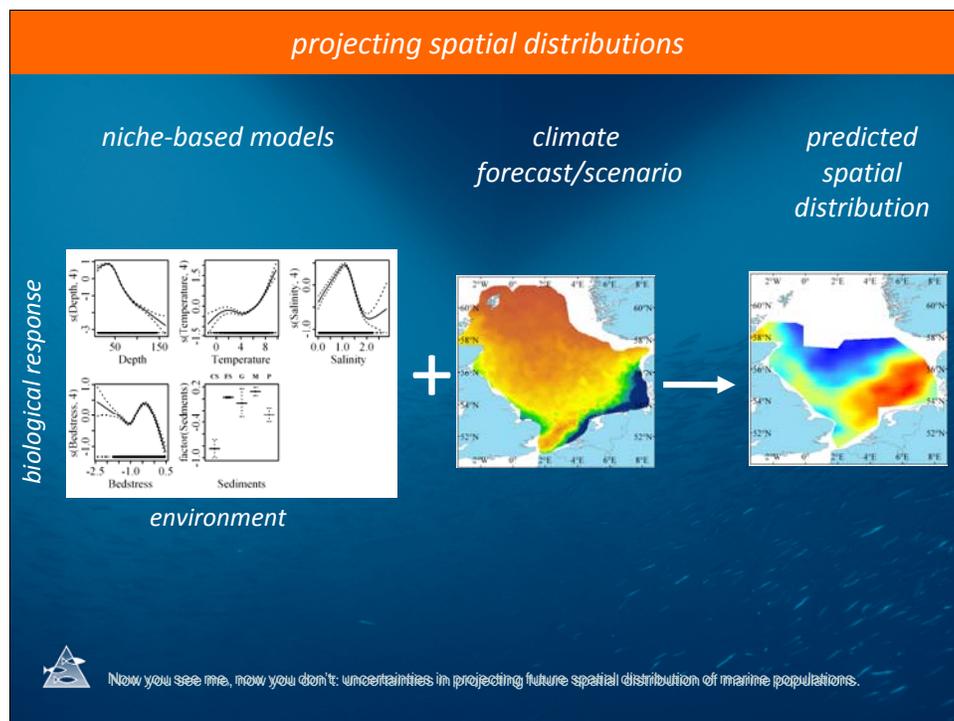
An underwater scene with a blue gradient background. Various marine life are depicted in white line-art style: a jellyfish in the top left, a large fish in the top center, a whale in the top right, a fish in the bottom left, and a scallop in the bottom center. The text is centered in the upper half of the image.

**Now you see me, now you don't:  
uncertainties in projecting spatial distribution of  
marine populations.**

*Benjamin Planque, Edwige Bellier,  
Frida Lasram and Christophe Loots*



**INSTITUTE OF MARINE RESEARCH**  
**HAVFORSKNINGSINSTITUTTET**

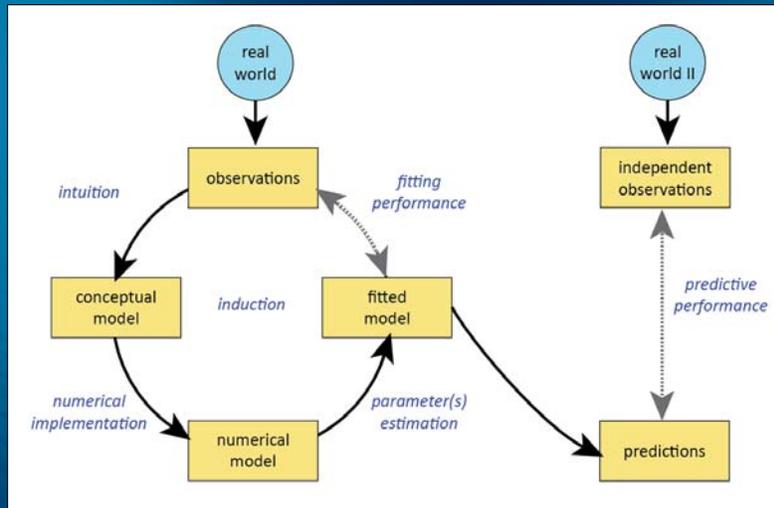


Start straight with an example: climate envelope models. Niche-based example: the niche is defined. The current realisation of the niche is the current spatial distribution. If the spatial distribution of temperature changes, then the spatial distribution of the population is also expected to change, following the geographical displacement of the niche.

