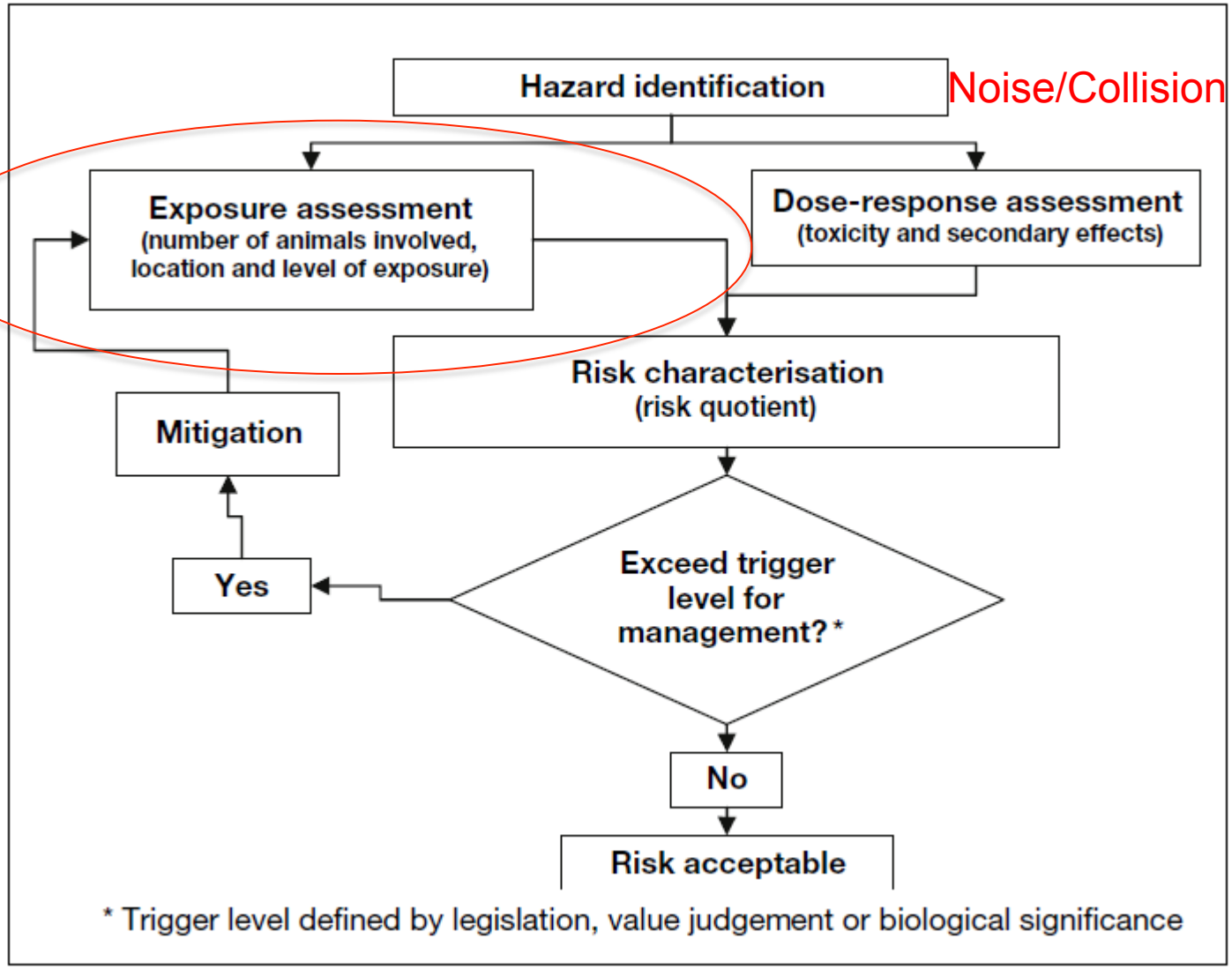
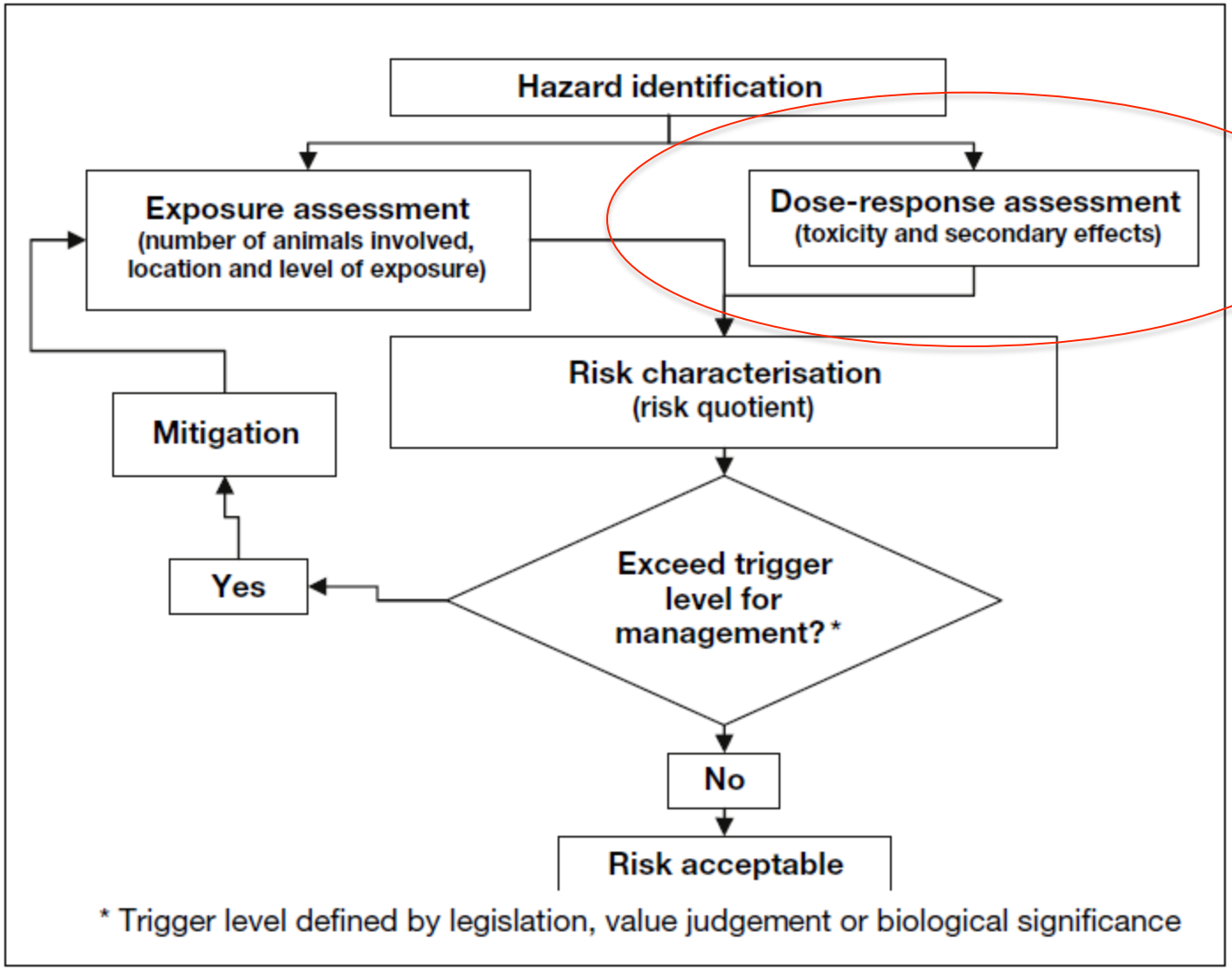
An introduction to the Interim PCoD Framework: background and model structure

