Does complexity and uncertainty inevitably lead to doomed Directives?

How do we do *translational ecology*?
'cos what we are presently doing isn't working!

Graham Harris

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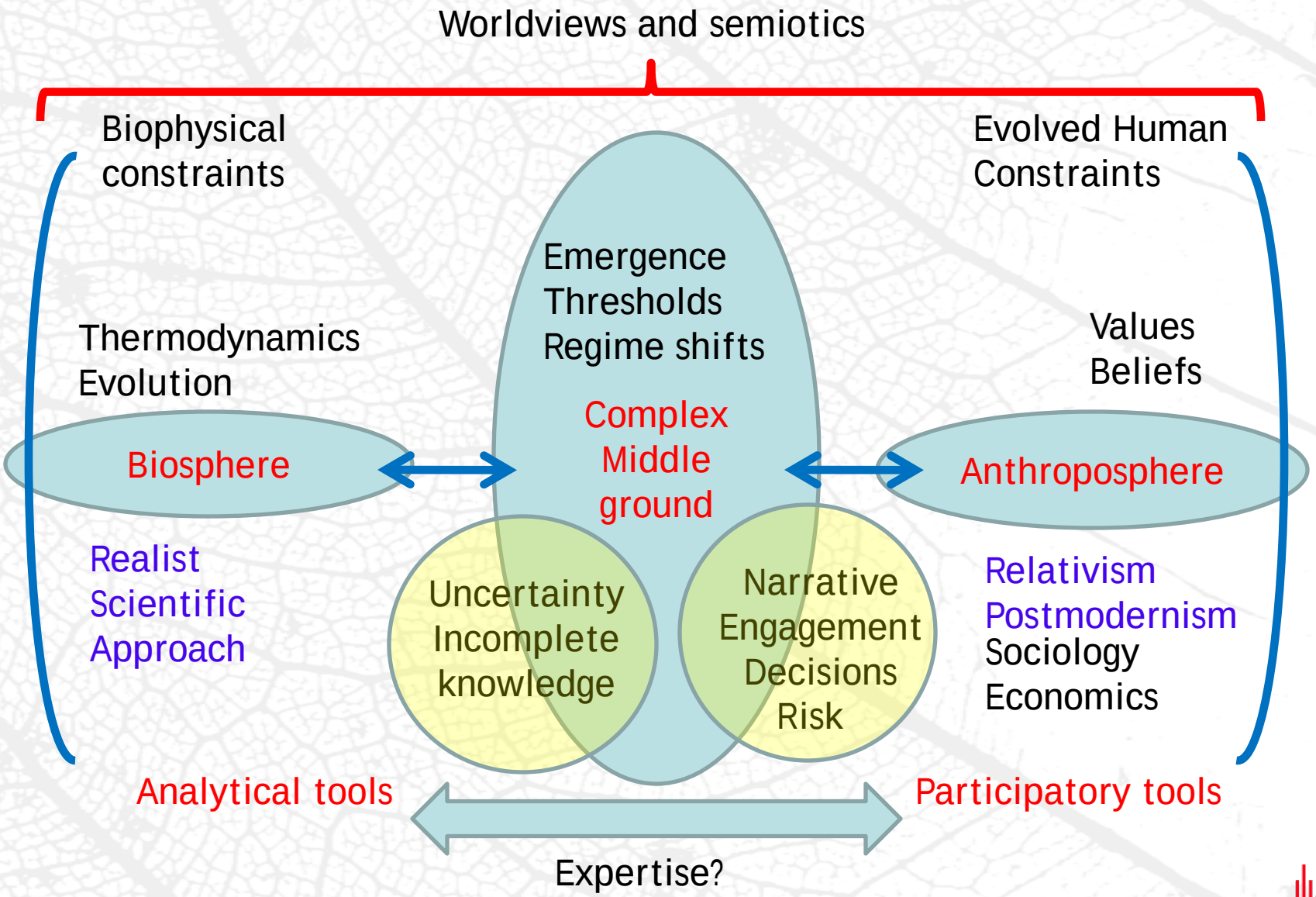
Restoration?