This is a simple, one can say simplistic, vision of how to build spatial distribution models. The process is in fact generally more complicated, even if many steps are often implicitly considered, i.e. explicitly ignored.

NOTE: The best would be to use the same example here as later to show variations in model output as a function of model uncertainty.

## A general view of the modelling method



adapted from Anderson, 2010



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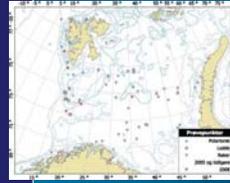
Here, I present a general view of the modelling method which explicitly state the different steps in the modeling process, from observations to prediction.

The modelling method, or how do we move from the real word towards predictions of what the world could look like in the future, or under scenarios. After explaining the different steps, we asked ourselves what uncertainties are associated with these different steps. This is developed in the coming slides.

## *uncertainties in observations*

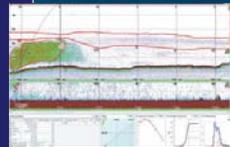
### *sampling design:*

*sampling intensity, spatial/temporal scales,  
aggregated distributions*



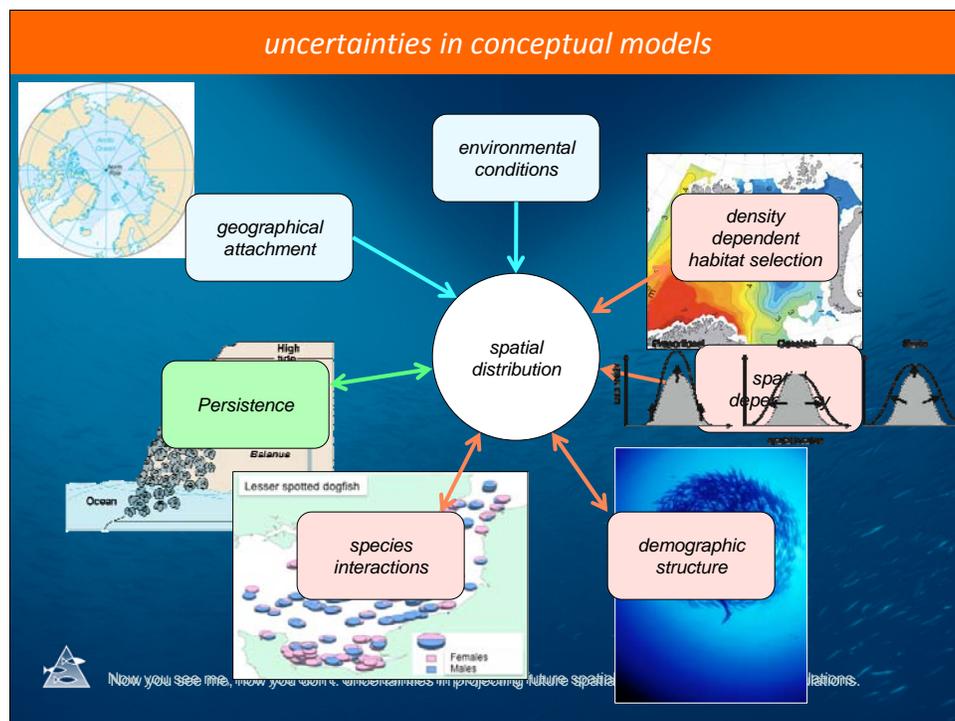
### *sampling gear (trawl) or observation (acoustics):*

*accessibility to observation, sensitivity, bias and  
precision*



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#1 Uncertainty in observations: we can only see the real world through the lenses of our observation methods. This results in observation uncertainty which is a direct function of the sampling design and observation tools.



