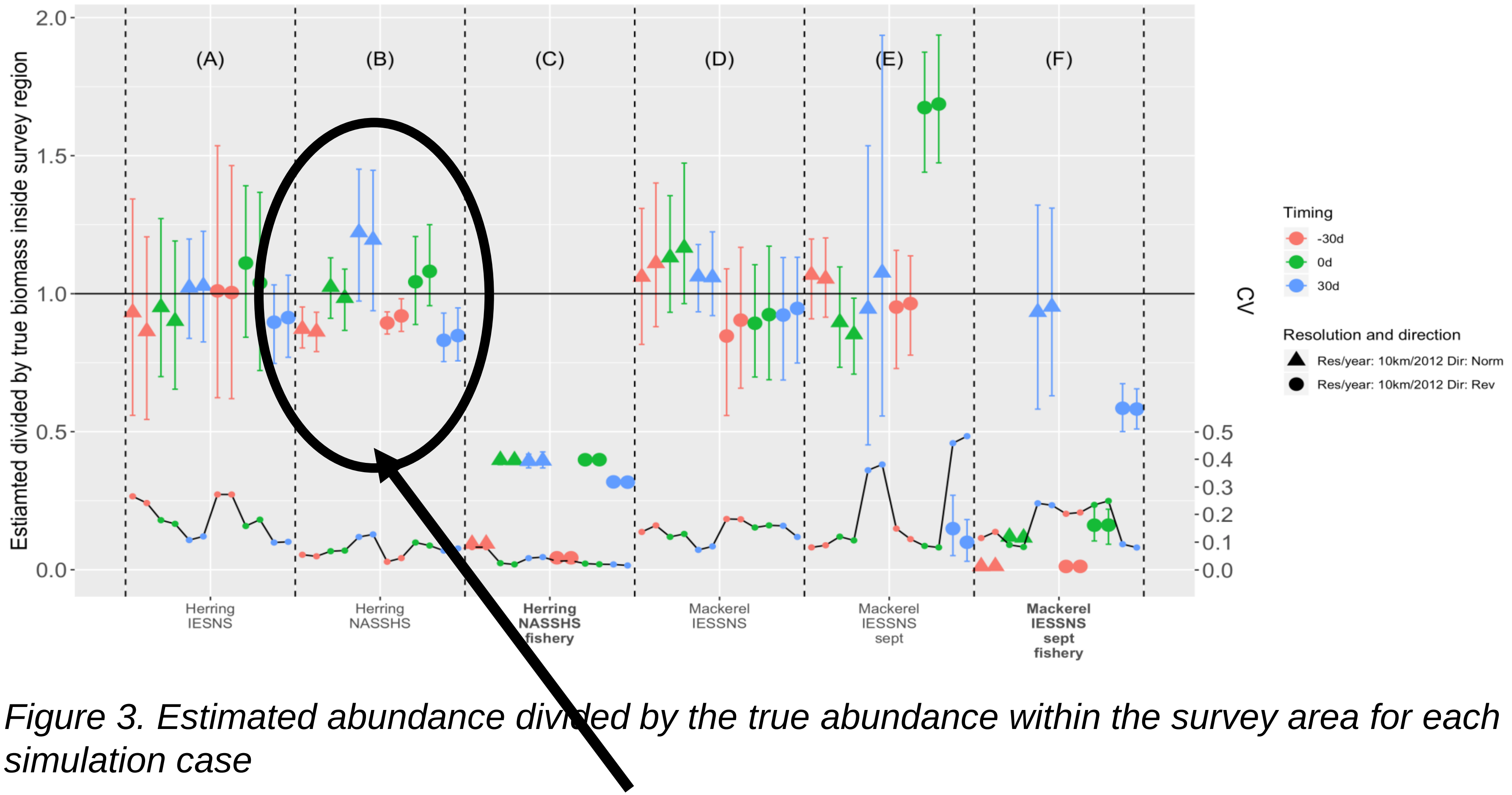


*Figure 3. Estimated abundance divided by the true abundance within the survey area for each simulation case*