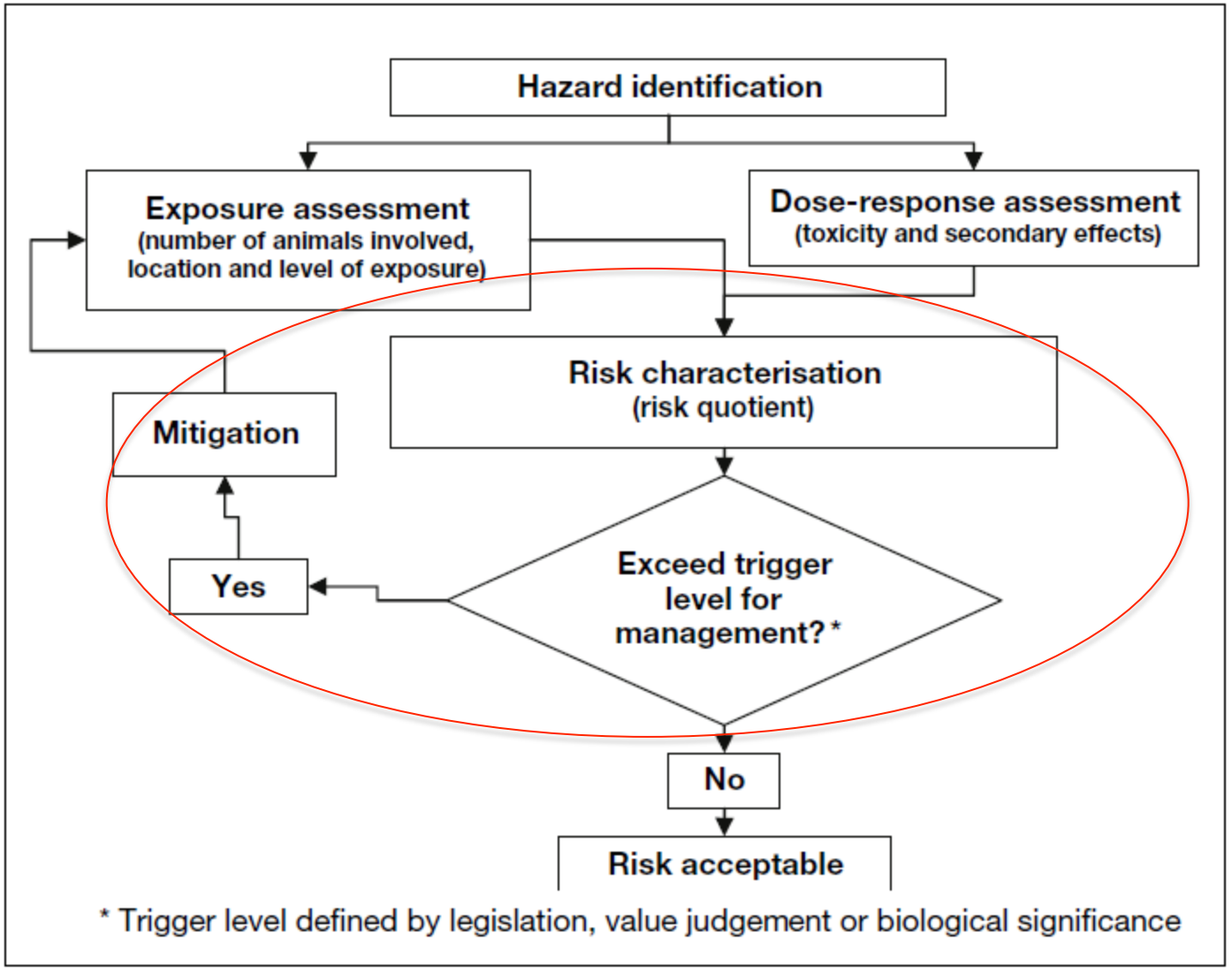
What you need and what you need to know to run the framework



A variety of tools are available to determine the number of animals that may experience particular RLs or SELS during **one day of operation**.
E.g. SAFESIMM, SAKAMATA, ESME, NAEMO, INSPIRE
Collision risk is more difficult to evaluate



Behavioural dose-response relationships have now been developed for a number of marine mammal species (e.g. ONR-funded MOCHA programme).
Dose-response relationships for injury (PTS) are based on captive studies of onset of TTS and extrapolation to PTS.

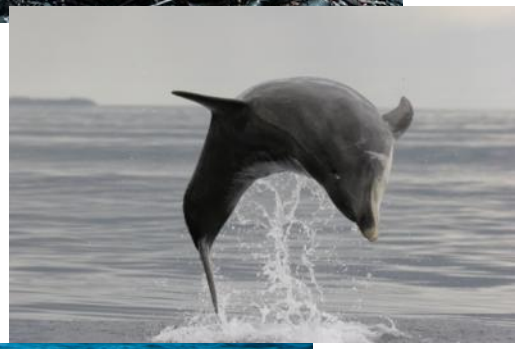


The Interim PCoD framework is mainly concerned with these aspects of the risk assessment

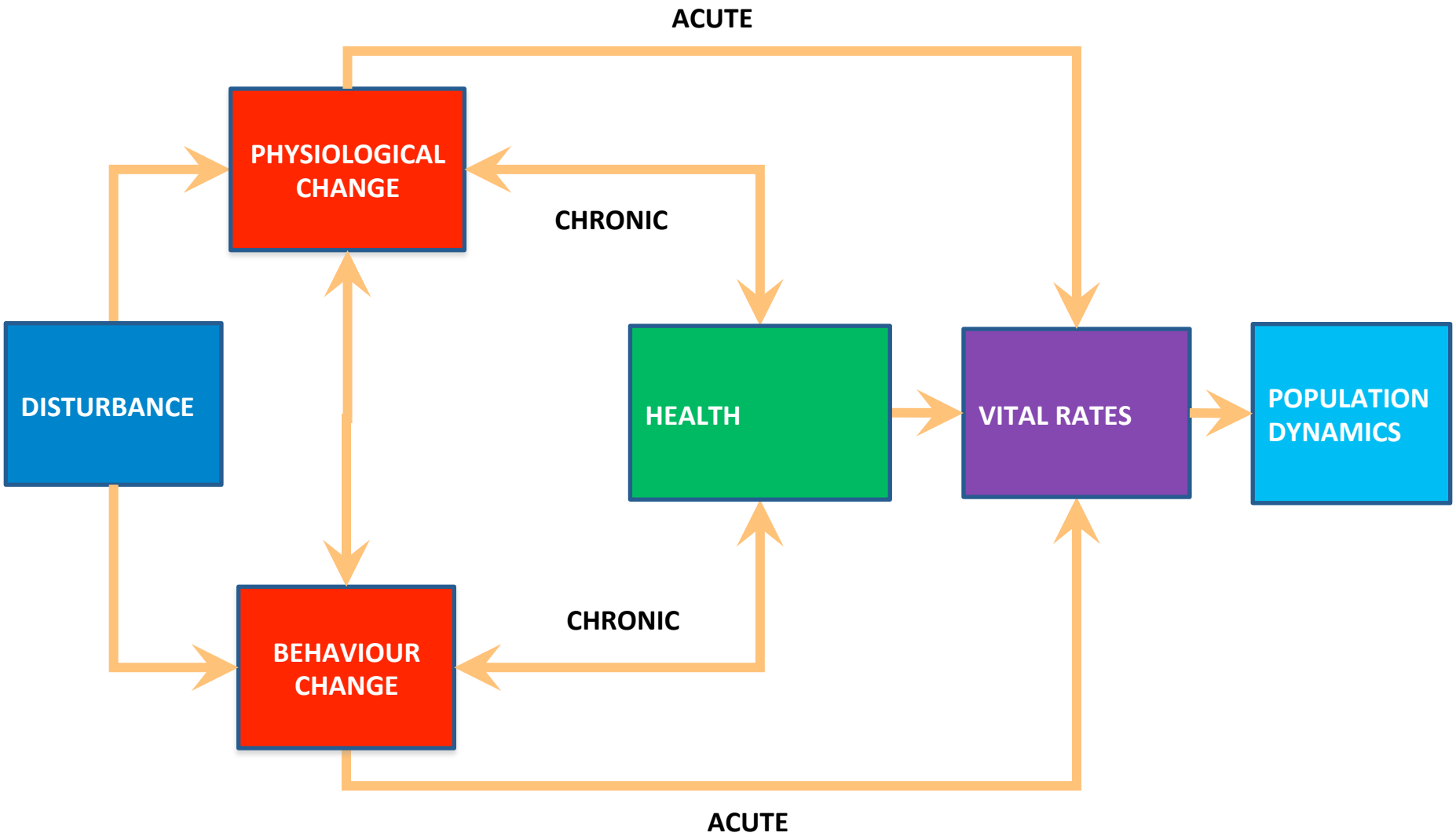
ONR Working Group on Population Consequences of Disturbance

