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Uncertainty and Policy-Making: How do we deal with the (known) unknowns?

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Some definitions – based on Knight (1921) *Risk, uncertainty & profit*

- **Risk** – the probability that something bad will happen. Possible outcomes are well known, probability of each can be estimated.
- **Pure uncertainty** – possible outcomes are known, but probabilities cannot be assigned reliably. When experts disagree = “the known unknowns”
- **Ignorance** – range of outcomes is not completely known. “the unknown unknowns”

The current state of opinion with marine mammals and noise

- Exposure to more than 160dB is bad, and more than 180dB very bad
- Exposure to **less** than 160dB can be very bad for beaked whales, and could be bad for some populations.
- But there is some disagreement as to why and when it's bad,
- and on how important it is.
- **Pure uncertainty** rather than **ignorance**.

Current mitigation measures

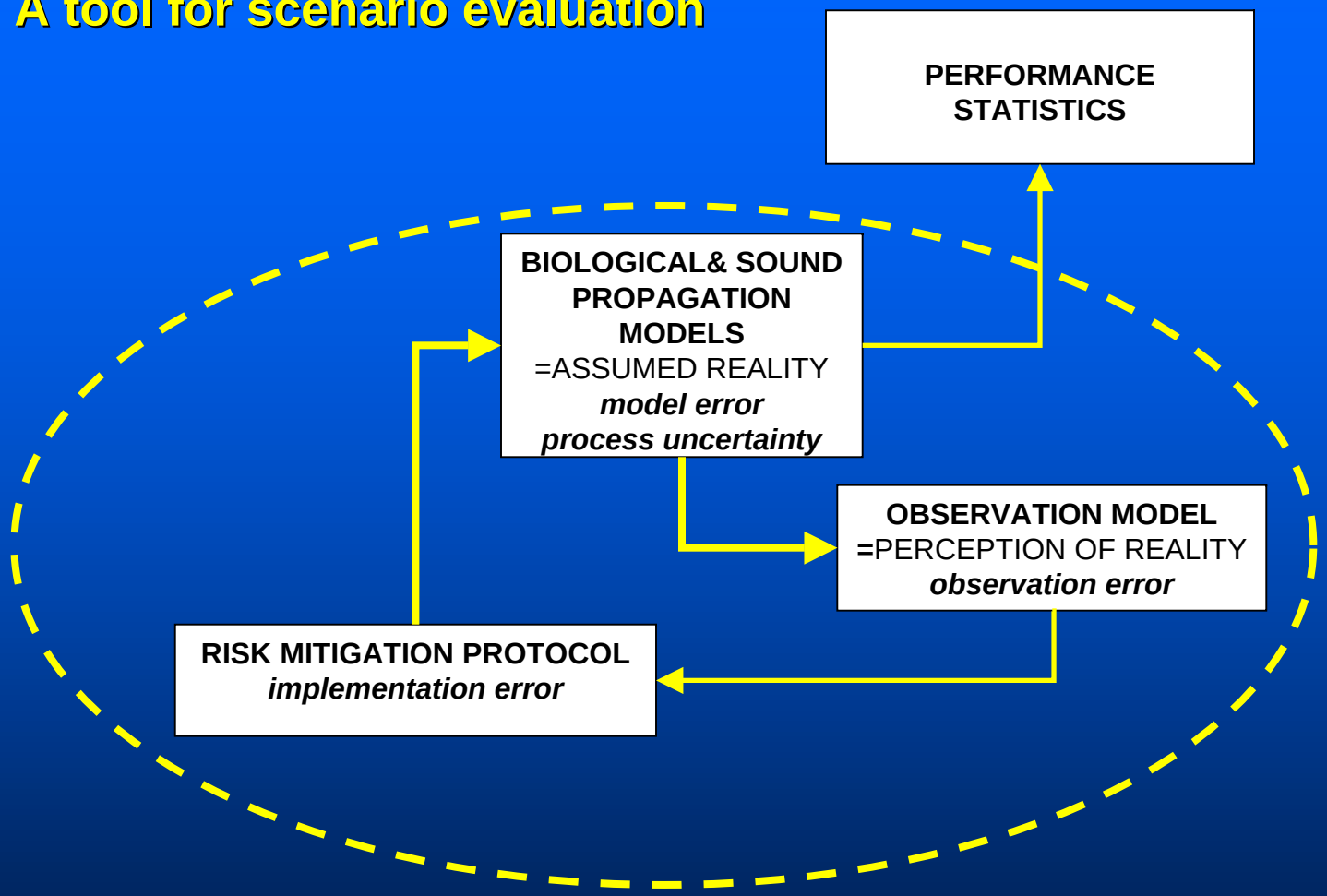
(MoD, JNCC, Maurice Ewing)

