Working with uncertainties and risk

Source: content.time.com

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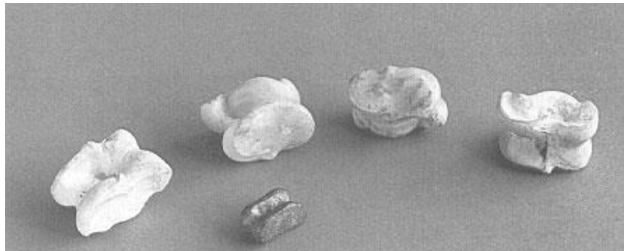
Overview

- Expert judgements are frequently used in risk assessment, including of invasive species
- Risk analysts should be cognizant of expert frailties, including:
  - e.g., over-confidence, motivational bias…
- Risk assessments contain various types of uncertainty, these should be understood and made transparent:
  - Epistemic uncertainty, natural variation, linguistic uncertainty

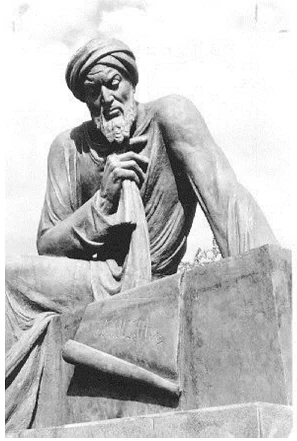
A Brief History of Risk

Greek, Hebrew and Roman systems used letters for numbers.
Lacked a numbering system that allowed calculations.



http://www.personal.psu.edu/users/w/x/wxk116/roma/tali.html

Hindu invention
of numerals



al-Khowârizmî, c. 825
Rules of arithmetic

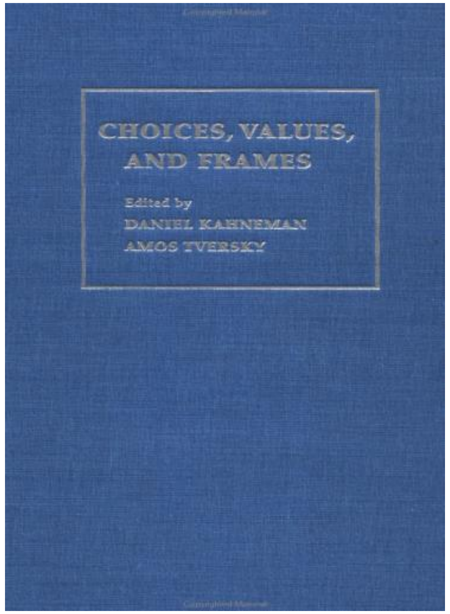
Fibonacci, *Liber Abaci* (1202)
Fractions, roots, interest, profit, ...

Pascal *Port Royal Logic*, (1654), Fermat, Huygens,
Hobbs, … (probability as chance and belief)

Risk perception: the phenomenon

Judgements under uncertainty are influenced by :

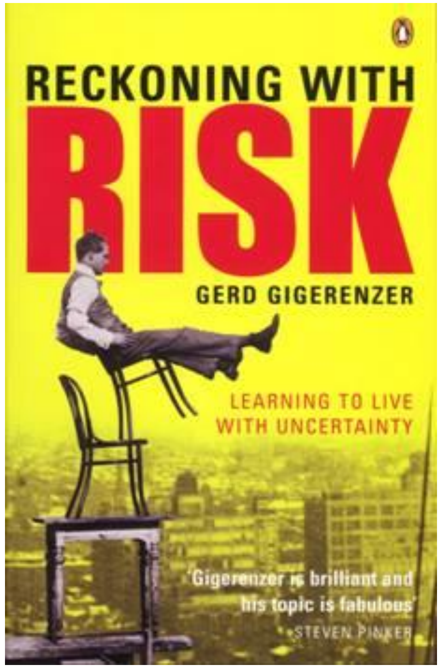
- Framing
- Level of personal control
- Understanding of the issue
- Prospects (for gain or loss)
- Degree of personal experience
- Dreadfulness of the outcome ('outrage factor')
- Equitability (or fairness)
- Visibility



Pathology of risk perception

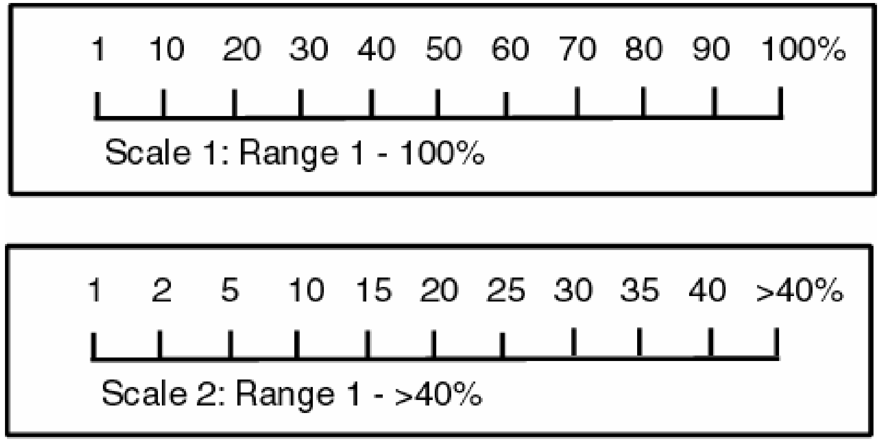
These influences lead to :

- Insensitivity to small sample size (Law of Small Numbers)
- Framing effects
- Anchoring
- Risk aversion
- Overconfidence
- Availability bias
- Motivational bias…