- Identify & use most robust datasets available
- Span a range of taxonomic groups and reproductive strategies (income vs capital breeders)

- Elephant Seals
- Coastal Bottlenose Dolphins
- North Atlantic Right Whale
- Beaked Whales

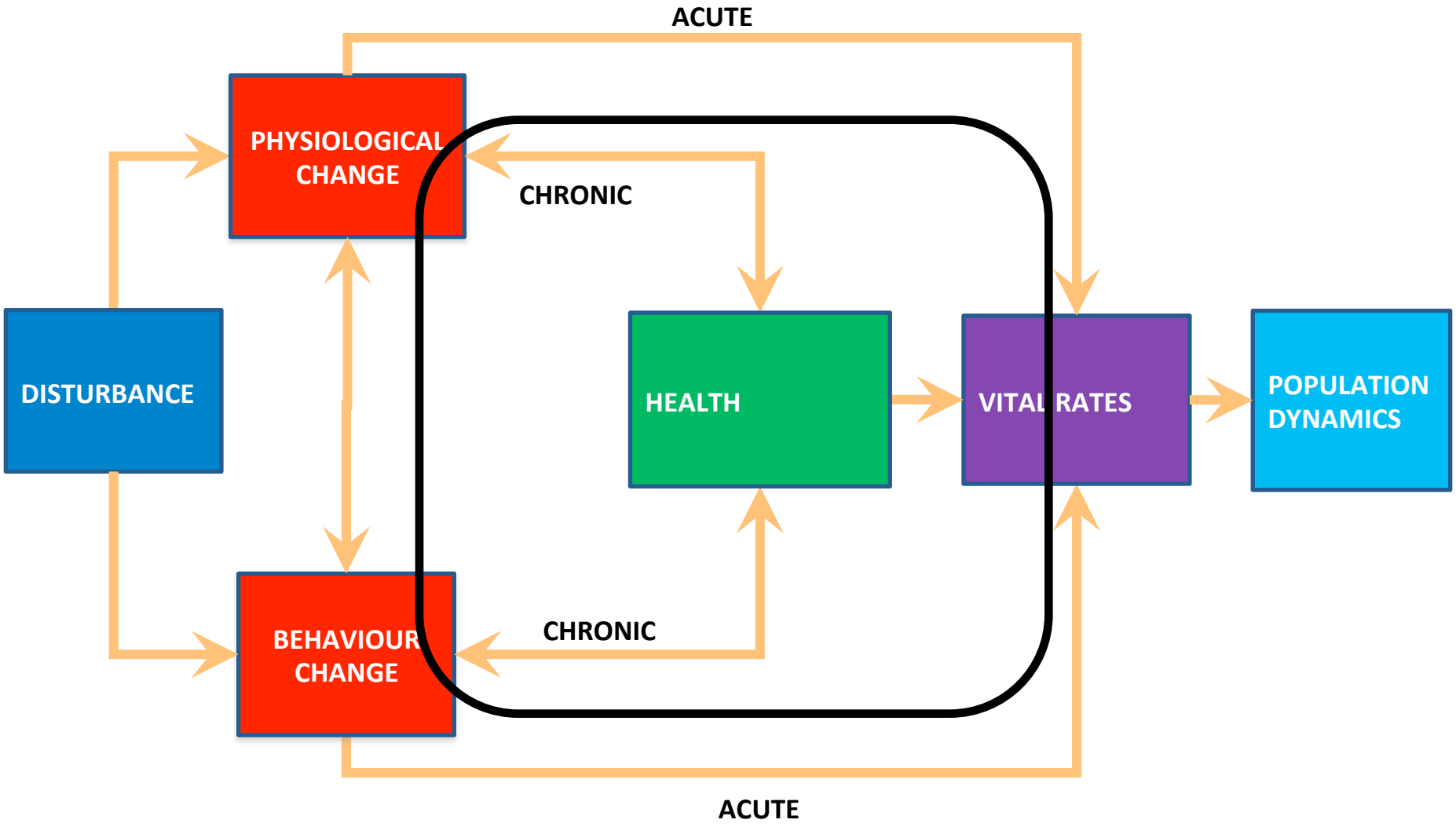


New PCoD Conceptual Model



New et al. 2014

However, these links will be difficult to quantify for most populations



- There are not enough data to build full PCoD models for most populations of the case study species,
- and for all populations of most other marine mammal species.
- How can we provide advice on the consequences of sound exposure for these populations?
- One possibility is to use expert judgment to fill this gap until empirical data are available

nature Vol 463|21 January 2010

OPINION

A route to more tractable expert advice

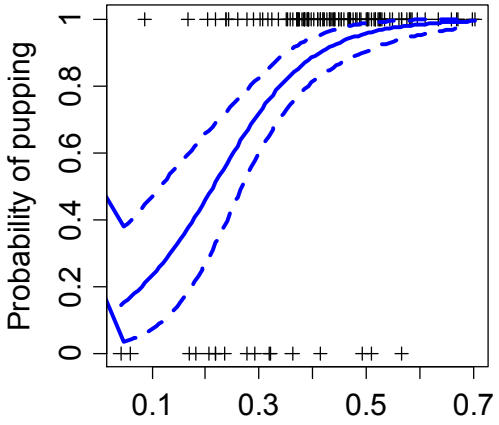
There are mathematically advanced ways to weigh and pool scientific advice. They should be used more to quantify uncertainty and improve decision-making, says **Willy Aspinall**.

Expert Judgement

- Rigorous set of methods for synthesizing expert knowledge to inform decision-making
- Reliable and practicable when empirical data are limited
- Quantifies scientific uncertainty and minimizes inadvertent bias in the elicited information
- Useful for identifying plausible alternative hypotheses, estimating model parameters, and prioritizing collection of data that have the greatest bearing on policy or management decisions

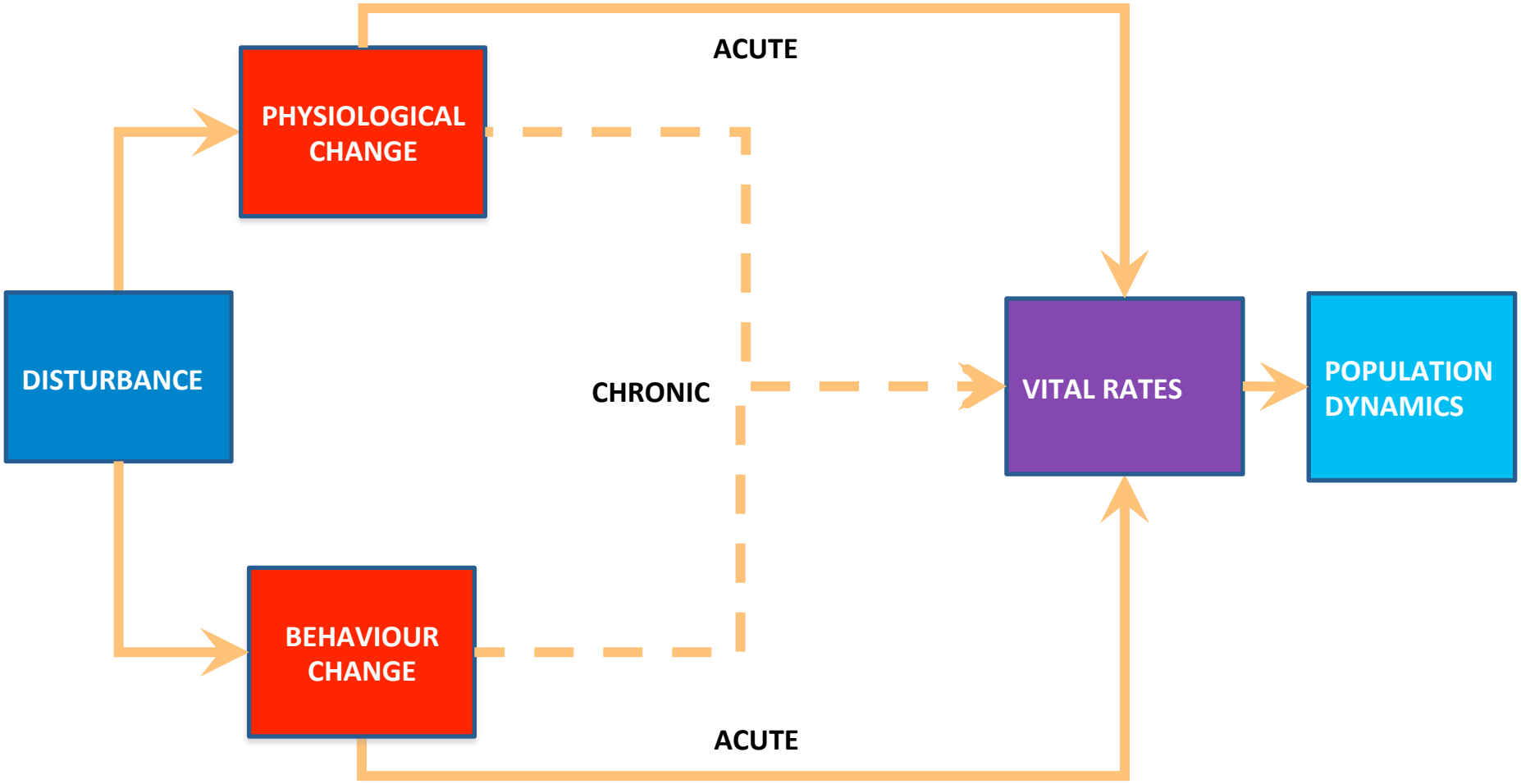
Some take home messages from the ONR working group