#2 Uncertainty in conceptual models. These are built from intuition and historical developments within the research community.

Conceptual models come in many shapes. We first include environmental conditions, which include e.g. temperature as before as well as other varying environmental factors or stable ones (bottom rugosity, tidal friction, etc.). Then we add 5 others (spatial dependency, DDHS, demographic structure, species interactions, memory). And finally, the geographical attachment, which constitute the null model under very poor knowledge (animals are there because they are there!). With this, we can start thinking that environmental control is not on its own and that it needs to be rather strong to override all the other controls. How much each of these conceptual models is attached to the truth is often uncertain and several model (which can include several of these hypotheses) may compete often without excluding one another.

## *uncertainty in numerical formulation*

### *functional relationships*

*linear, polynomial, piecewise, etc...*

### *model complexity*

*number of parameters, non-linearity*

### *interactions*

*additive, multiplicative, other*

### *statistical distributions*

*Normal, Poisson, Log-Normal, Gamma, Binomial,...*



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### #3 uncertainty in numerical formulation of models.

Once we have selected a number of candidate conceptual models, these must be specified in numerical form. Again the choice of the numerical form can be wide and there are uncertainties into which form may be best suited to express the concepts.

## *uncertainty in parameter estimates and model fitting*

### *statistical distribution of parameters*

*confidence intervals, statistical significance*

### *correlated parameters*

*are parameters independent, and how is this handled by the modeling method?*

### *overparametrisation and overfitting*

*number of parameters vs. number of independent observations*

### *autocorrelated observations*

*spatial/temporal autocorrelation reduces the true number of independent observations*

### *metric for model fitting performance*

*variance, deviance, likelihood, AIC, AUC, GCV,...*



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#### #4 uncertainty in parameters estimates and model fitting

After the numerical formulation(s) have been set, the parameters of the models must be estimated and this is generally achieved through model fitting. Again, there is uncertainty in the values of the parameters estimated and this can be sensitive to the data properties, links between parameters, model complexity and the metrics chosen to evaluate model fitting performances.

## *uncertainty in model evaluation*

*metric for model predictive performance*

*variance, deviance, likelihood, AIC, AUC,...*

*true independence of the validation data*

*are the validation data correlated with fitting data?*



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### #5 uncertainty in model evaluation

Once a range of concepts, numerical formulation and parameters are developed, the models should be evaluated for their predictive performances. This should be done on truly independent data, using appropriate metrics.

## *Additional considerations*

### *Spatial scale*

*is spatial scale considered?  
are the scales of observation and modelling consistent?*

### *adaptability of living systems*

*complex adaptive systems, these may modify their  
behaviour in the future, surprise is to be expected*