Framing

- What is the probability of re-offending?
- Two different scales presented

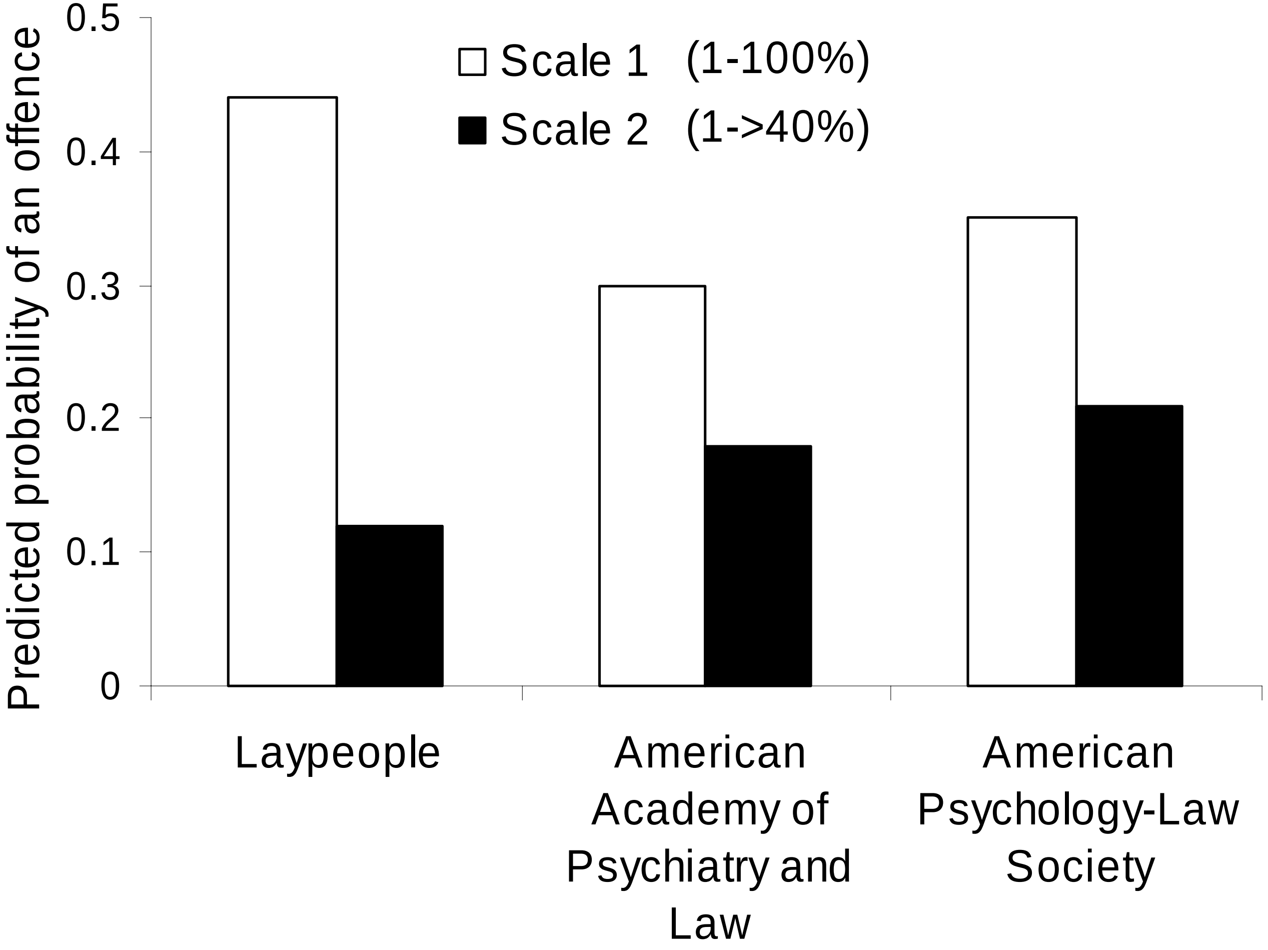


(Slovic *et al.,* 2000)

(Source: www.images.wisegeek.com)

Framing

- What is the probability of re-offending?
- Group given the first scale led to judgements of higher risk, those given the second scale made lower judgements of risk
- Peoples judgements can be influenced by how the problem is framed, the scale of the measurement and structure of the questions



(Slovic *et al.,* 2000)

Framing

A. Is it acceptable for each species Australian endemic mammal to have a 50% chance of persisting for 50 years?

What about a 90% chance?

What about a 95% chance?

For 100 years?

B. Australia has the worst conservation record on Earth, when it comes to mammal extinctions. Of roughly the 70 species that have become extinct globally in the last 400 years, more than 20 have become extinct in Australia in the past 200 years.

Is this an acceptable record?

200 endemic, 20 extinct (10%) or roughly 5% every 100 years

Prospects for gain or loss

- Preference for a smaller reward with greater certainty, than a larger reward with less certainty – *Risk aversion*

Thaler (1991) asked groups:

‘How much would you pay to eliminate a 1 in 1000 chance of immediate death?’ $200

‘How much would you have to be paid to accept a 1 in 1000 chance of immediate death?’ $50 000

- Losses loom larger than gains – *Loss aversion*

Anchoring

- Tendency to be influenced by initial estimates
- Sensitive to numerical cues
- Tversky and Kaheman (1974) groups of participants observed a spinning wheel predetermined to stop at 10 (group 1) and 65 (group 2).
    - Asked to guess the % of the United Nations that were African nations?
    - Group 1 guessed 25% on average, group 2 guessed 45% on average
- People are drawn to guesses of others and defer to authority

Source: i01.i.aliimg.com

Personal control and understanding

- Judgement of perceived risks
- People tend to underestimate risks of high probability events, overestimate the probability of low risk events
- People tolerate greater risk when they feel in control of the situation, and when they are given a choice
- Experts usually do better than lay people
    - In their own domain of expertise
    - But not substantially better

(Fischhoff *et al.*, 1982)

Availability bias


(Source: www.lovethesepics.com)

- For example, Lamb *et al*. (2005) found estimated numbers of shark attacks by locals exaggerated
- Experience base of the expert(s) and relative ease at which they can remember information
- Vivid and memorable examples are overestimated

Motivational bias

- For example, Campbell (2002) sustainable, consumptive use of turtles
  - Revealed 4 positions defendable on scientific grounds that differed in how they dealt with uncertainty
  - Irrespective of there own view, experts saw opposing view as influenced by emotions
- Experts honestly believed they were being objective and dispassionate – this makes them credible
- Experts are susceptible to the normal range of human emotions and values
- Intentional and unintentional

Equitability

A. 1% chance of 100 people dying (99% chance that everyone lives)

OR

B. Randomly select 1 individual and sacrifice them to ensure everyone else lives

Most considered A fairer.