**Robust, except for 30 days shift in time**

**Holmin et al., 2020**

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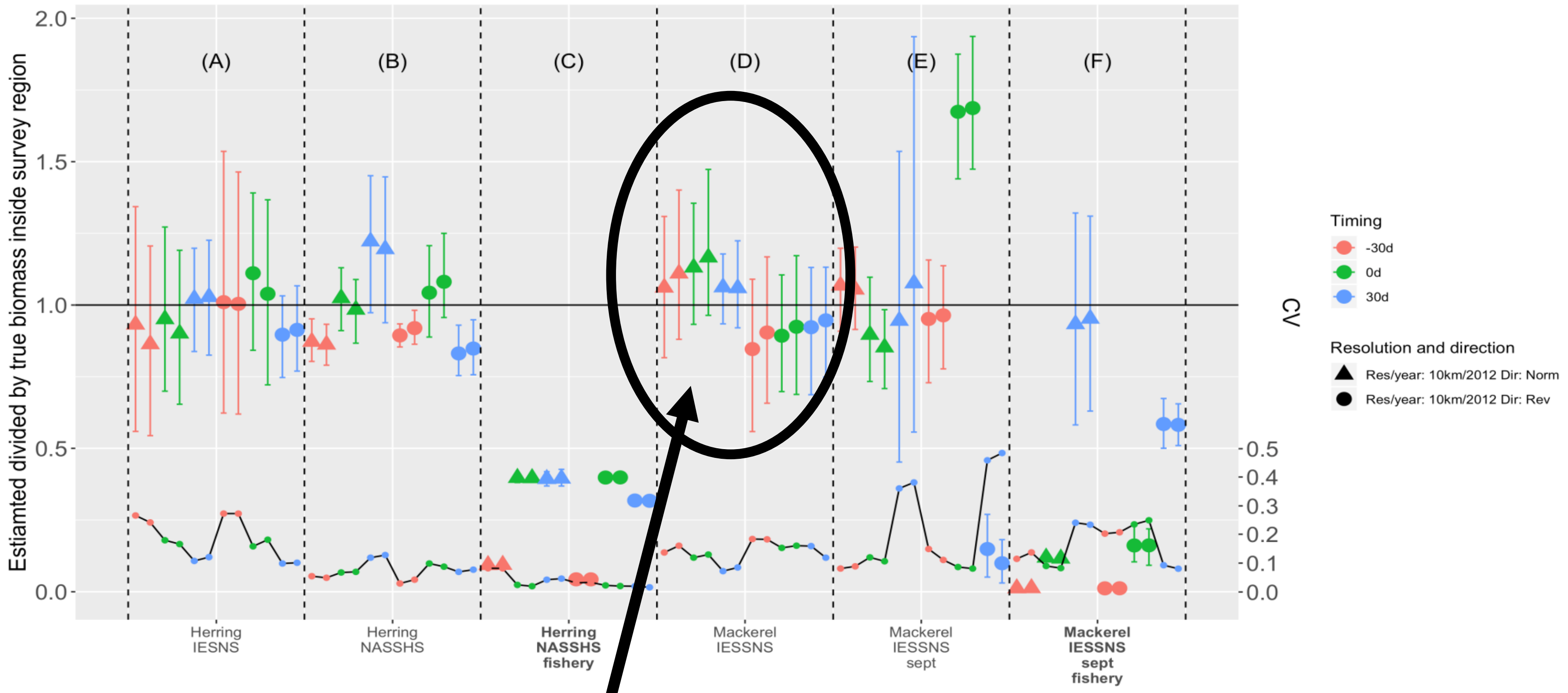



*Figure 3. Estimated abundance divided by the true abundance within the survey area for each simulation case*

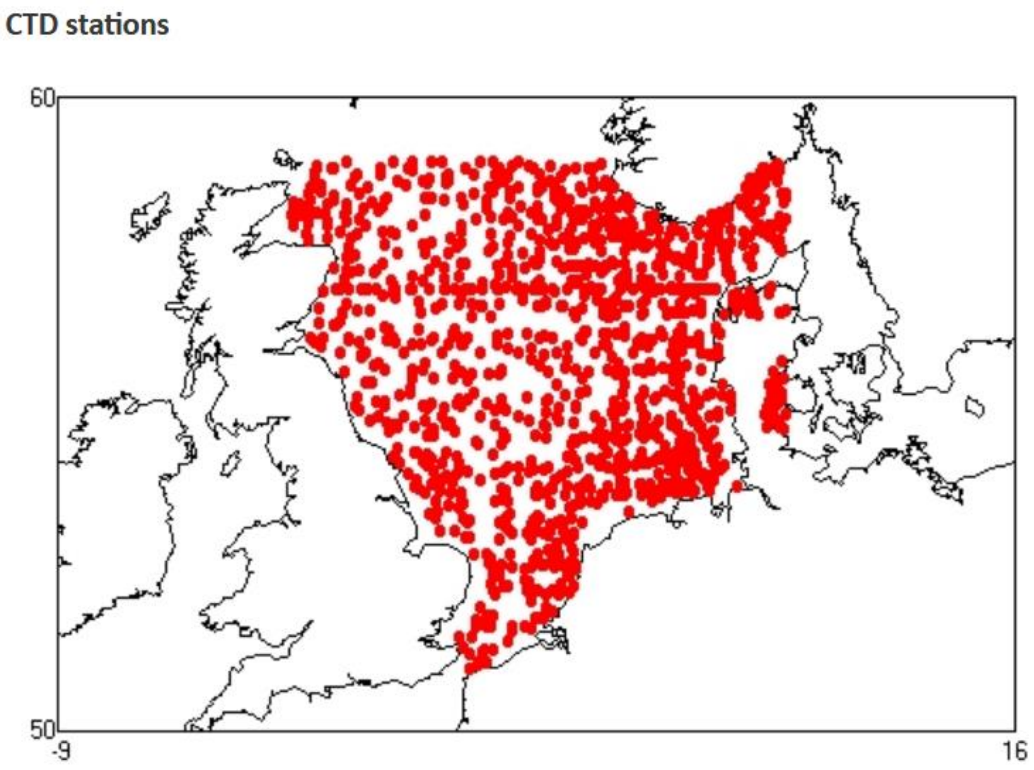
**Systematic change in biomass when reversing direction**