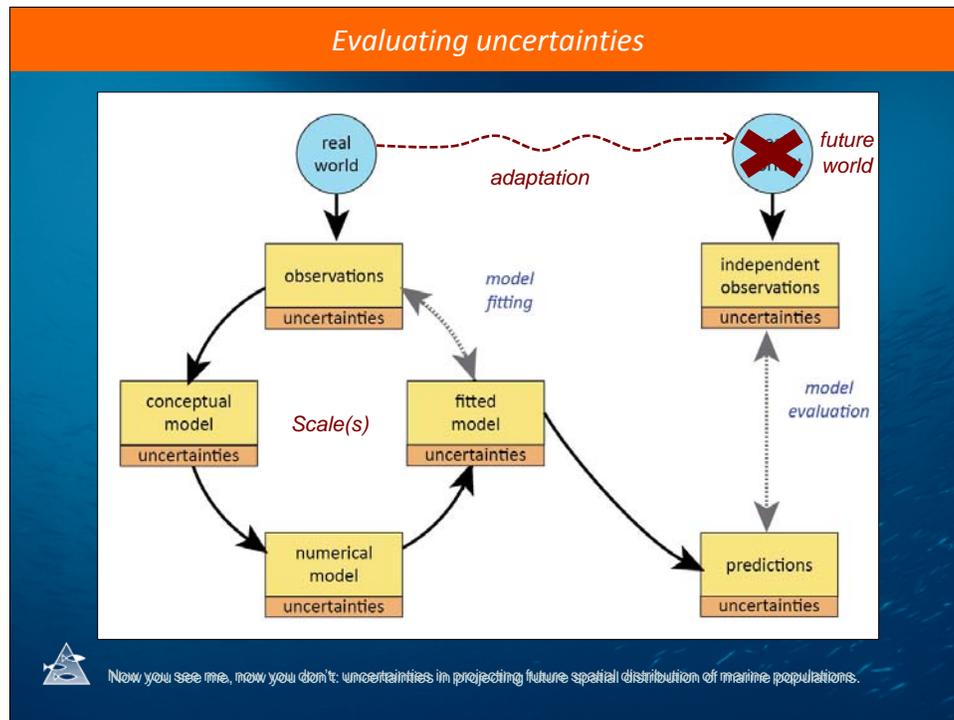


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## #6 some final considerations

The issue of scale is critical, since processes that govern the distribution at individual level, groups of individuals, population or species level may differ.

In addition, one must not forget that living systems are highly complex and adaptive and that their response to various kinds of controls may vary in the future as a result of such adaptive capabilities.



Here, I present a general view of the modelling method which explicitly state the different steps in the modeling process, from observations to prediction.

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*How are these uncertainties currently handled?*

survey of the published literature 2005-2010

<< Back to previous

**Results** TS=((spatial or geograph\* or distribution\* or habitat) and (fish\* or benth\*) and (sea or ocean or coast\* or marin\*) and model\*)  
Refined by: Subject Areas=( MARINE & FRESHWATER BIOLOGY OR OCEANOGRAPHY OR FISHERIES )  
Timespan=2005-2010. Databases=SCI-EXPANDED, SSCI, A&HCI.

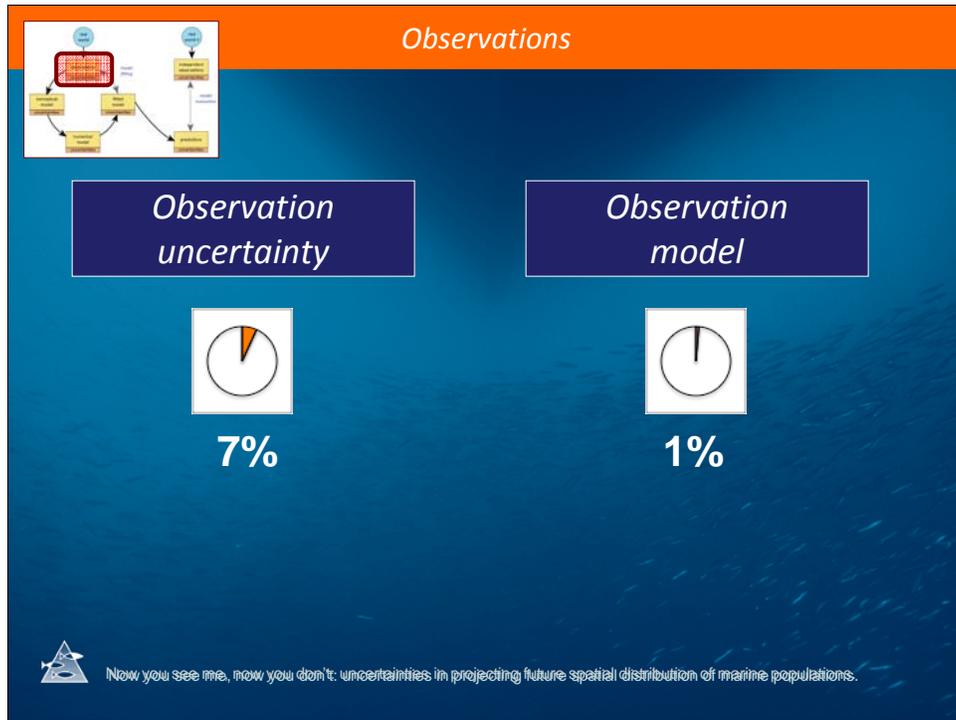
Results: **1,137** Page 1 of 114 Go Sort by: Latest Date

1137 articles -> 75 retained, which are developing models which are (or can be) used in a predictive fashion.