- Aim for a low probability that any individual is exposed to 160dB.
- Avoid areas/times of high cetacean abundance
- Calculate safety region around source
- Try to ensure that source is not emitting if a marine mammal is in or enters this region
- How much does this reduce **risk**?
- We don’t really know.

What do we do when experts disagree (or they agree that they don't know what will happen)?

- Compare the expected outcomes of different scenarios
- Look for a "minimax" risk mitigation protocol
- One way to implement the Precautionary Principle
- Models must account for uncertainty,
- particularly in the detection of animals in the "safety radius"/"standoff zone"
- and especially for beaked whales.

A tool for scenario evaluation



We can combine scenario evaluation and an appreciation of the consequences of uncertainty in the same way that the IWC developed its Revised Management Procedure

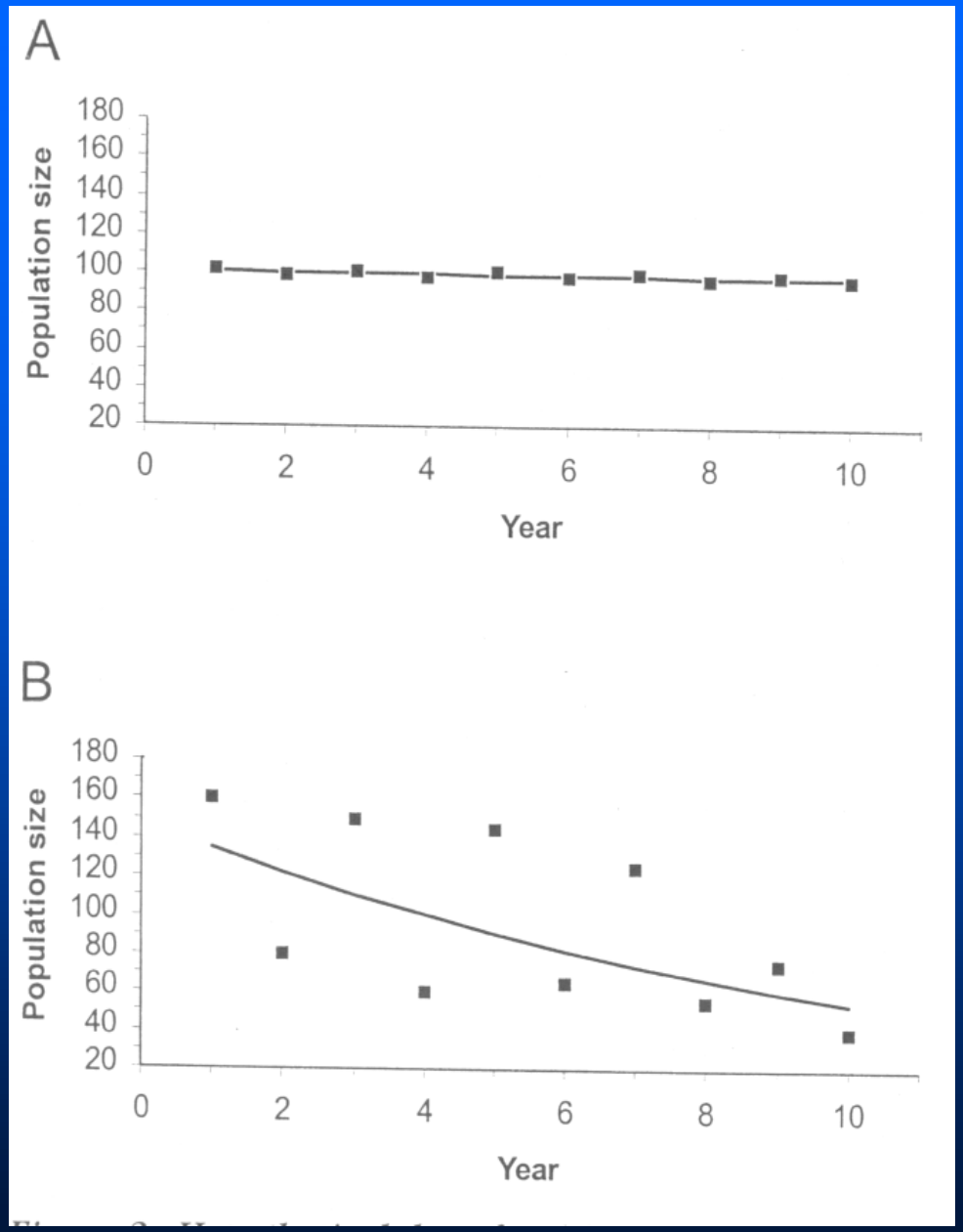
One step beyond the IWC/RMP approach: using new data to refine the models