- The main effects of disturbance are likely to be on net energy intake, not predation risk
- Probability of giving birth and juvenile survival are the vital rates most likely to be affected by disturbance
- Most marine mammal populations can probably tolerate some disturbance (e.g. relationship between fertility and energy intake in elephant seals)
- However, the threshold level will depend on the availability of resources (bottlenose dolphins in Sarasota Bay vs Shark Bay)



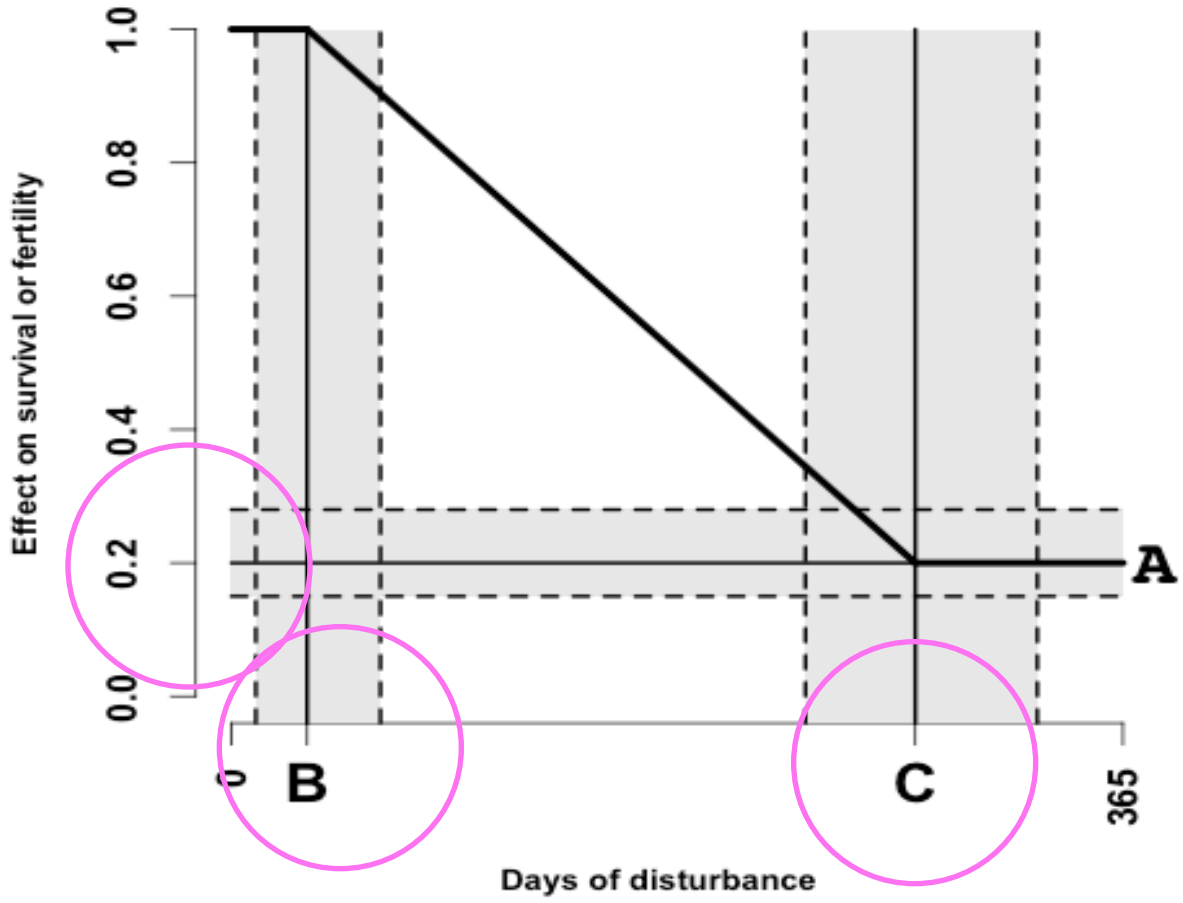
Schwarz *et al*. (in prep)

An interim version of the PCoD conceptual model



Use expert judgement to quantify the potential effects of physiological and behavioural change on vital rates

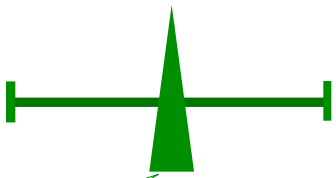
We asked experts for their best estimates of these three quantities, and the accompanying uncertainty for each of the five species in the NE Atlantic