Bian and Keller (1999) Chinese and Americans agree on what is fair, but disagree on what is best in societal decisions affecting health and safety risks, *Risk Analysis*, 19, 439-452

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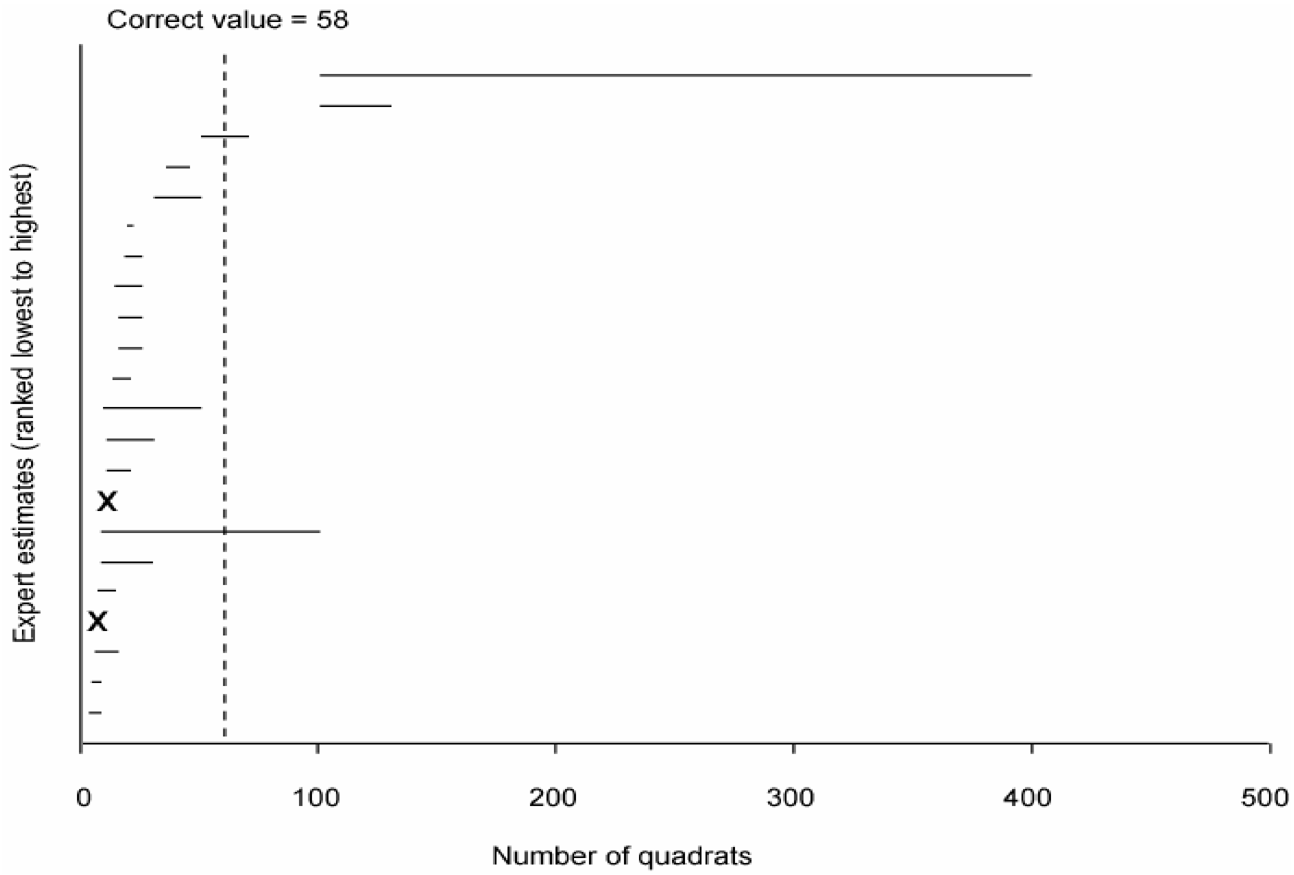
Overconfidence



(Baron, 2000)

- For example, how many quadrats are needed to sample 95% of plants in a patch of forest?
- Tendency for optimism
- Confidence and accuracy generally not related – cannot trust confident experts
- Motivation to appear confident