- Compliance problems with WFD
  - Lack of achievement of ecol outcomes
- Huge investments little results
  - Indicators, assessments, EQRs, protocols
- Critique by Moss (2007,2008)
  - Lack of eco*system* indicators: symptoms only
  - Use of assessment data, inability to detect change, low diagnostic power
- Directives assume that "predict-act" works

Restoration?

- Big investments – little ecological benefit
- Actually a global problem; USA, EU, Aus
  - Reviews and meta-analyses
  - USA rivers (Palmer, Allan et al.)
  - Oz env flows (Overton, Colloff et al.)
  - EU Agri-environment schemes (Kleijn, Kay)
  - Why is this so hard?
  - 10% success: no better than chance?
- Translational ecology: "rack and field"


Inability to detect effects of management interventions:
also there are multiple stressors
and surprises!!
Billions invested: no apparent result?
Failure of adaptive management



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Change in focus required

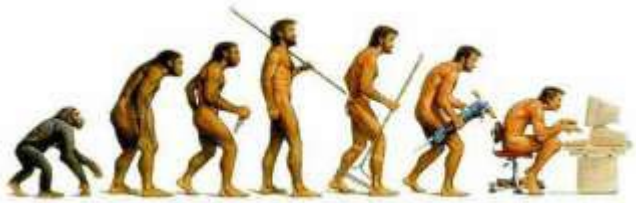
- Much focus on social engagement
  - But uncertainty a major issue in ecol data, models and practice
- Complex entities with dynamic properties
  - Noise isn't noise: need more power… (?)
- Understanding of both analytical and engagement tools required
  - Informational and normative uncertainty
  - Severe knowledge needs

The "framing issue"

- Usual debate framed around balance and equilibrium – has very old roots - realism
  - Theory, data collection and analysis issues
- Philosophical basis is idealised (Wimsatt)
  - Not appropriate for complex systems
  - Ecology is "special"; uncertainty, no general, precise laws – life is different (Rosen)
- *Collating data from "big databases in the sky"… we are making strong assumptions*

Problems with incorrect framing

- Unknown threats and risks are masked
  - Realist focus on the (apparently) computable complex problems are non-computable (Rumsfeld's unknown unknowns!) no system
  - Second, belief in dominant models even though incomplete; belief may be strong enough to filter out inconsistent signals
- Beware group think
  - (Carpenter et al. 2009)



The Complexity "turn"

- Adaptive local interactions: no ecosystem
  - agents, institutions, evolved systems
  - Robustness and fragility: tipping points
  - Precariousness and thresholds
- Uncertainty: knowledge and models partial
  - Emergence, surprises will occur
- Multiple stressors – *"causal thickets"*
  - *Predict-act frameworks unreliable*
- Many players, institutions, governance

Complicated and complex?

- In trying to monitor change and restore (more sustainable) landscapes
  - Clearly not everything works right now!
- How much is complicated/constrained?
  - i.e. Is computable? Predictable with more cross-scale data, higher resolution?
- How much is truly complex?
  - fundamentally uncertain, non-computable?
- And which bits are which?