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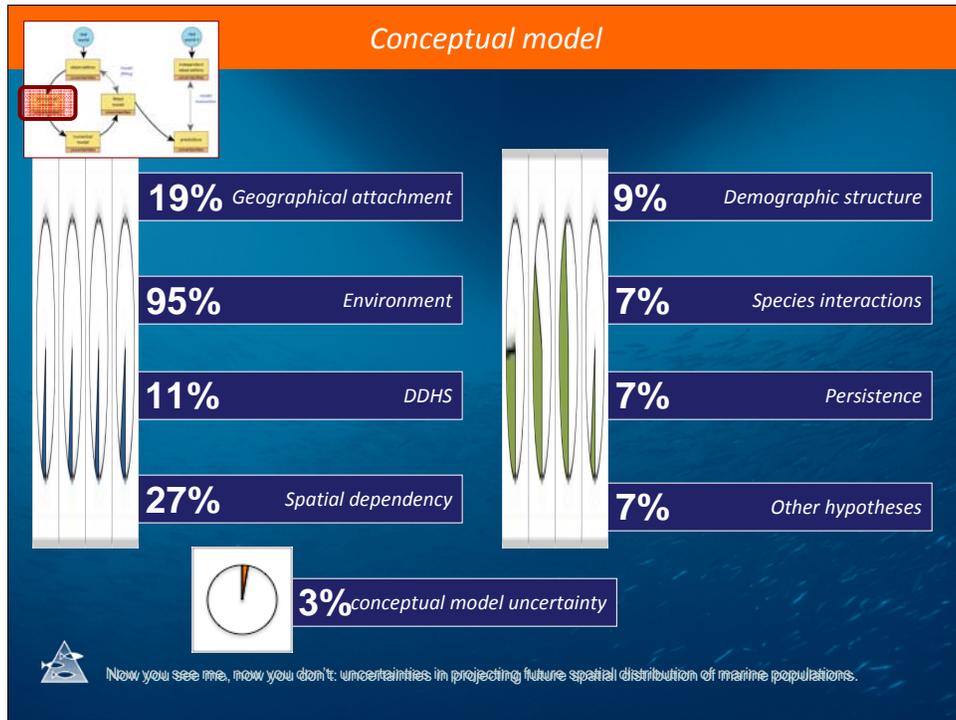
We investigated through a review of published papers over the last 5 years. Extracted from ISI (show figure). We only retained articles that were developing models which were or could be used in a predictive fashion.