4-step question format…

1. Realistically, what do you think the lowest plausible value is?

2. Realistically, what do you think the highest plausible value is?

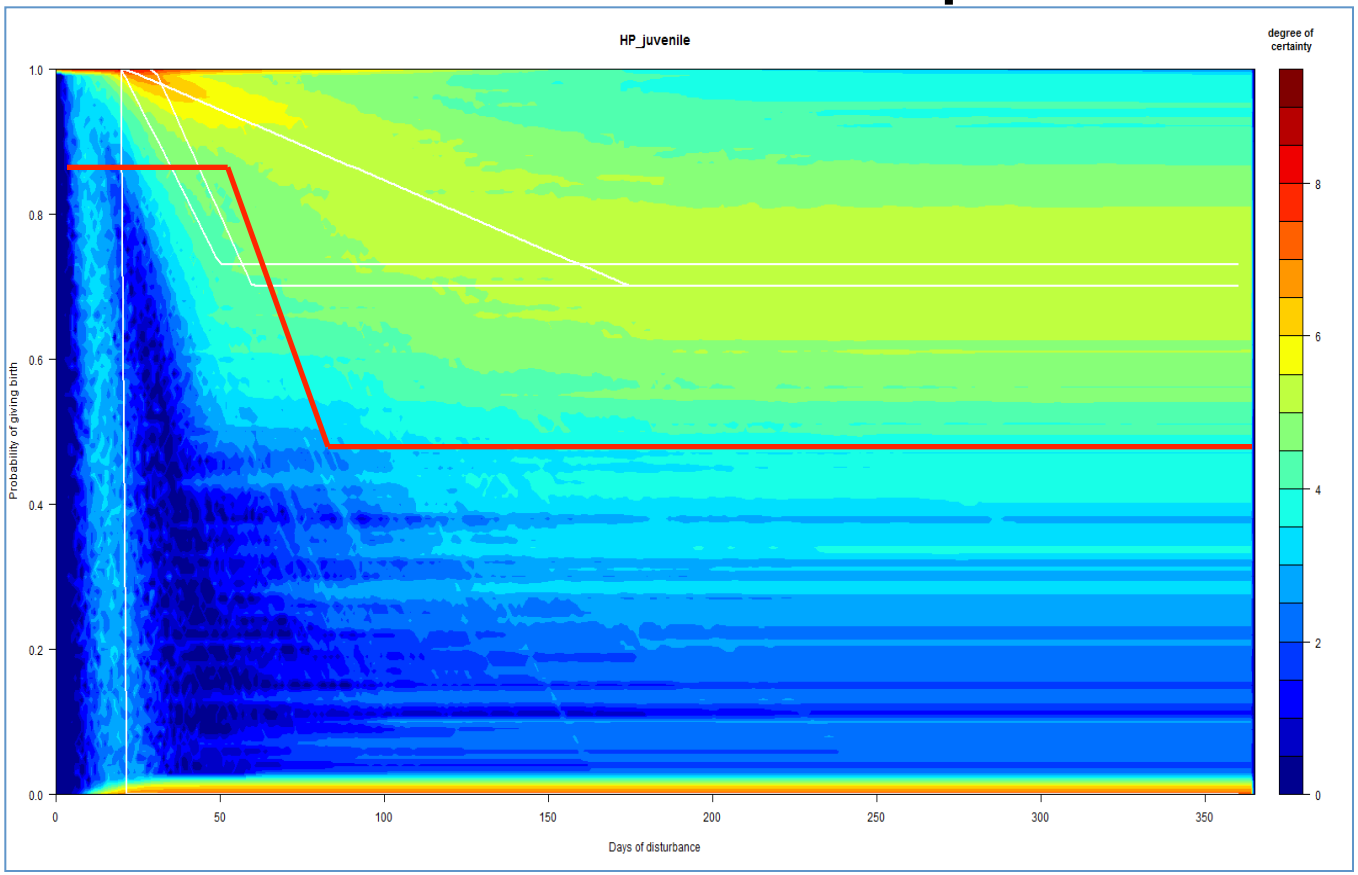


3. Realistically, what is your best estimate?

4. How confident are you that the interval you created, from lowest to highest, could capture the true value? Enter a number between 50 and 100%.

(Speirs-Bridge et al., 2010)

Estimating the effects of disturbance on each individual's vital rates: the combined judgement of all experts, and one "virtual" expert



Donovan et al. (in press)

Information required to implement the interim PCoD approach

- The sound field produced during construction and operation of a particular development (with associated uncertainty).
- The sound levels that are likely to cause PTS for each species.
- The sound levels that are likely to result in a significant behavioural response for each species.
- Estimates of the number of animals of each species that may be exposed to sound levels that could result in PTS, and of the number that may show a 'significant' behavioural response during one day of construction.
- The number of animals that are likely to be exposed to sound levels likely to result in PTS or a 'significant' behavioural response over the entire course of construction.
- An estimate of the number of animals that might be killed or injured during one year of operation for an operational wave or tidal project, or a range of plausible values.
- The potential effect of experiencing PTS at a specified frequency on the vital rates for an individual of each species, by age/stage class (e.g. adult males, adult females, calves, juveniles), with associated uncertainty.
- A mathematical function linking the number of days on which an individual experiences a 'significant' behavioural response and its vital rates, with associated uncertainty, for the different age classes of each priority species.
- The current population size and population history for each MU.
- Estimates of the key demographic parameters (adult survival, calf survival, juvenile survival, annual probability of pupping/calving, age at first pupping/calving, longevity) for each species, in each MU, with an indication of likely levels of variation between years.

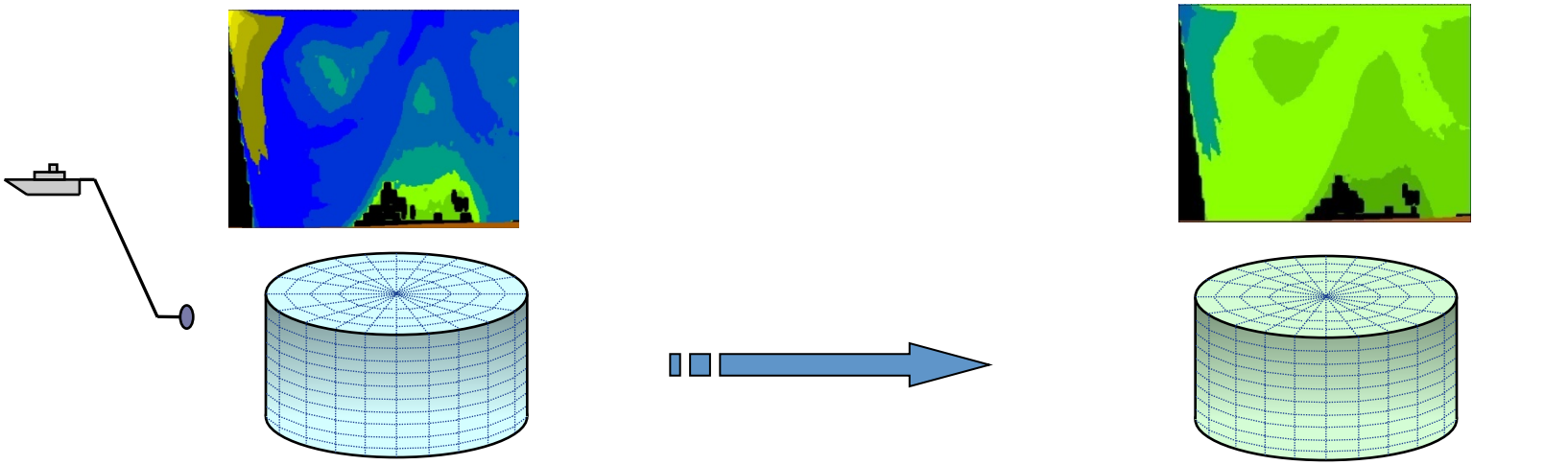
Information required to implement the interim PCoD approach

- The sound field produced during construction and operation of a particular development (with associated uncertainty).
- The sound levels that are likely to cause PTS for each species.
- The sound levels that are likely to result in a significant behavioural response for each species.
- Estimates of the number of animals of each species that may be exposed to sound levels that could result in PTS, and of the number that may show a 'significant' behavioural response during one day of construction.
- The number of animals that are likely to be exposed to sound levels likely to result in PTS or a 'significant' behavioural response over the entire course of construction.
- An estimate of the number of animals that might be killed or injured during one year of operation for an operational wave or tidal project, or a range of plausible values.
- The potential effect of experiencing PTS at a specified frequency on the vital rates for an individual of each species, by age/stage class (e.g. adult males, adult females, calves, juveniles), with associated uncertainty.
- A mathematical function linking the number of days on which an individual experiences a 'significant' behavioural response and its vital rates, with associated uncertainty, for the different age classes of each priority species.
- The current population size and population history for each MU.
- Estimates of the key demographic parameters (adult survival, calf survival, juvenile survival, annual probability of pupping/calving, age at first pupping/calving, longevity) for each species, in each MU, with an indication of likely levels of variation between years.

Estimates of the number of marine mammals that may be injured or disturbed during one day of operation are often included in developers' Environmental Statements

Packages such as SAFESIMM, SAKAMATA, ESME, NAEMO and INSPIRE use agent-based models to estimate these quantities.

Interim PCoD does not have a facility to estimate them



Sound propagation model gives Sound Field

Species or guild-specific audiograms

Sound Field combined with hearing ability gives Effect Field

Estimates of the number of marine mammals that may be injured or disturbed during the entire operation

- The interim PCoD approach uses simplified version of the agent-based models used to estimate daily exposure to predict the range of exposures experienced by individual animals over the entire period of operation
- It can model situations where all individuals, or only a fraction of the population, are susceptible to noise or collision
- It then uses expert judgement to infer the potential effects of these different exposures on individual vital rates

Information required to implement the interim PCoD approach

- The sound field produced during construction and operation of a particular development (with associated uncertainty).
- The sound levels that are likely to cause PTS for each species.
- The sound levels that are likely to result in a significant behavioural response for each species.
- Estimates of the number of animals of each species that may be exposed to sound levels that could result in PTS, and of the number that may show a 'significant' behavioural response during one day of construction.
- The number of animals that are likely to be exposed to sound levels likely to result in PTS or a 'significant' behavioural response over the entire course of construction.
- The number of animals that might be killed or injured during one year of operation for an operational wave or tidal project (given that the probability of collision or entanglement per day is likely to be low), or a range of possible values, if it is impossible to provide an actual estimate.
- The potential effect of experiencing PTS at a specified frequency on the vital rates for an individual of each species, by age/stage class (e.g. adult males, adult females, calves, juveniles), with associated uncertainty;
- A mathematical function linking the number of days on which an individual experiences a 'significant' behavioural response and its vital rates, with associated uncertainty, for the different age classes of each priority species.
- The current population size and population history for each MU.
- Estimates of the key demographic parameters (adult survival, calf survival, juvenile survival, annual probability of pupping/calving, age at first pupping/calving, longevity) for each species, in each MU, with an indication of likely levels of variation between years.