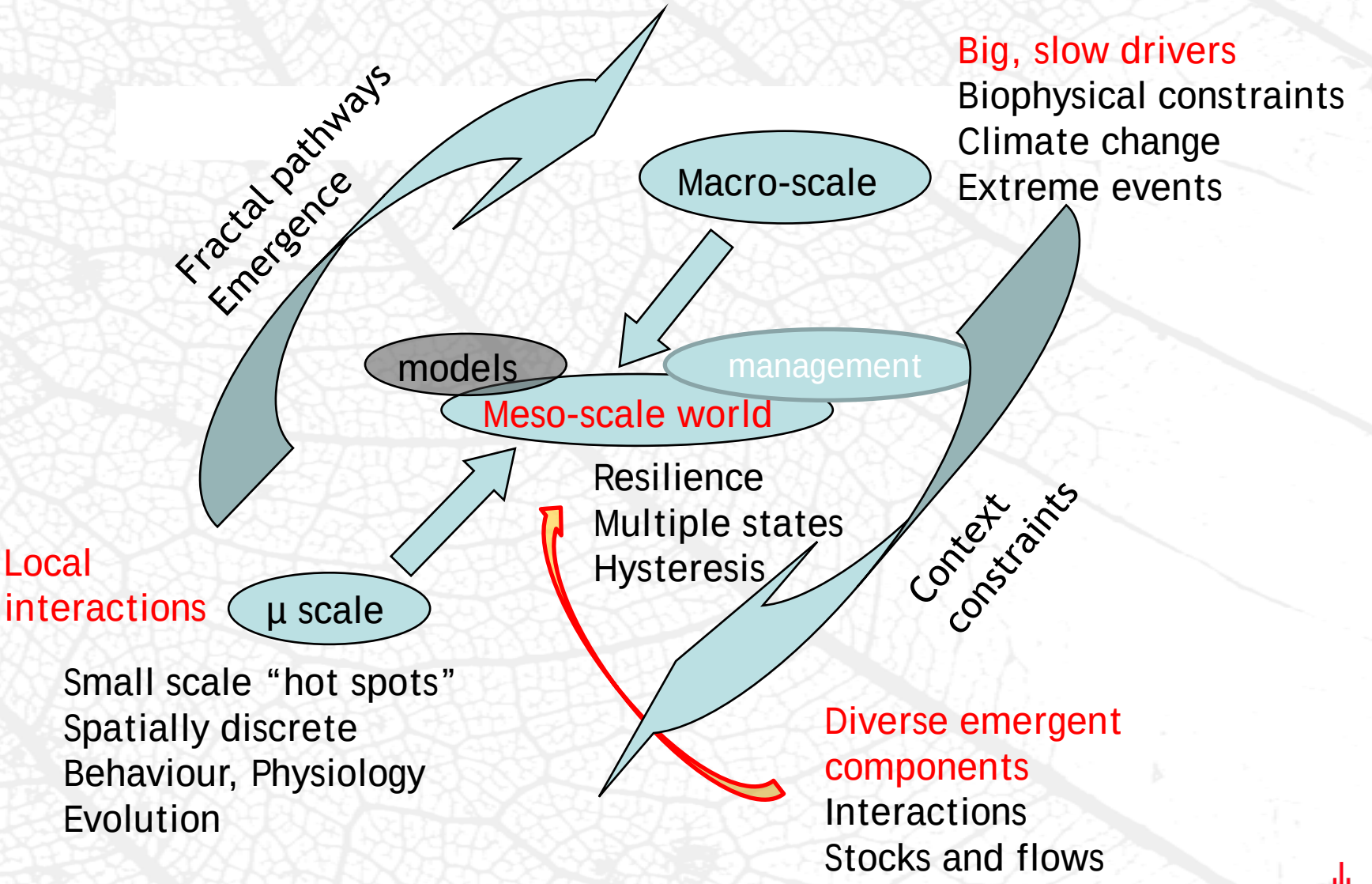
No general precise laws?

- Landscape science is a "middle number" problem: components >> 1 and << gas laws
  - Human scale is the meso-scale
- Components are evolved – HOT systems (Carlson and Doyle) – interconnected, adaptive – therefore self-organising
- "Entities" are multi-scaled, non-linear and show "strong" emergence: scale issues
  - More is different (Anderson 1972)

Hierarchical (nested) dynamics

- Small is really important (micro-ecology)
  - Emergence and non-linearity
- Both bottom up and top down causation
  - Philosophers have real problems with this!
- Modelling from the middle-out: emulation
  - Systems biology idea attributed to Sydney Brenner but actually a very old concept
- *Capturing the essence whilst recognising uncertainty (Unknown Unknowns again)*