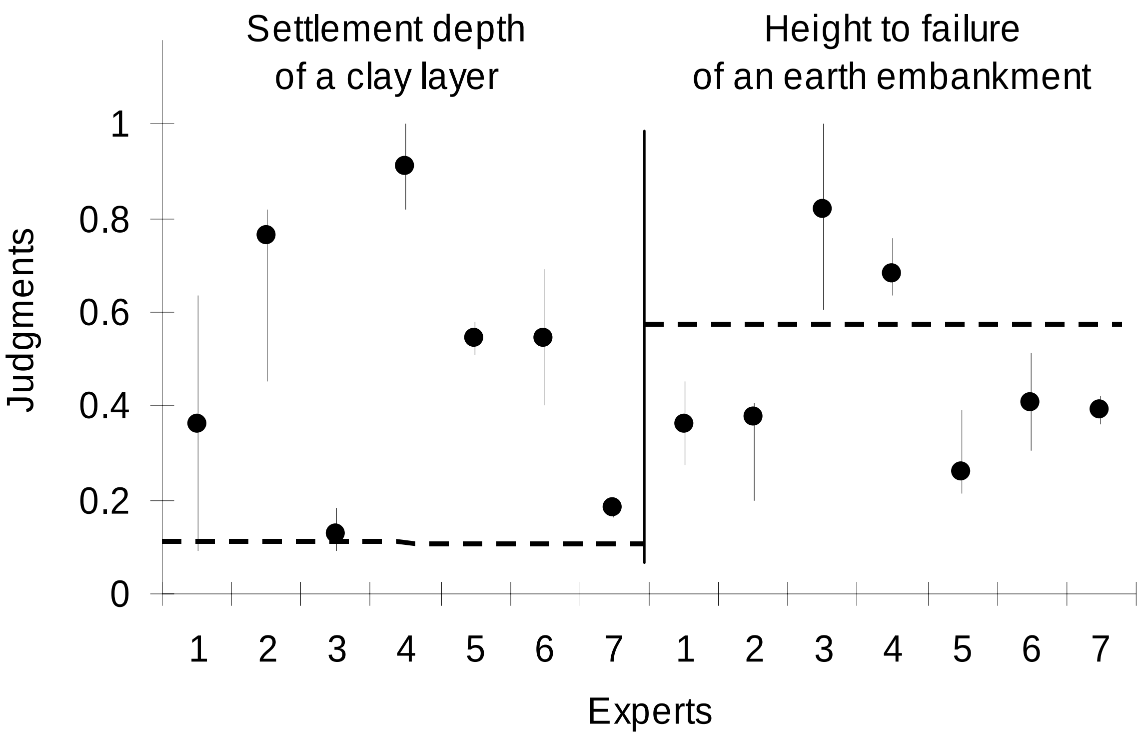
Challenger

NASA 1985: *'the risk of catastrophic failure is 1 in 100,000 launches'*

Chernobyl

Ukranian Minister of Power 1987: *'risk of a meltdown is 1 in 10,000 years'*

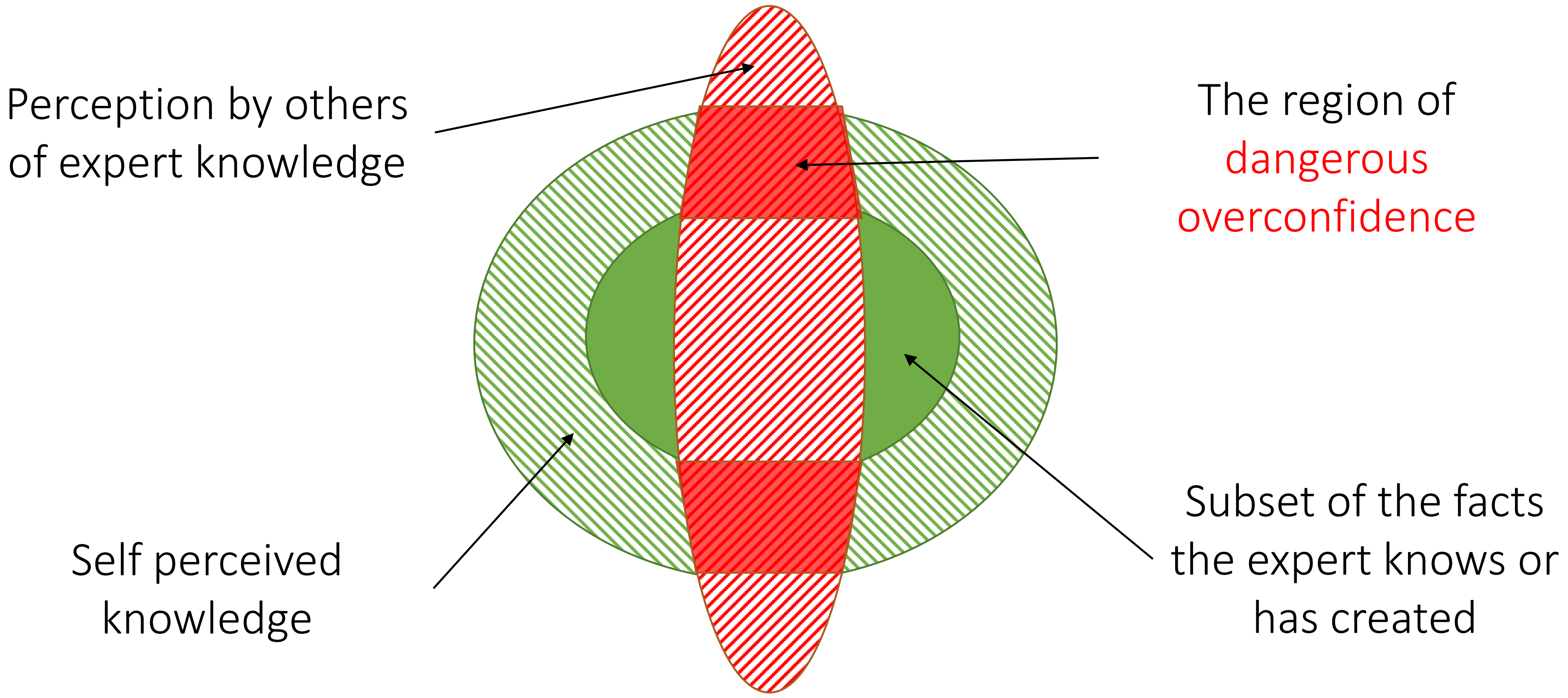
Overconfidence



(Hynes and Vanmarchke, 1975)

- Example, standard geotechnical problems experts are expected to assess – earthquake risk
- Experts given the data used different methods to calculate estimates
- The true value lay outside the ranges of all experts, experts generally over confident
- Averaging expert opinions does not converge on the truth, whole groups can be biased
- The same expert will not always be reliable
- No clear relationship between confidence and accuracy
- Level of technical skill does not predict ones ability to make good judgements