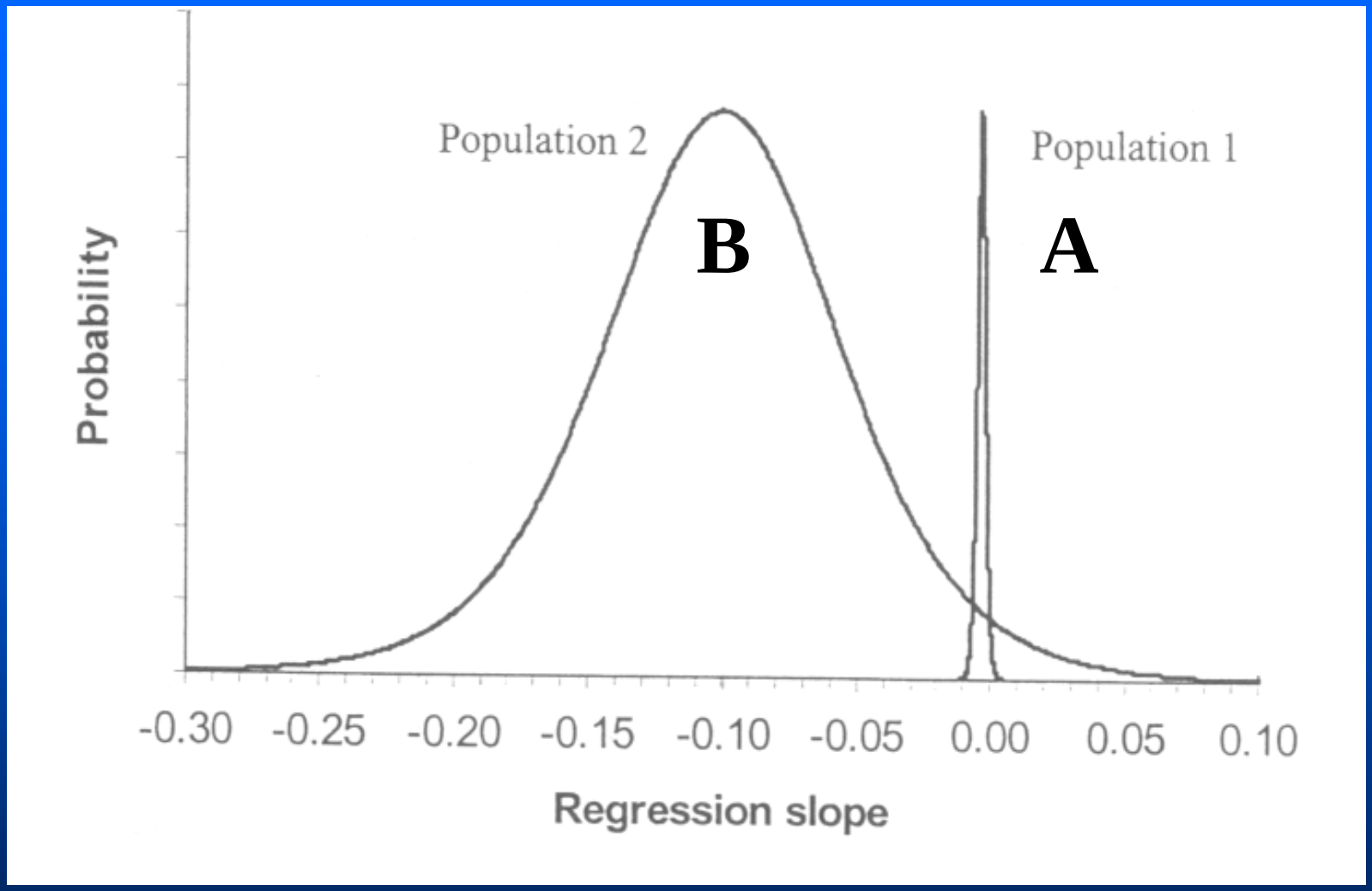
- Identify most **robust** protocol (effective across a wide range of scenarios)
- **Quantify** the benefits of current protocols (eg soft-starts/ramp-ups)
- Use a Bayesian approach to improve weak or subjective information