Information required to implement the interim PCoD approach

- The sound field produced during construction and operation of a particular development (with associated uncertainty).
- The sound levels that are likely to cause PTS for each species.
- The sound levels that are likely to result in a significant behavioural response for each species.
- Estimates of the number of animals of each species that may be exposed to sound levels that could result in PTS, and of the number that may show a 'significant' behavioural response during one day of construction.
- The number of animals that are likely to be exposed to sound levels likely to result in PTS or a 'significant' behavioural response over the entire course of construction.
- The number of animals that might be killed or injured during one year of operation for an operational wave or tidal project (given that the probability of collision or entanglement per day is likely to be low), or a range of possible values, if it is impossible to provide an actual estimate.
- The potential effect of experiencing PTS at a specified frequency on the vital rates for an individual of each species, by age/stage class (e.g. adult males, adult females, calves, juveniles), with associated uncertainty;
- A mathematical function linking the number of days on which an individual experiences a 'significant' behavioural response and its vital rates, with associated uncertainty, for the different age classes of each priority species.
- The current population size and population history for each MU.
- Estimates of the key demographic parameters (adult survival, calf probability of pupping/calving, age at first pupping/calving, longe an indication of likely levels of variation between years.

Inter-Agency Marine Mammal Working Group report on MUs for Marine Mammals

Information required to implement the interim PCoD approach

- The sound field produced during construction and operation of a particular development (with associated uncertainty).
- The sound levels that are likely to cause PTS for each species.
- The sound levels that are likely to result in
- Estimates of the number of animals of eac
  in PTS, and of the number that may show
  construction.
- The number of animals that are likely to b
  behavioural response over the entire cour
- The number of animals that might be kille
  wave or tidal project (given that the proba
  a range of possible values, if it is impossib
- The potential effect of experiencing PTS a
  species, by age/stage class (e.g. adult mal
- A mathematical function linking the numb
  behavioural response and its vital rates, w
  priority species.
- The current population size and populatio
- Estimates of the key demographic parameters (adult survival, calf survival, juvenile survival, annual probability of pupping/calving, age at first pupping/calving, longevity) for each species, in each MU, with an indication of likely levels of variation between years.

This information is then incorporated into stochastic dynamic models for populations of each species

- Essentially a form of Population Viability Analysis, but accounts for more sources of uncertainty than a standard PVA
- Compares changes in size of many 100s of pairs of simulated populations that differ only in whether or not they experience disturbance
- Indicates the likely range of population consequences given current levels of scientific uncertainty about underlying processes.
- Not intended to provide a “best” estimate of these consequences
- Only an interim solution until more empirical data become available
- Can be used to identify what research is most likely to reduce uncertainty.

A protocol for implementing the interim PCoD approach

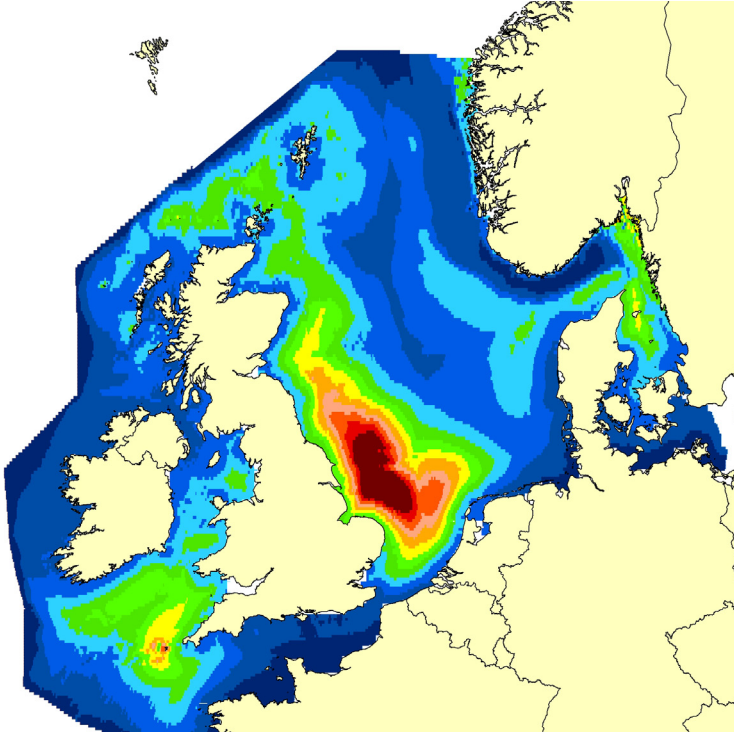
- Identify the marine mammal MUs that may be affected by each development.
- Look up the estimate for the current size of the population in each MU.
- Look up the appropriate values for the key demographic rates in Harwood & King
- Decide on a range of values for the proportion (or proportions) of this population that is likely to be vulnerable to the effects of each development.
- Prepare a schedule of information on the estimated days on which activity (e.g. piling or turbine operation) are expected to take place for each development.
- Compile estimates of the number of animals of the species under consideration that may be disturbed or experience PTS on each day of construction work. The default is to assume that these values are constant throughout the year. However, it is possible to specify different values for different seasons.
- Decide on an appropriate range of values for the number of days of 'residual' disturbance associated with one day of actual disturbance
- Decide which model for vulnerability to PTS will be used.
- Compile estimates of the number of animals in the same MU that may be involved in collisions or entanglement with tidal turbines or wave energy devices during each year of operation.
- Prepare appropriate data files, run the R program files and compare the results of the different scenarios.

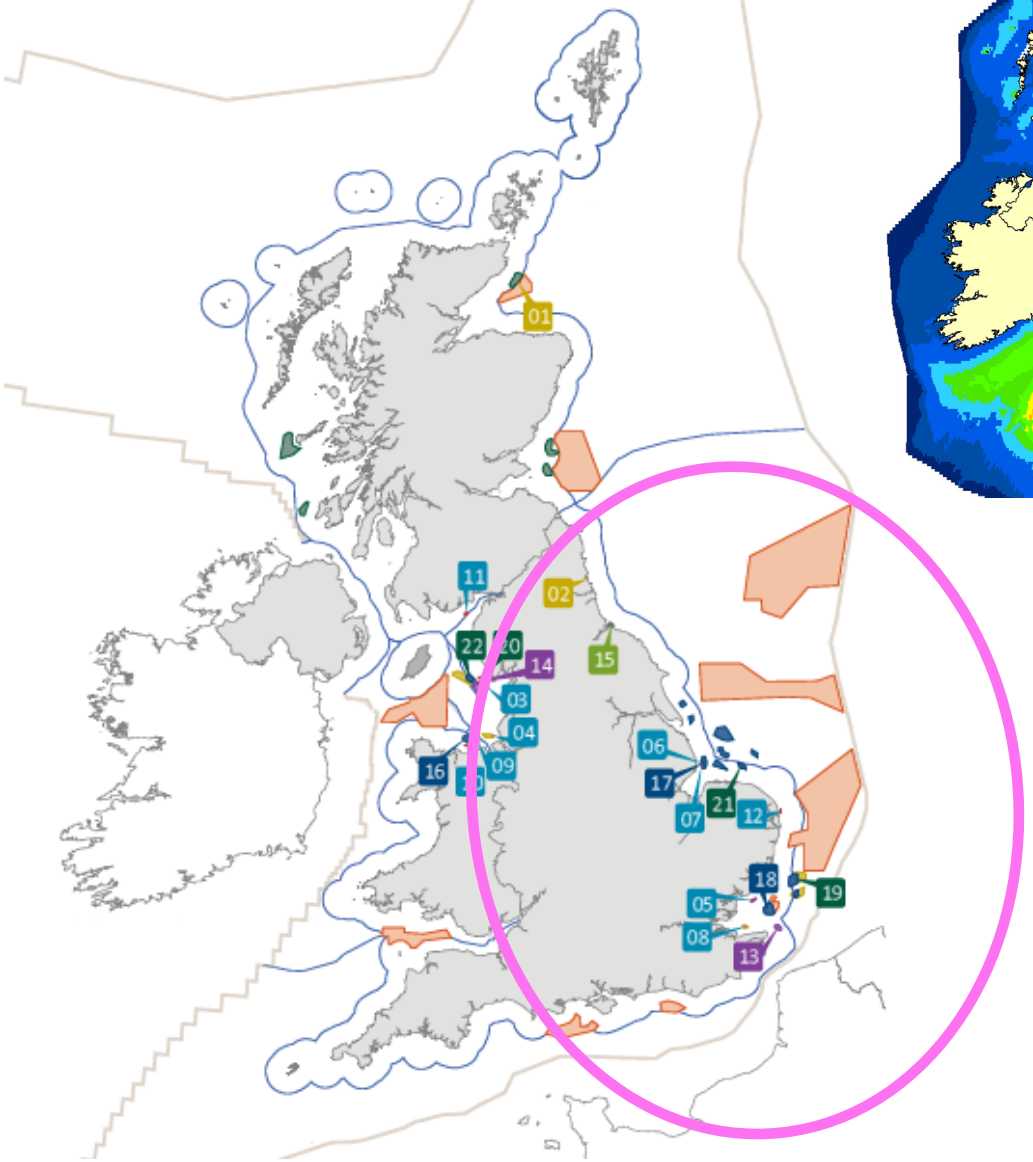
A protocol for implementing the interim PCoD approach

