Risk Assessment and Decision Analysis
• Risk: probability of an adverse outcome
• Regulatory risk assessment
  – EPA guidance in the context of chemical exposures
• Moving toward ecosystem services
Conceptual Model: Example

Source:
Ecosystem Services: Context for Ecological Risk

Source: Munns et al. 2015 *Integrated Environmental Assessment and Management*, DOI: 10.1002/ieam.1707
Risk Assessment in the Coral Reef Context

In the context of management of coral reefs, ‘exposure’ is best used to capture pressures that originate outside the system, such as climate change-related stresses and extreme events. These are outside the direct control of individual environmental management agencies. Pressures that can be controlled or influenced through direct management interventions, such as water quality and overfishing, should be considered as aspects of sensitivity. Characterizing local pressures provides an important window into the sensitivity of our coral reef system to external pressures, and provides the basis for identifying the ‘levers’ available to us for building resilience of the system. By measuring both ecological resilience indicators and local stress indicators we are able to assess resilience and identify local actions that can make a difference to the condition and trend of coral reefs in the face of un-manageable external pressures like climate change.

Figure 1. Vulnerability assessment framework used by the IPCC; vulnerability is a function of exposure to disturbances (especially those that originate outside the system, such as climate-related stresses) and resilience describes how the system (social-ecological) responds (Turner et al. 2003).

Source: A Guide to Assessing Coral Reef Resilience for Decision Support, UN 2017; Resilience Assessment for Coral Reefs, IUCN
Resilience indicators:

1. *Resistant coral species
2. *Coral diversity
3. *Herbivore biomass
4. *Coral disease
5. *Macroalgal cover
6. *Recruitment
7. Temperature variability
8. Herbivore diversity
9. Habitat/structural complexity
10. Mature colonies
11. Light (stress)
12. Coral size-class distribution
13. Substrate suitability

Anthropogenic stressors:

1. Nutrients (pollution)
2. Sedimentation
3. Physical human impacts
4. Fishing pressure
Many methodologies available

– Influence diagrams/Bayesian Belief Networks (BBN)
– Decision trees
– Structured decision-making
– Multi-criteria decision analysis (MCDA)

Not a matter of picking up one piece of software

Iterative process – MUST involve stakeholders and that may be the biggest advantage

– Not going to “make the decision for you”
• Working toward safer consumer products
  – Explored use of MCDA, SDM, and “default” decision making

• Lessons learned
  – Group dynamics matter a lot
  – Group rejected MCDA outcome even as it performed well and software learning curve was ok
  – Need to communicate rationale and alignment with “gut” and “what matters”
  – No correlation between ”decision satisfaction” and understanding of values, information and tradeoffs
Research and development project decision tree

The management board of a certain company is considering two R&D investment options, both of which may generate profits. The following options are considered:

An R&D project conducted by an internal R&D department with an estimated cost of €100,000. A successful project would generate income of €800,000 on the domestic market, while failure would result in no investment profit whatsoever. The likelihood of success is estimated at 50%. The second alternative is to outsource R&D activities; such services are more expensive and cost €500,000 but they are more efficient too: the probability of a successful project generating €800,000 on the domestic market is estimated at 70%.

In the case of success, the company may expand the outsourced R&D project abroad for another €500,000. High demand on the external market, with a probability of 50%, would generate an additional €1,200,000. If demand on the external market is low, the income generated abroad would only be €300,000.

Source: silverdecisions.pl
MCDA: Example
Bayesian Network: Example

Source: Franco et al. 2016, A Bayesian Belief Network to assess rate of changes in coral reef Ecosystems, Ecol Model & Software 80:132-142
Fig. 1. Conceptual model of interacting stressors in the Great Barrier Reef. Light grey nodes were informed by data; dark grey nodes are composite nodes formed by assigning weights to each of their inputs; white nodes were our response variables (outcomes) of interest. Blue nodes represent activities or processes amenable to alteration by management. An example of the values contained within a conditional probability table is provided for the low salinity event (floodling) node – this provides the probability associated with each possible state of a node for each combination of states of its parent nodes. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Decision Analysis Recap

- Many different ways to structure the issue
- How do attributes/criteria/indicators change across interventions?
- Process encourages stakeholder engagement
  - Required to reach consensus on key inputs
- Basis for weighting attributes
- What are the important decision drivers
- What are the tradeoffs across interventions
Revisiting the Statement of Task

Assess the likelihood that implementation of particular intervention strategies will substantively improve the persistence and resilience of coral reefs and their ecological functions, including support of reef-associated ecosystems and fisheries, over and above conventional management regimes

- Likelihood – probability
- Improve resilience – what are the indicators for that (UN 2017; IUCN 2015; Lam et al.)
- Over and above conventional management regimes – implies comparison to business as usual or “restoration” kinds of options

Describe the nature and likelihood of predicted risks (e.g. disease introduction; loss of reefs, ecological functions, or coral species) and potential unintended consequences (e.g., species invasions, loss of genetic diversity) and tradeoffs of specific intervention strategies;

- Identifies specific suggested risks
- Transitions to decision analysis “tradeoffs of specific intervention strategies”
  - May mean just in terms of risks
  - Risks may differ across interventions – assumes they are equally weighted
Assess the relative harms and benefits of different interventions compared with one another and the status quo of conventional management techniques

- Harms = risks; but also benefits
- Again a reference to “status quo” and “conventional management techniques” – which really means managing reef fisheries, goes back to “typology of management strategies” (Comte and Pendleton)

Develop a decision pathway (a conceptual sequence of events) spanning initial research, laboratory and field-based research, to implementation and monitoring of the potential interventions. The pathway will include identification of specific ecological criteria or thresholds (e.g. population or environmental tipping points such as onset of annual bleaching) that may justify implementation of a more risky intervention strategy depending on the magnitude and urgency of the degradation. Case studies may be used to illustrate how the decision pathway could guide selection of an intervention strategy under different scenarios of near-future conditions for tropical coral reef systems

- ”decision pathway” – sounds a lot like a decision tree or flow chart. Could be a BayesNet. Clearly intervention specific.
  - Somewhat impossibly detailed, from initial research to lab to field to implementation and monitoring relative to the indicators (what to monitor)
- ”identification of specific thresholds” is an entirely different decision pathway – reef specific
- “justify implementation of a more risky intervention strategy” – that’s decision analysis and requires information on risk tolerance of decision makers and stakeholders

Higher-level metrics used by monitoring and resilience studies. Blue and red areas represent monitoring programs and resilience assessments respectively. Axes points represent the proportion of studies within each study group that measured a given metric.