Marine Ecosystems Research Programme

Seeing the bigger picture: models of systems or systems with models?

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Fact: Human activities and environmental change can have wide consequences for marine ecosystems and the benefits they provide, such as supplying food and supporting leisure and recreation ('ecosystem services'). The modern view is that humans are part of the ecosystem.
Question: **What are the potential consequences for ecosystem services of different possible management decisions?**

Predicting consequences in an uncertain future requires a model or models, which may be of various types: conceptual; statistical; complex numerical, but as George Box said, "*All models are wrong but some are useful*." The consequences in question are difficult to predict because of our limited understanding of marine food webs, in particular how interactions and changes in relationships between organisms affect the delivery of ecosystem services at various scales of space and time. Forgetting for the moment all the other information needed, let us focus on one key requirement – **how may we model the entire marine ecosystem?** Completely different modelling approaches are required to represent microbial and plankton processes compared to upper trophic levels (fish, birds, mammals) or socio-economic links.

Issues relevant to modelling the entire marine ecosystem		
Biogeochemistry/Lower trophic levels	**Higher trophic levels**	**Ecosystem services**
Intrinsic time-scales short	Intrinsic time-scales long	Time-scales vary depending on relevant processes
Behaviour and demography are second-order effects	Behaviour and demography are dominant processes	Human action and interaction are key elements
Biology may be approximated in terms of chemistry and physics	Demographic dynamics are critical	Trade-offs underpinning action and decision-making are dynamic
Species can reasonably be grouped into functional types	Life stages within species can have fundamentally different properties	The currencies used to understand natural variability do not match those used to support decisions

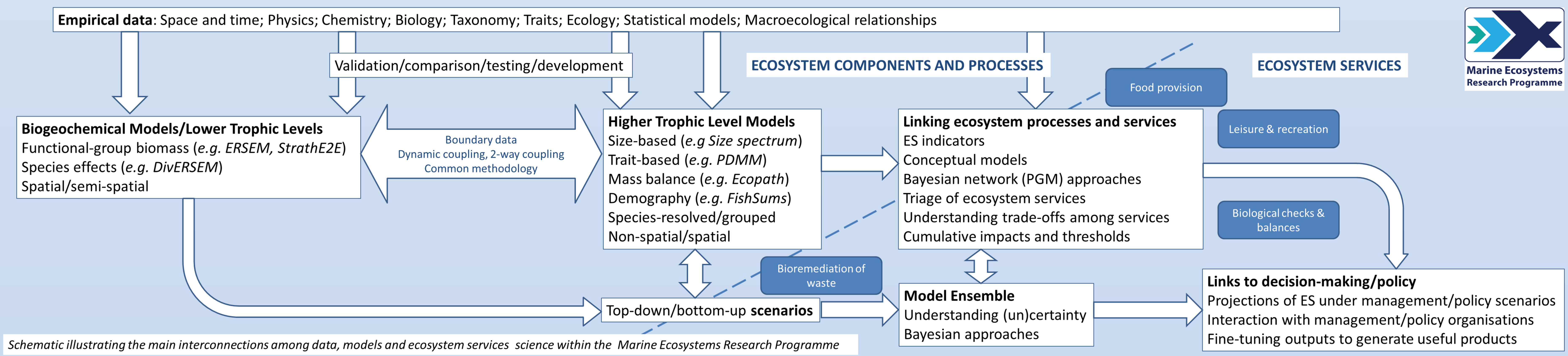
Existing models do not address the question in full (or at all). Should we choose and use an existing model and run with it? Should we develop a new model that includes more connection? But, Box again: "*Since all models are wrong the scientist cannot obtain a 'correct' one by excessive elaboration*." Nate Silver, in 'The signal and the noise: the art of science and prediction (Penguin, 2013)' says the key to better prediction is to 'think like a fox' from a quote by Archilocus: "*The fox knows many little things, but the hedgehog knows one big thing*." The table below is adapted from that book and explains what he meant:

FOX	HEDGEHOG
Multidisciplinary (incorporate ideas from different disciplines regardless of origin)	**Specialised** (spend bulk of career on one or two big questions/approaches)
Adaptable (pursue multiple approaches, and willing to use different ones)	**Stalwart** (stick to one 'all-in' approach, new data used to refine original model)
Self-critical (willing to acknowledge mistakes and act on them)	**Stubborn** (mistakes blamed on luck– a good model has a bad day)
Tolerant of complexity (see the world as complicated, maybe inherently unpredictable)	**Order-seeking** (expect relatively simple governing relationships once signal identified amongst noise)
Cautious (express predictions in probabilistic terms and qualify opinions)	**Confident** (rarely hedge opinions and reluctant to change them)
Empirical (rely more on observation than on theory)	**Ideological** (expect solutions to be manifestations of theory)
Foxes are **better forecasters**	Hedgehogs are **weaker forecasters**

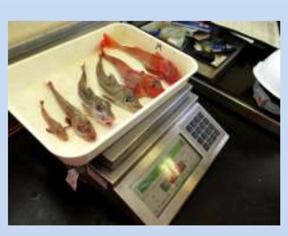
Given that a single model or 'modelling system' cannot be able to model and predict everything, how can we 'be more foxy'?

Principles: Do not rely on a single model, use a variety; Make the best use of different models, embracing difference; Explore why different models give different predictions; Determine which models are appropriate for different things; Consider potentially important processes that may be lacking; Develop systems to combine models; Use model differences to understand (un)certainty.

Within the Marine Ecosystems Research programme we are attempting to put these principles into practice, integrating data, models and ecosystem services within a common framework to understand the whole ecosystem rather than parts of it. Our overarching goal is to improve our ability to understand how changes in the marine ecosystem (managed or not) propagate and affect delivery of ecosystem services. The figure below outlines how the elements of the programme are structured to interact to deliver this goal.



Schematic illustrating the main interconnections among data, models and ecosystem services science within the Marine Ecosystems Research Programme



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