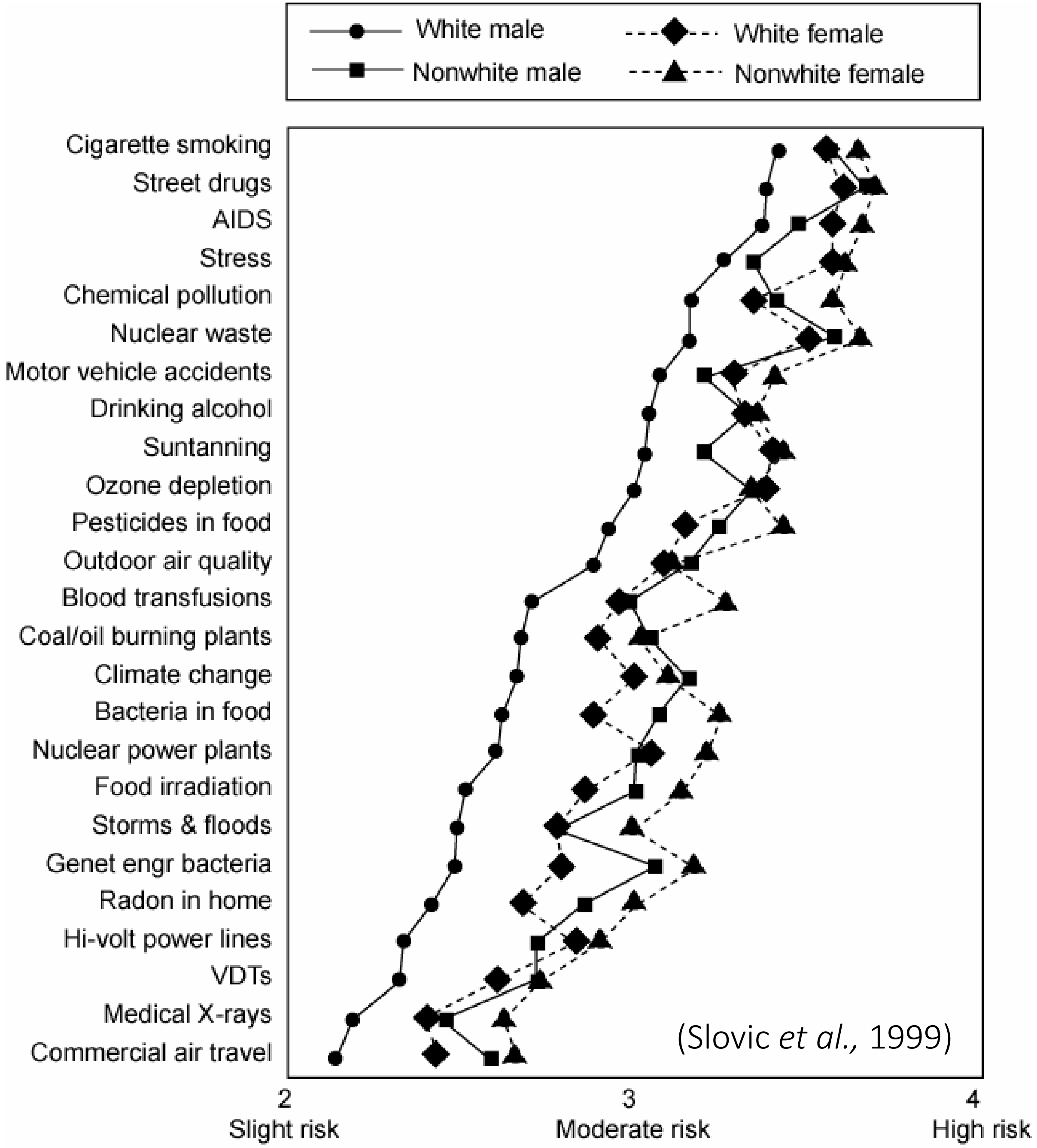
Overconfidence



(adapted from Ayyub, 2001)

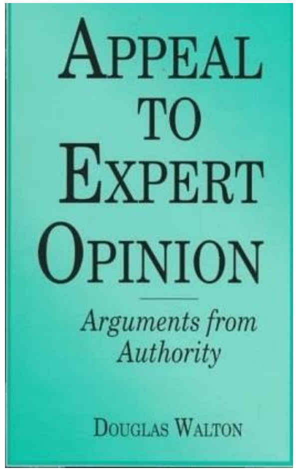
Culture and values

- Different groups of people vary in their response to the same hazards
- Race, religion, culture, gender substantially contribute to values and perceptions



Culture of technical control

- Experts are typically defined by their qualifications, experience and status among peers, someone we can understand and trust
- Tendency to accepted expert judgements uncritically, less critically than other types of data
- *'There is a naked assertion that the identity of the expert warrants acceptance of the proposal'* (Douglas Walton, Philosopher)
- Opportunty for experts to impose their values on society
- Appeal to authority is legimate only if it can be challenged



‘Classical’ taxonomy of uncertainty

Natural (aleatory) variation

Variability is naturally occurring, unpredictable change, differences in parameters attribute to ‘true’ or ‘inherent’ variation, i.e. natural variation.

Knowledge-based (epistemic) uncertainty

Incertitude is lack of knowledge about a fact, parameter or model, i.e. measurement error, systematic error, model uncertainty, subjective judgement.

- Can be reduced by learning, collecting data, etc.

Language-based (linguistic) uncertainty

Regan *et al*. (2002) natural language is imprecise, and this can lead to:

- Ambiguity – words have more than one meaning, it is not clear which one is meant
- Vagueness – borderline cases
- Underspecificity – unwanted generality
- Context dependence – failure to specify context

Ambiguity

Vagueness

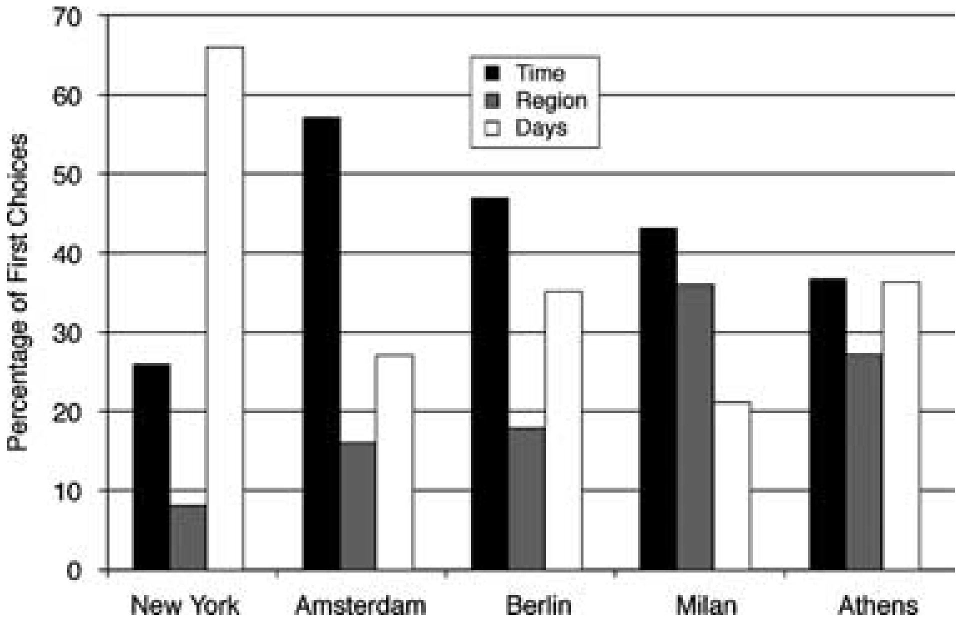
Underspecificity

Will it rain on me?

There is a 30% chance of rain.

Does that mean?