Rev Thomas Bayes

- 1701-1761
- Only published two papers
- The famous one was published posthumously in the Philosophical Transactions of the Royal Society in 1763
- “An essay towards solving a problem in the doctrine of chances”
- Uses prior information to interpret observations
- Accepts that many hypotheses may be compatible with the available data
- Appropriate for situations of “pure uncertainty”

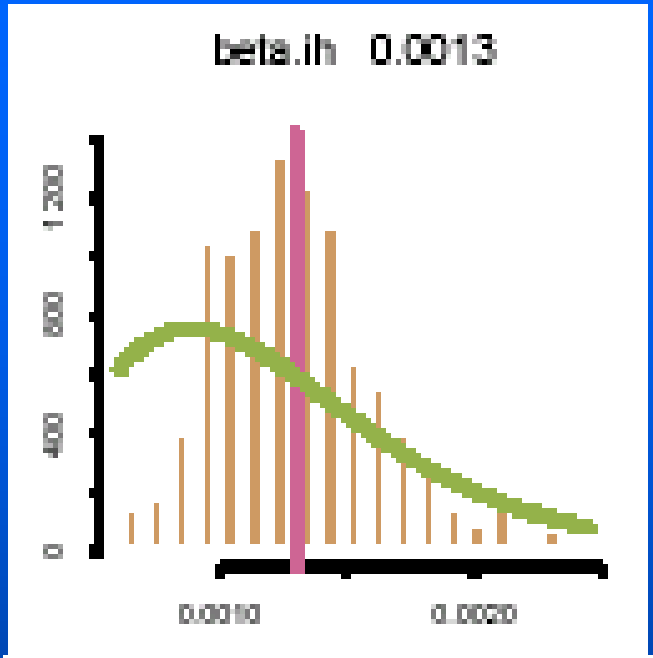
- An example from the work of Paul Wade, NMML
- Classical statistical analysis: population A is definitely decreasing (albeit very slowly), but can't be sure about population B.
- But the implications for population B are much more severe

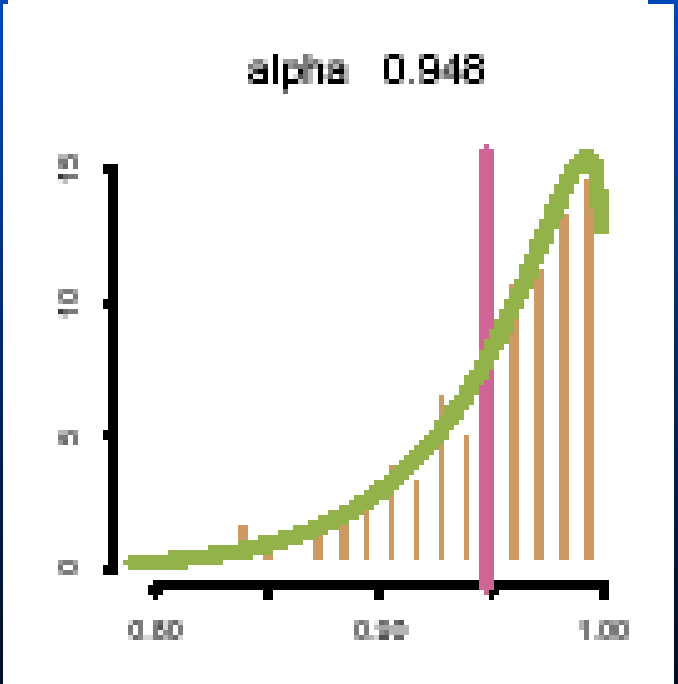




A Bayesian analysis indicates that the probability that population B is declining is 0.86 (ie pretty high!)