The non-equilibrium hierarchical patch dynamics view



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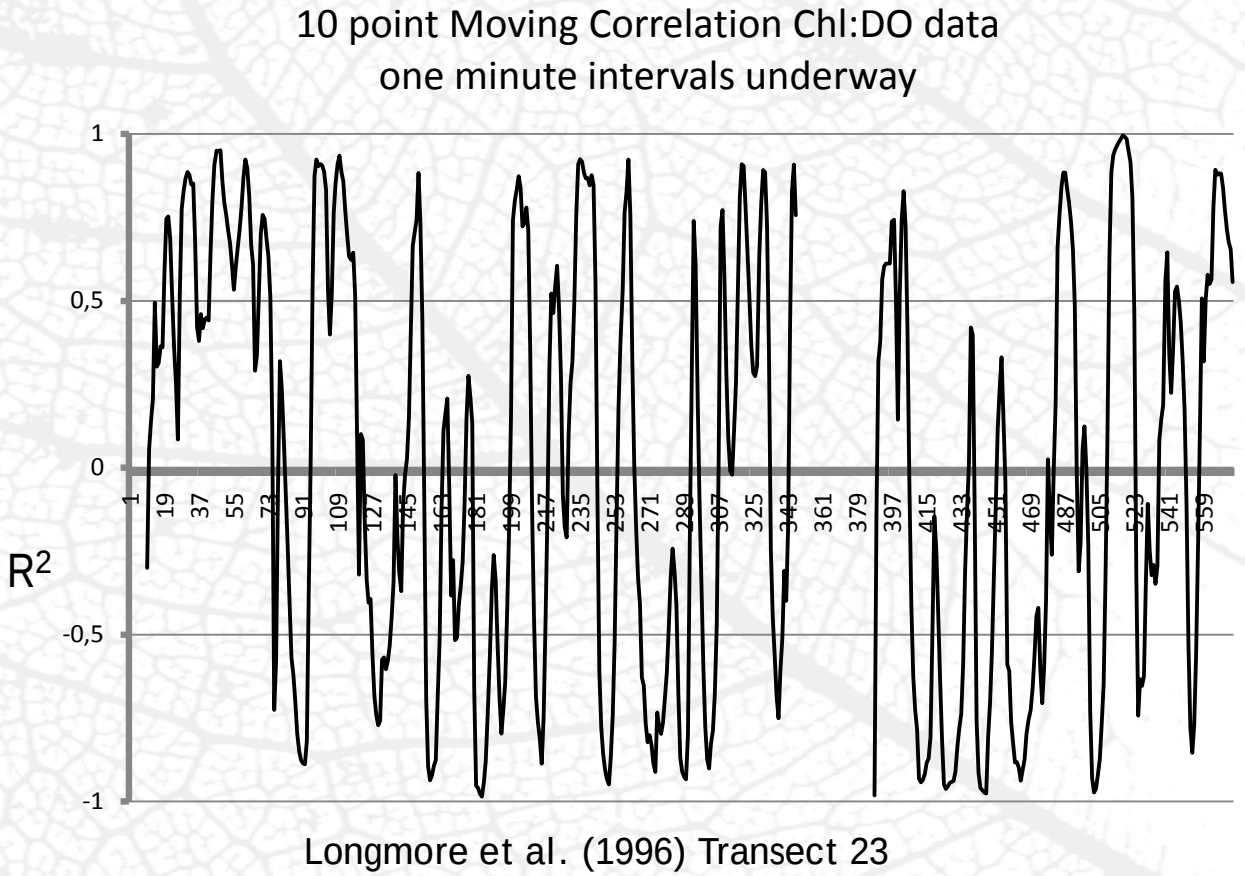
Percolation, patches, advection

- Small scale patchiness has upwards (bigger, slower, larger scale) implications
  - Percolation in A(R-D) processes
- Changes in small scale processes change dynamics of evolved HOT systems
  - Interaction of disturbance regime with patch dynamics determines scaling of response
- Self-organisation: small scales in soils, water percolation, macropores, fractal flowpaths

Small, local patches, evolving differently, unknown initial conditions



Entities evolve over time on different paths at different scales… Controls??

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Uncertainty

- Complexity means problem is not computable (there is no system!)
- But there are patterns – constraints: evolved stoichiometry, physiology, thermodynamics
  - Predictive power is low but does exist
- Embeddedness also means that upstream/external influences unknown/unexpected
- Knightian uncertainty (Rumsfeld 'UU' problem) at extreme precautionary principle

It's an A(R-D) problem

- Cross scale Advection(Reaction-Dispersion) problem with adaptive, evolved agents
- HOT (high performance) lattices
  - Balance of fragility and robustness
- Ensemble properties of non-equilibrium, spatially distributed, biodiverse assemblages
  - Underlying evolved, genomics, biochemistry and physiology: there are constraints
- Micro-ecology with macro-connections