- Rain during 30% of the day (time)
- Rain over 30% of the area (area)
- Rain on 30% of days like this one (days)

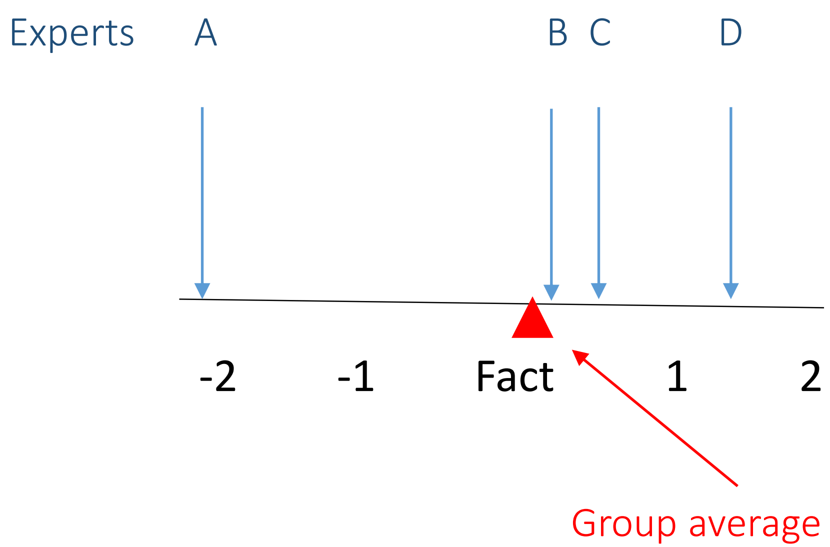


Gigerenzer *et al*. (2005) A 30% chance of rain tomorrow: How does the public understand probabilistic weather forecasts? *Risk Analysis*, 25, 623-629

Context dependence

Individual vs group expert elicitation

- Groups outperform individuals in making accurate estimates, even the best performing individual or most well regarded expert, most of the time



Surowiecki, J. (2005). The wisdom of crowds: why the many are smarter than the few and how collective wisdom shapes business, economies, societies and nations. New York, Doubleday.

Conjunction fallacy

Bill is an intelligent, unimaginative, compulsive rather lifeless individual.

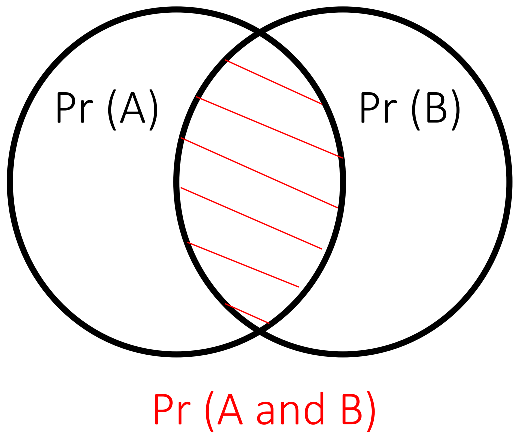
Rank the number of possible attributes of Bill.

A. Bill is an accountant.

B. Bill plays jazz for a hobby.

C. Bill is an accountant who plays jazz for a hobby.

D. Bill surfs for a hobby.



Tversky and Kahneman (1982) report more than 80% of respondents judged C to be more likely than A or B. Even though C is a combination of A and B.

Conditional probabilities vs raw frequencies

Conditional probabilities

The probability of a woman of age forty having breast cancer is about 1%.

If she has breast cancer, the probability that she tests positive in a mammogram is 90%.

If she does not have breast cancer, the probability that she tests positive is 9%.

So, what are the chances that a woman who tests positive actually has breast cancer?

Raw frequencies

Consider 100 women of age 40.

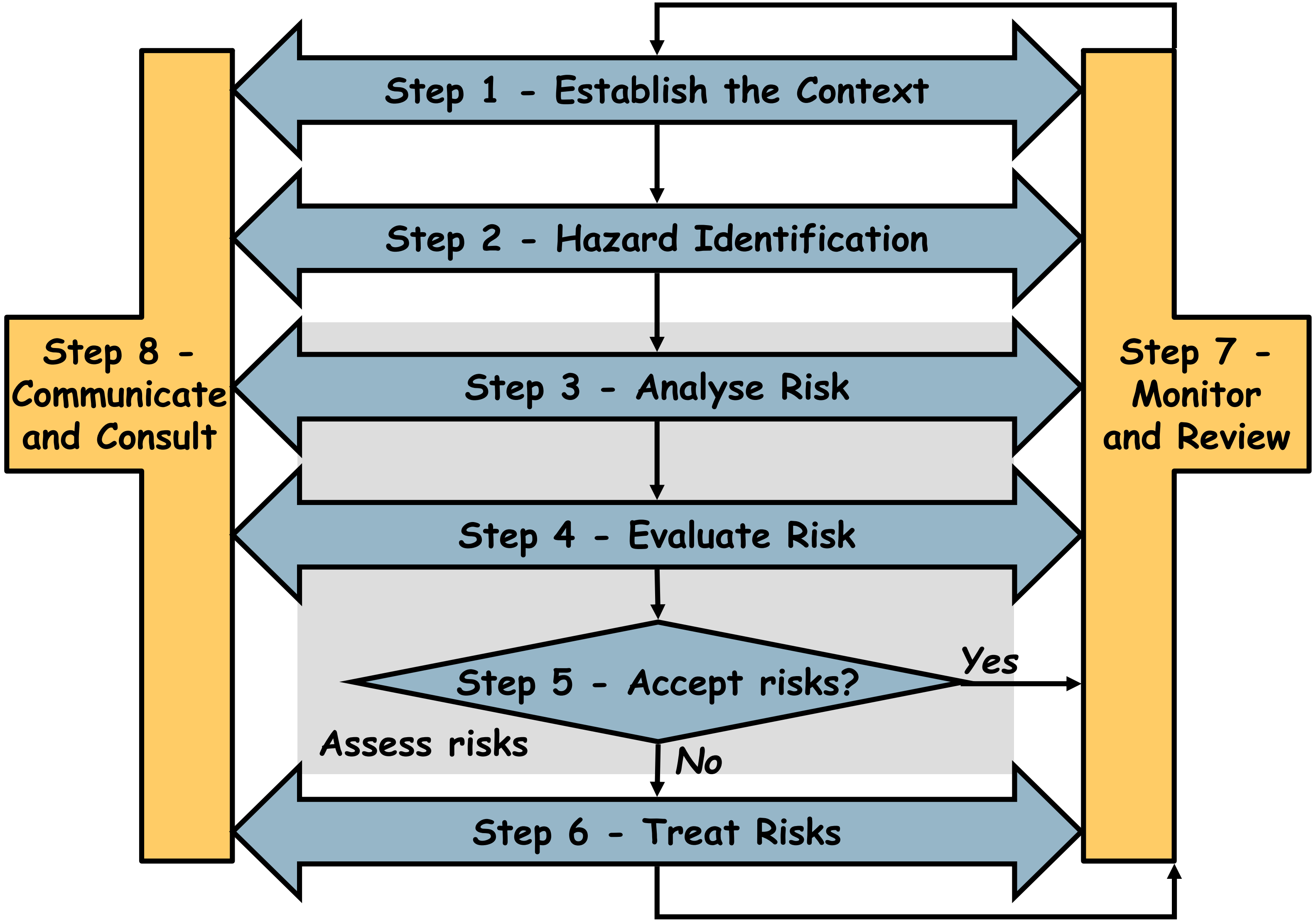
One has breast cancer. She will probably test positive.