- Assign prior distribution for all the important parameters
- Challenge the model with data
- Generate new distributions (posteriors)
- Compare with priors
- Sometimes there's a big effect
- Sometimes there isn't
- Implies that new data ave done very little to reduce uncertainty

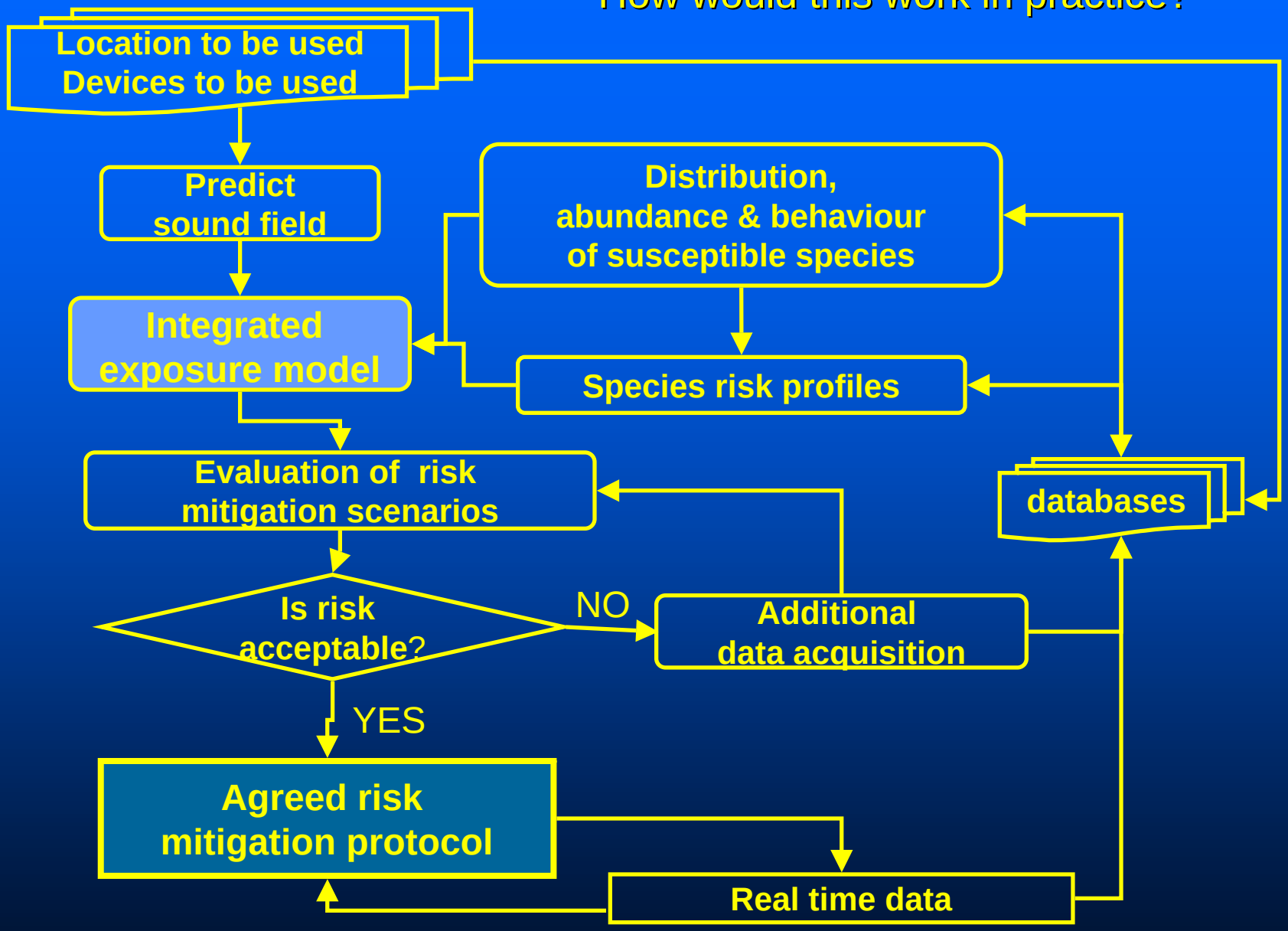




What are the advantages in this context?

- Provides an incentive to collect new information
- Helps identify what new information is most likely to reduce risk
- Is **transparent** (the form of the priors documents precisely what is being assumed)
- Can provide an incentive for high levels of vigilance

How would this work in practice?