1. the hypotheses



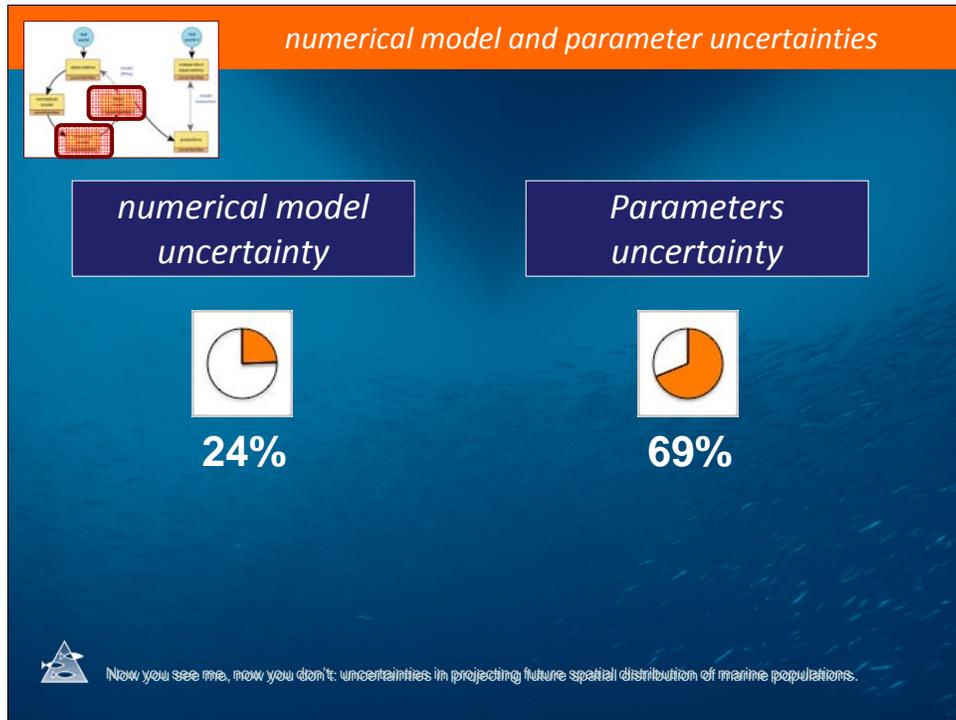
We investigated through a review of published papers over the last 5 years. Extracted from ISI (show figure). We only retained articles that were developing models which were or could be used in a predictive fashion.

## 2. Estimating the uncertainties



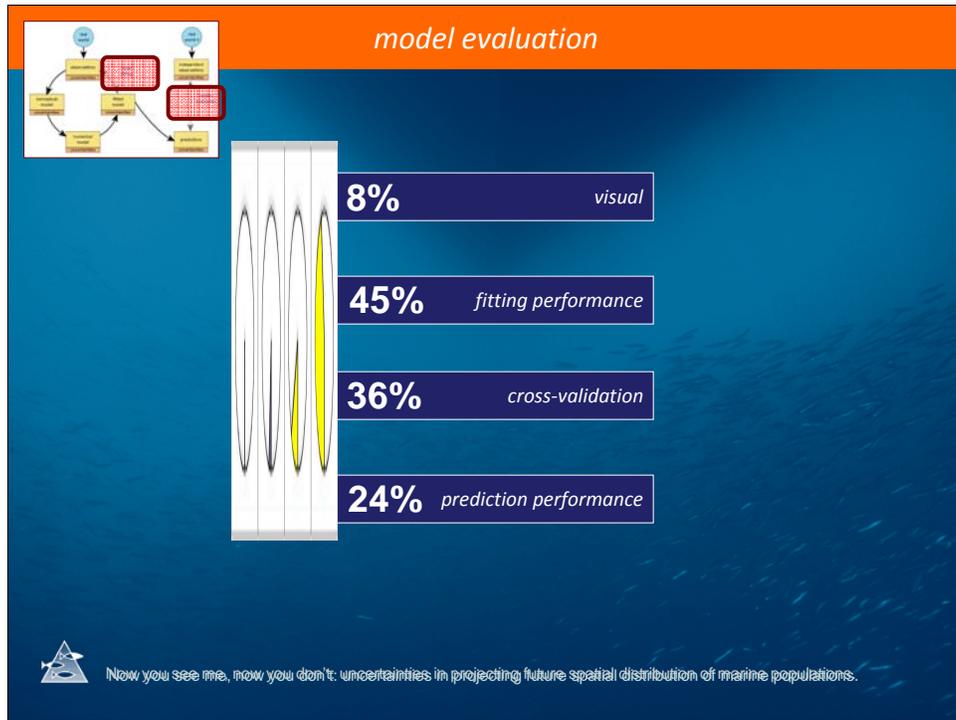
We investigated through a review of published papers over the last 5 years. Extracted from ISI (show figure). We only retained articles that were developing models which were or could be used in a predictive fashion.