Of the 99 who don't have breast cancer, 9 will also test positive.

So, how many of those who test positively actually have breast cancer?

(Gigerenzer, 2002)

The International Standard for Risk Management: ISO 31000



Risk Ranking Matrix

Likelihood	Consequence Severity				
	Low	Minor	Moderate	Major	Critical
Almost Certain	High	High	Extreme	Extreme	Extreme
Likely	Moderate	High	High	Extreme	Extreme
Possible	Low	Moderate	High	Extreme	Extreme
Unlikely	Low	Low	Moderate	High	Extreme
Rare	Low	Low	Moderate	High	High

IUCN rules
‘Critically endangered’

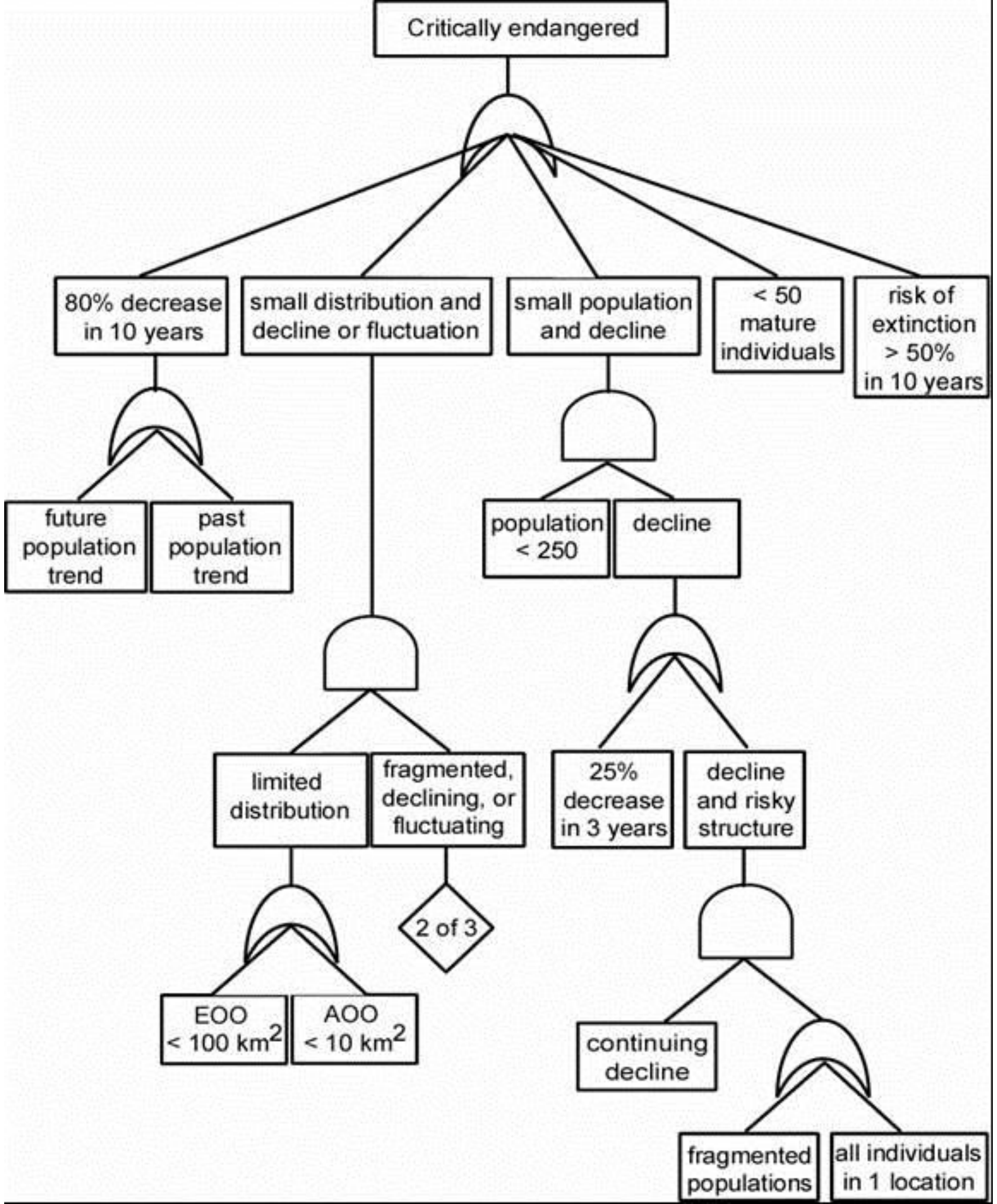
- ***IF*** *Decline of >= 80% in 10 years or 3 generations*
- ***OR*** *Range <100 km2 or occupied habitat <10 km^2*

  AND

  at least 2 of the following 3 conditions are met:
  1) severely fragmented or in 1 subpopulation
  2) continuing to decline
  3) fluctuations > 1 order of magnitude
- **OR** *number of mature individuals < 250*

  AND

  at least 1 of the following 2 conditions are met:
  1) >=25% decline in 3 years / 1 generation
  2) continuing decline and 1 subpopulation or <=50 per subpopulation
- **OR** *< 50 mature individuals*
- **OR** *>= 50% risk of extinction in 10 years / 3 generations.*


Critically endangered
80% decrease in 10 years
small distribution and decline or fluctuation
small population and decline
< 50 mature individuals
risk of extinction > 50% in 10 years
future population trend
past population trend
population < 250
decline
limited distribution
fragmented, declining, or fluctuating
25% decrease in 3 years
decline and risky structure
2 of 3
EOO < 100 km2
AOO < 10 km2
continuing decline
fragmented populations
all individuals in 1 location