- Identify the marine mammal MUs that may be affected by each development.
- Look up the estimate for the current size of the population in each MU.
- Look up the appropriate values for the key demographic rates in Harwood & King.
- Decide on a range of values for the proportion (or proportions) of this population that is likely to be vulnerable to the effects of each development.
- Prepare a schedule of information on the estimated days on which activity (e.g. piling or turbine operation) are expected to take place for each development.
- Compile estimates of the number of animals of the species under consideration that may be disturbed or experience PTS on each day of construction work. The default is to assume that these values are constant throughout the year. However, it is possible to specify different values for different seasons.
- Decide on an appropriate range of values for the number of days of 'residual' disturbance associated with one day of actual disturbance
- Decide which model for vulnerability to PTS will be used.
- Compile estimates of the number of animals in the same MU that may be involved in collisions or entanglement during each year of operation.
- Prepare appropriate data files, run the R program files and compare the results of the different scenarios.

Defining Vulnerable Sub-Populations:

e.g. North Sea harbour porpoise

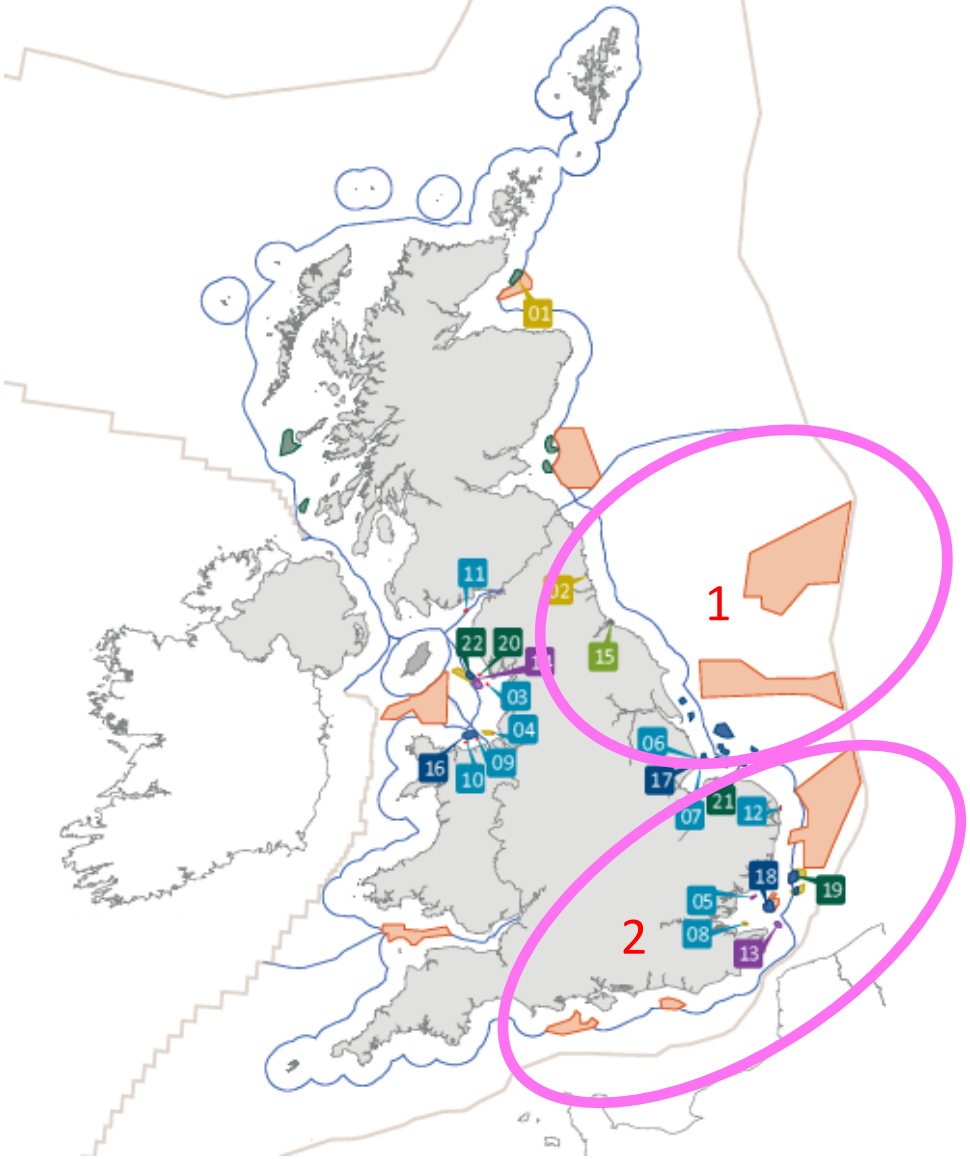




Vulnerable Sub-Population corresponds to animals in SCANS II Blocks B, H , U and Y = 61.7% of North Sea population

Defining Vulnerable Sub-Populations:

e.g. North Sea harbour porpoise



Vulnerable Sub-Population 1 corresponds to animals in SCANS II Blocks H , U and Y
= 43.7% of North Sea population

Vulnerable Sub-Population 2 corresponds to animals in SCANS II Block B
= 18% of North Sea population

A protocol for implementing the interim PCoD approach

- Identify the marine mammal MUs that may be affected by each development.
- Look up the estimate for the current size of the population in each MU.
- Look up the appropriate values for the key demographic rates in Harwood & King
- Decide on a range of values for the proportion (or proportions) of this population that is likely to be vulnerable to the effects of each development = **Vulnerable Sub-Population.**
- Prepare a schedule of information on the estimated days on which activity (e.g. piling or turbine operation) are expected to take place for each development.
- Compile estimates of the number of animals of the species under consideration that may be disturbed or experience PTS on each day of construction work. The default is to assume that these values are constant throughout the year. However, it is possible to specify different values for different seasons.
- Decide on an appropriate range of values for the number of days of 'residual' disturbance associated with one day of actual disturbance
- Decide which model for vulnerability to PTS will be used.
- Compile estimates of the number of animals in the same MU that may be involved in collisions or entanglement during each year of operation.
- Prepare appropriate data files, run the R program files and compare the results of the different scenarios.

‘Residual’ disturbance

- There is considerable evidence (at least for harbour porpoises and beaked whales) that animals disturbed by anthropogenic noise may be displaced from the area where disturbance occurs for more than one day
- The interim PCoD framework provides an option to model this by adding “residual” days of disturbance to each day of actual disturbance
- In the absence of empirical data on the actual number of residual days of disturbance caused by, for example, piling activity, this option makes it possible to explore the sensitivity of the models predictions to this effect.

A protocol for implementing the interim PCoD approach

- Identify the marine mammal MUs that may be affected by each development.
- Look up the estimate for the current size of the population in each MU.
- Look up the appropriate values for the key demographic rates in Harwood & King
- Decide on a range of values for the proportion (or proportions) of this population that is likely to be vulnerable to the effects of each development = **Vulnerable Sub-Population.**
- Prepare a schedule of information on the estimated days on which activity (e.g. piling or turbine operation) are expected to take place for each development.
- Compile estimates of the number of animals of the species under consideration that may be disturbed or experience PTS on each day of construction work. The default is to assume that these values are constant throughout the year. However, it is possible to specify different values for different seasons.
- Decide on an appropriate range of values for the number of days of 'residual' disturbance associated with one day of actual disturbance
- Decide which model for vulnerability to PTS will be used.
- Compile estimates of the number of animals in the same MU that may be involved in collisions or entanglement during each year of operation.
- Prepare appropriate data files, run the R program files and compare the results of the different scenarios.