**Holmin et al., 2020**

# Example 5

Observations are scare in space and time

# CTD stations in ICES database, 2019, n=2608




Synoptic: 200km², (14x14km grid)
Monthly : 2380km², (49x49km grid)

Copernicus: 10km² (0.03x0.014 degree) every 15 minutes (n ≈1.8 x $10^9$)

1. Monitoring programs should be designed with models in mind

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2. New paradigm:  data (i.e. observations and models) validation

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3. Bury Karl Popper

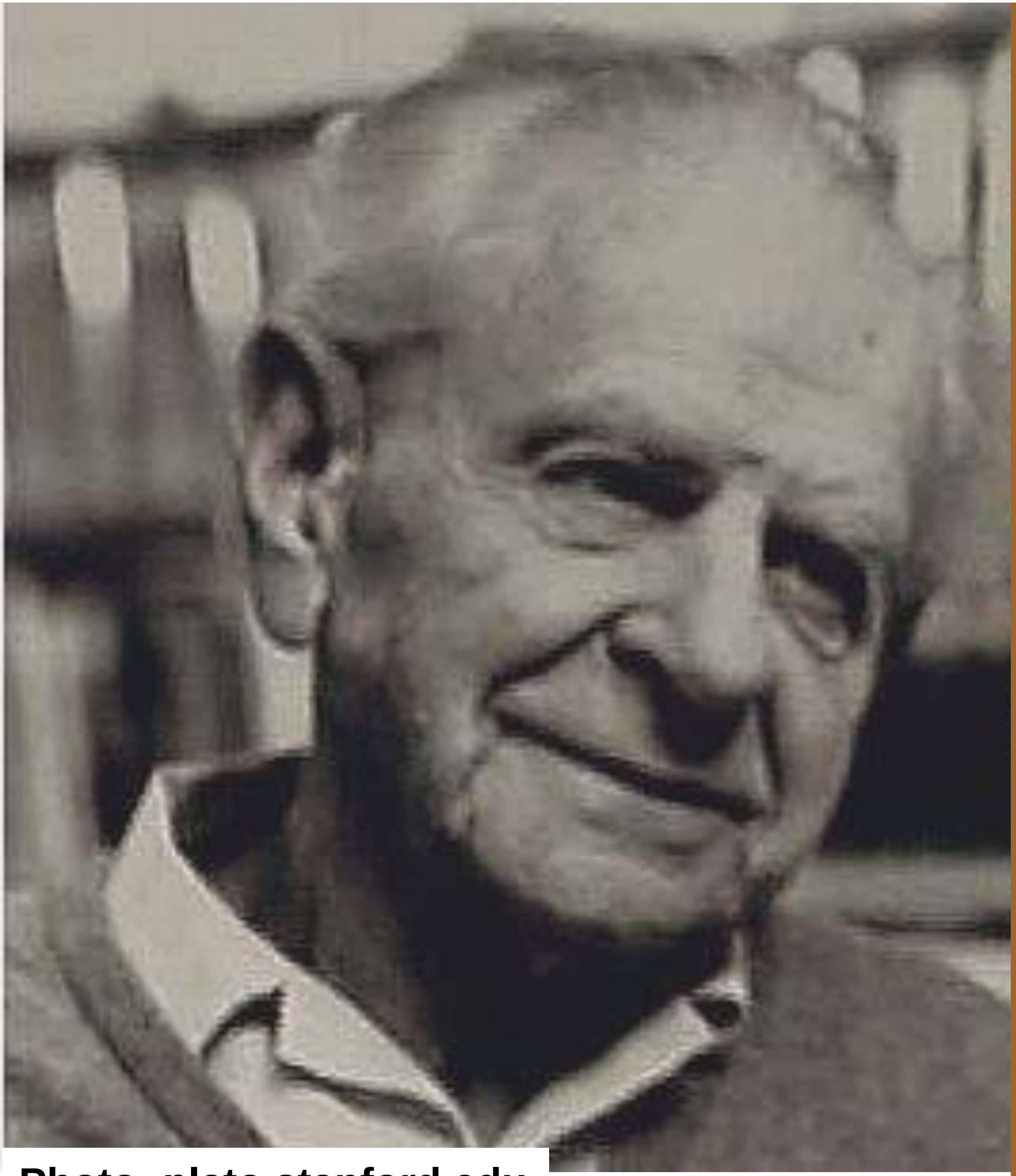

Photo: plato.stanford.edu

*No theory is completely correct, but if it can be shown both to be falsifiable and supported with evidence that shows it's true, it can be accepted as truth*

*Karl Popper (1902-1994)*

# TAKE HOME MESSAGE:

Going forward, it should not be models **or** observations, but rather models **and** observations. Using them together generates synergy and allows us to support science better and thereby increase our knowledge and understanding of marine ecosystems **to disclose the truth.**

# Thank you for your attention!!

Bergen seen from Mt. Ulriken, Photo: MDS