Working with risk and uncertainty

Pest Prioritization Protocol (Dodd et al. 2017, Biol Inv)

1. Define planning horizon
2. List target species
3. Estimate species' risk
4. Identify management interventions
5. Estimate cost of intervention
6. Estimate probability of success of intervention
7. State constraints
8. Choose optimal combination of interventions

Rank projects by cost-efficiency

$$CostEfficiency = \frac{Risk \times Effectiveness \times Probability}{Cost}$$

where

- *risk* is a score reflecting the severity of the species' effects times the likelihood that the species will enter, establish and spread
- *effectiveness* is the proportional reduction in risk resulting from interventions
- *probability* is the chance that the intervention will be implemented successfully
- *cost* is the monetary cost of the project in net present value

Overview

- Expert judgements are frequently used in risk assessment
- Risk analysts should be cognizant of expert frailties, including:
  - e.g., over-confidence, motivational bias…
- Risk assessments contain various types of uncertainty, these should be understood and made transparent:
  - epistemic, incertitude, linguistic

Further reading

Burgman, M.A. (2005) ***Risks and Decisions for Conservation and Environmental Management***, Cambridge University Press, UK. *(Chapters 2 and 4)*

Burgman, M.A. (2016) ***Trusting Judgements: How to get the Best out of Experts***, Cambridge University Press, UK.

What doesn’t work

Relying on individuals...

- overconfidence, hindsight bias
- Framing, availability bias
- reference group, base rate neglect
- using the person who (everyone believes) knows the most: status effect
- undetected linguistic uncertainty

Relying on naïve groups...

- naïve question formulation: linguistic uncertainty
- unstructured discussion
- dominance, group-think
- uniformity in context, culture, styles of reasoning

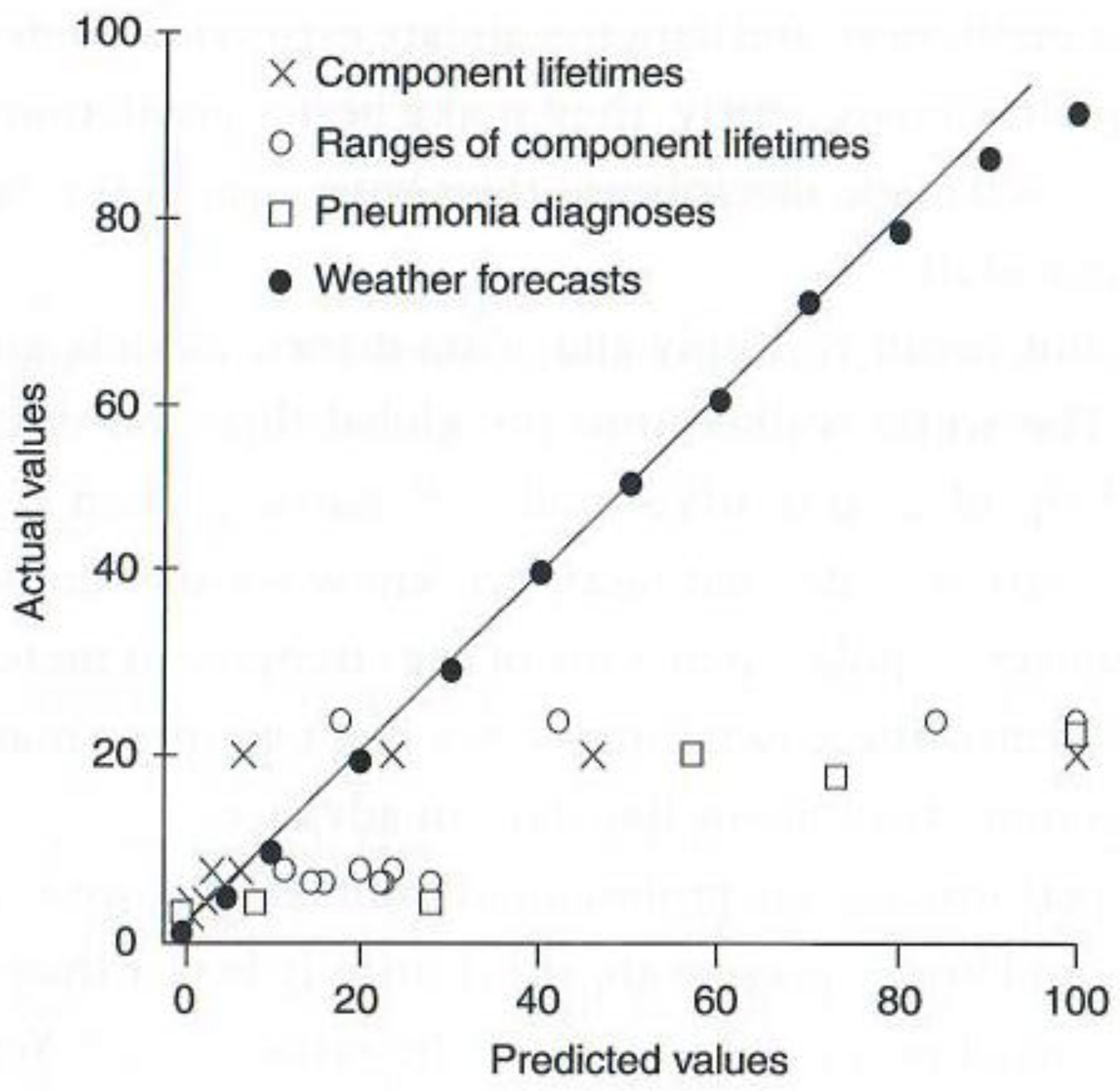
To fix the problems

Ask individuals to...

- Answer the same question in different ways (lowest, highest, most likely)
- Indicate confidence
- Examine estimates made by other people (feedback), consider counter-argument
- Revise original estimates after feedback
- Anticipate issues with conditional probabilities, base rates, ...

Then, don’t rely on individuals...

- Discuss questions to eliminate linguistic uncertainty
- Make groups diverse—age, gender, background and cognitive style, culture
- Avoid group think— Delphi structures / anonymity in judgments



100
80
60
40
20
0
Actual values
Component lifetimes
Ranges of component lifetimes
Pneumonia diagnoses
Weather forecasts
0
20
40
60
80
100
Predicted values