### 3. Model evaluation, observation model



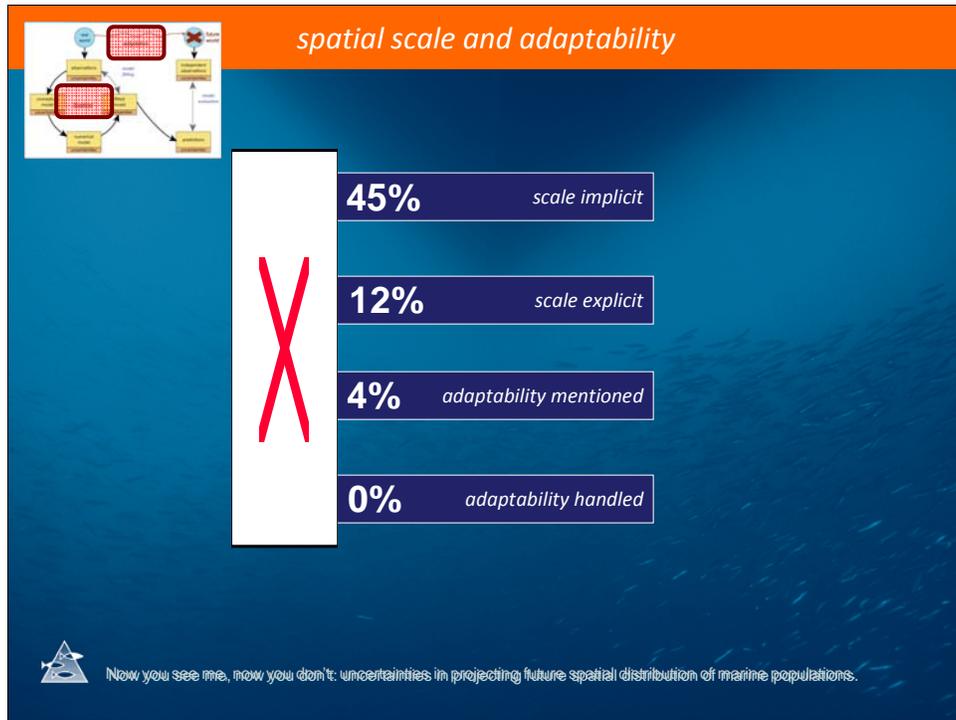
We investigated through a review of published papers over the last 5 years. Extracted from ISI (show figure). We only retained articles that were developing models which were or could be used in a predictive fashion.

#### 4. Scale and adaptability



We investigated through a review of published papers over the last 5 years. Extracted from ISI (show figure). We only retained articles that were developing models which were or could be used in a predictive fashion.

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#### 4. Scale and adaptability

## Review summary

- Uncertainty is seen primarily as parameter uncertainty
- Observation uncertainty is poorly investigated and not modelled
- Conceptual model uncertainty is generally ignored and environment models heavily dominate (+ spatial autocorrelation a little)
- Model validation is only performed on independent datasets in 1/4<sup>th</sup> of the studies analysed
- Adaptability of marine systems remains largely ignored



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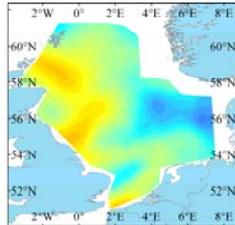
### Conclusions:

1. Uncertainty define our ability (or lack of) to provide an advice on the possible fate of marine populations under climate change. Ignoring uncertainty is ignoring the value of the result presented. It is therefore key that the is quantitatively determined in any attempts to project future species distributions (this point may be moved to the introduction).
2. Because what controls spatial distribution or marine populations is more than just temperature, model development is complex and the uncertainties are present in many areas (climate models, parameter estimates within one model, model uncertainty within a single hypothesis, and uncertainty in the hypotheses themselves)
3. The consequences on such uncertainties can be major as shown by the selected examples.
4. This is generally not considered by the scientific community currently working on these issues.