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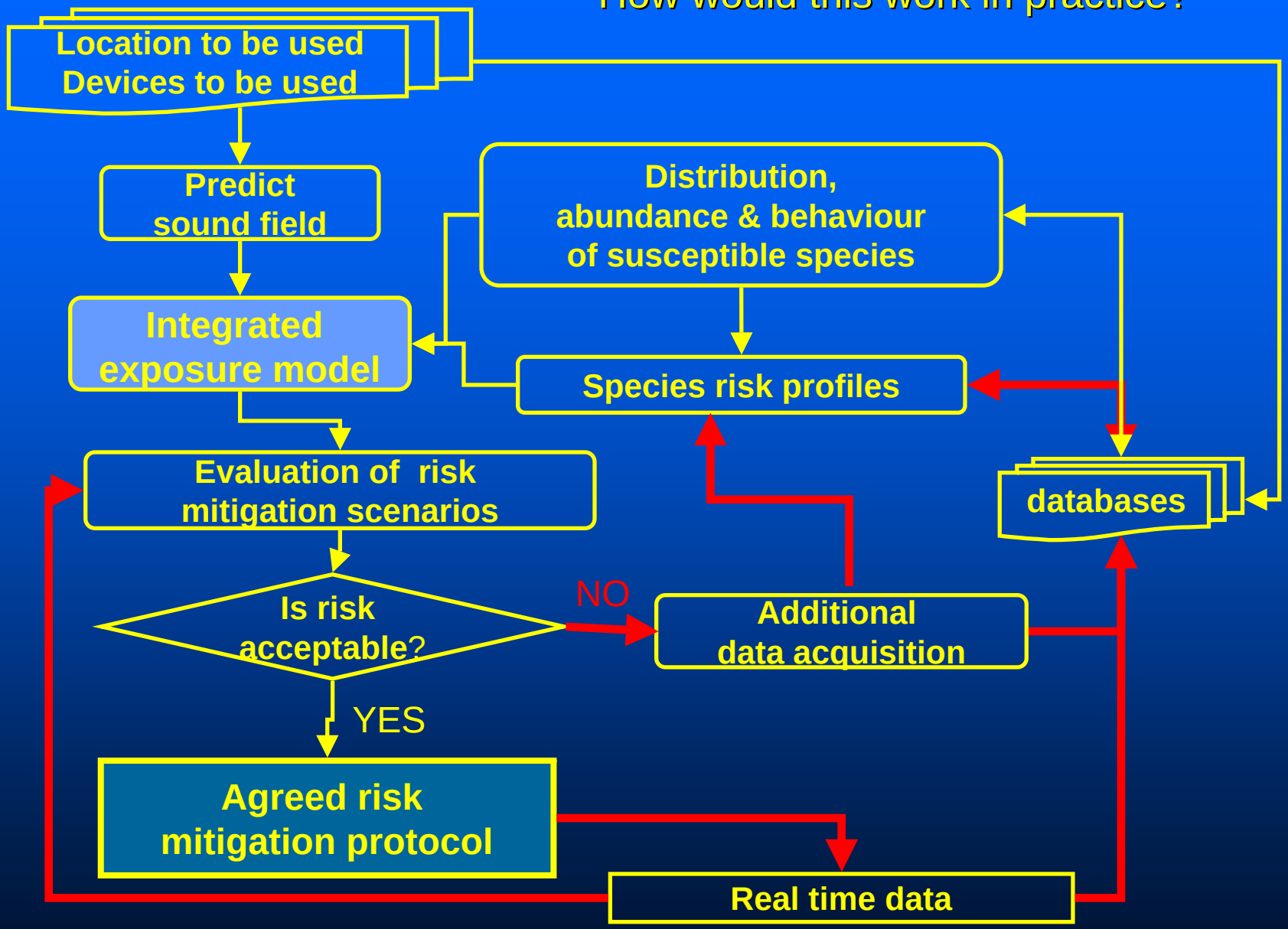

What are the implications for policy-making?

- We need a scenario-based tool for identifying **robust** risk mitigation – think RMP
- This will allow operators and regulators to document the extent to which different protocols reduce risk.
- Risk assessments must account for uncertainty – think PBR.
- Take advantage of a Bayesian approach to provide **transparency**, incorporate new data and plan experiments