Vulnerability to PTS

- The basic interim PCoD model assumes that individuals are always at the same risk of experiencing PTS, no matter what their exposure history
- We've included an option to assume that animals will avoid the area closest to a source of disturbance after their first exposure to noise from this source.
- The result of this is that the risk of experiencing PTS is substantially (excessively?) reduced once animals have experienced disturbance

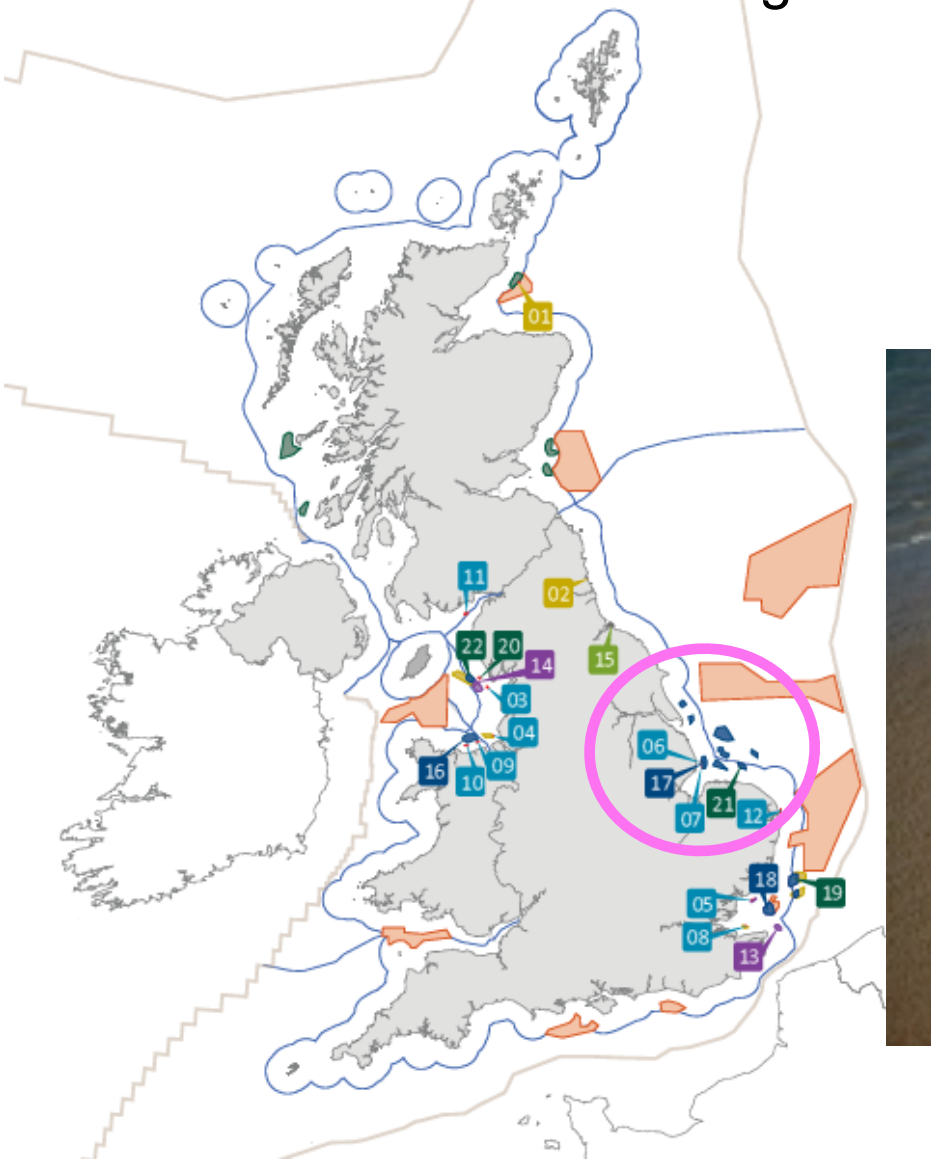
Sources of uncertainty that are automatically incorporated into the model predictions

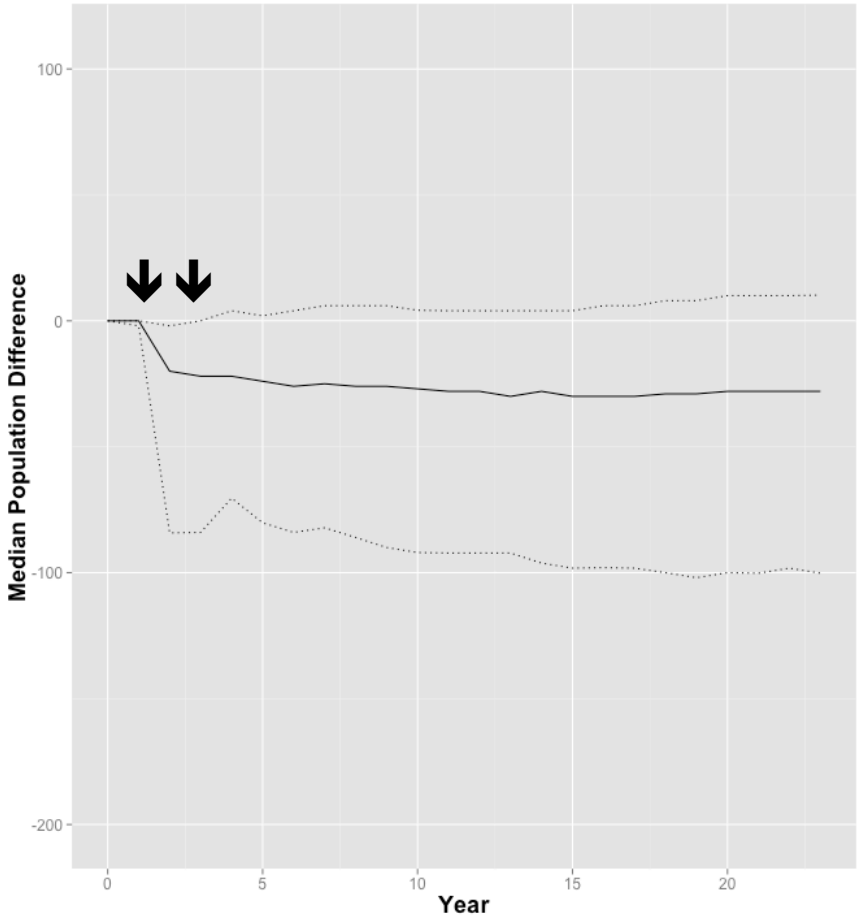
- Estimates of population size
- Number of animals predicted to experience disturbance & PTS on 1 day of operation
- Effect of PTS on survival and/or fertility (by resampling from expert opinion posteriors)
- Effects of number of days of disturbance on survival and/or fertility (by resampling from expert opinion posteriors)
- Environmental stochasticity in survival and fertility (resampled from experts' opinions)
- Demographic stochasticity (only an issue for "small" populations: users can set the maximum population size for this)

Estimating the effects of collisions and entanglements with tidal turbines and wave energy devices

- There is no standardised method for estimating the risk of collision/ entanglement during a defined period of operation of these devices.
- However, any available estimates can be included in the Interim Framework.
- However, the population model does not include any density dependence (unlike the one which underpins PBR type calculations).
- As a result, any population that is exposed to a collision/ entanglement risk will be predicted to decline (although probably slowly) over time, unless the undisturbed population is currently increasing.
- The output of the Interim Framework can therefore be considered as a “worst case” scenario.

Hypothetical effect on SE England harbour seal MU of concurrent piling at all wind farm sites in Wash that have been granted consent





Harbour Seal: Concurrent piling

6 years after start of construction

	Risk of 1% decline	Risk of 2% decline
Disturbed population	0.21	0.08
Undisturbed population	0.19	0.07
Additional risk	0.022	0.008

12 years after start of construction

	Risk of 1% decline	Risk of 2% decline
Disturbed population	0.14	0.02
Undisturbed population	0.12	0.02
Additional risk	0.016	0.002