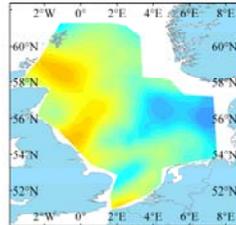
## An example of uncertainty in the conceptual model

North Sea whiting: three different candidate models with equivalent predictive power

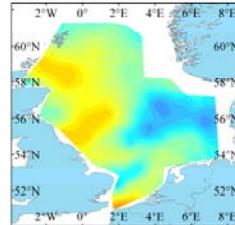
Model 1



Model 2



Model 3



- Geographical Attachment
- Environment
- Population size
- Population Demography
- Population Memory

- Geographical Attachment
- 
- Population size
- Population Demography
- Population Memory

- Environment
- Population size
- Population Demography
- Population Memory

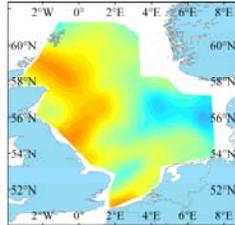


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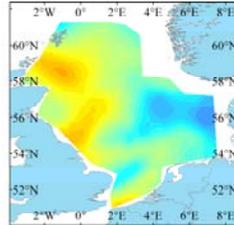
## An example of uncertainty in the conceptual model

Prediction under a scenario with 2° C temperature increase

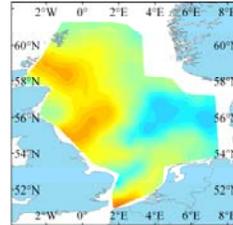
Model 1



Model 2



Model 3



Models 1 and 3 (with environment) forecast an increase of abundances whereas model 2 without environment does not forecast any change

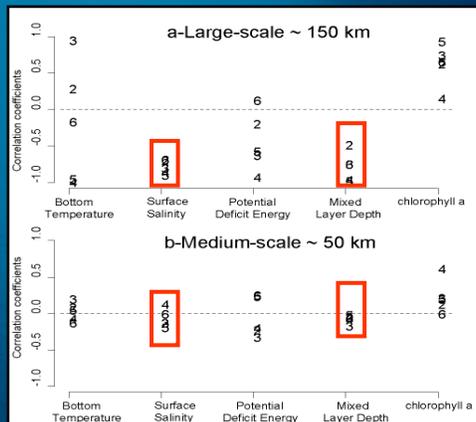
Three models with equivalent present-day predictive power,  
forecast different distribution with future conditions  
= uncertainty in predictions due to conceptual model uncertainty



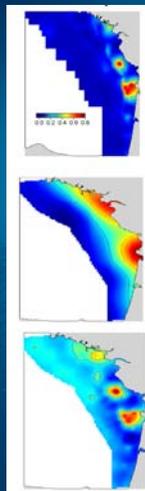
Now you see me, now you don't: uncertainties in projecting future spatial distribution of marine populations.

## An example of explicit account of scale

Correlation between the presence of auks (*Uria aalga*) and several hydrographic parameters, at 2 scales



Strong correlation at large scale and weak correlation at finer scale



observations

environmental model at large scale

environmental model at medium scale



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Bellier et al. in press

## Conclusion

Reliable projections of future spatial distribution of marine populations requires that uncertainty is considered in its entirety, from observations to concepts, numerical models and the potential for adaptations of living marine systems.

The lack of clear recognition of various sources of uncertainty, as is the case today, limits our ability to produce reliable, believable, and ultimately useful predictions.



Now you see me, now you don't: uncertainties in projecting future spatial distribution of marine populations.

# Thank you

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E. Bellier



NINA  
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F. Lasram



Univ.  
Montpellier  
France

C. Loots



DFO  
Canada

A post doctoral position is open to work on spatial distribution models in Tromsø for three years, starting in September 2010.  
If you are interested, please contact me: [benjamin.planque@imr.no](mailto:benjamin.planque@imr.no)



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