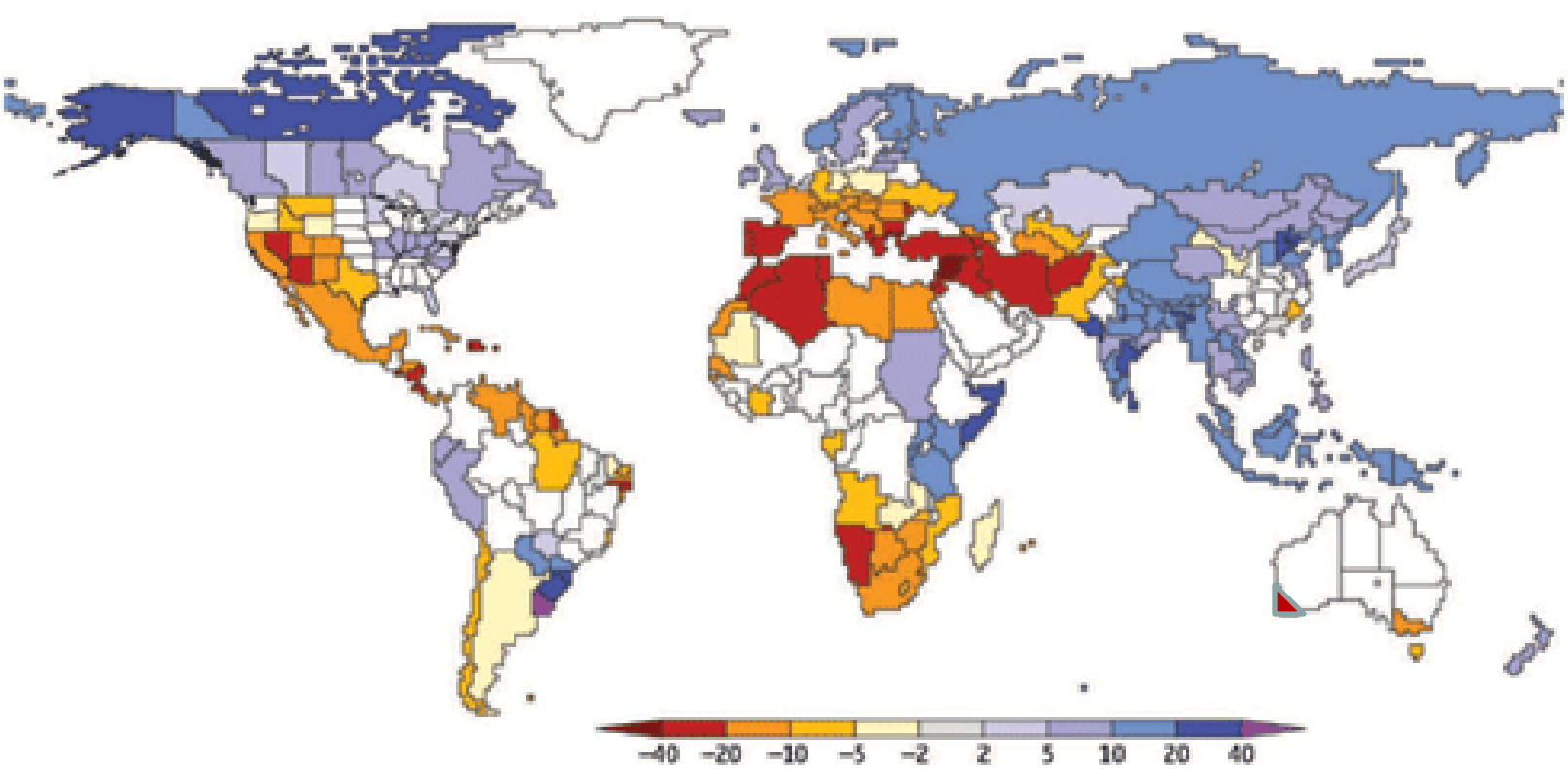
Non-stationarity

- Ecology (the planet) is non-equilibrium and non-stationary at scales from minutes to evolutionary time scales (>10My)
  - Fundamental uncertainty
- Something we must accept and plan for
- GFC has similar uncertain origins
  - Flawed assumptions and models
- Contingency, path dependence, extreme events are critical – physiology -> evolution

Milly et al (2008) Science 319: 573-4

Stationarity is dead: climate change affects water management

Widespread anthropogenic environmental change: dams, LUC



Percentage change in runoff 2050

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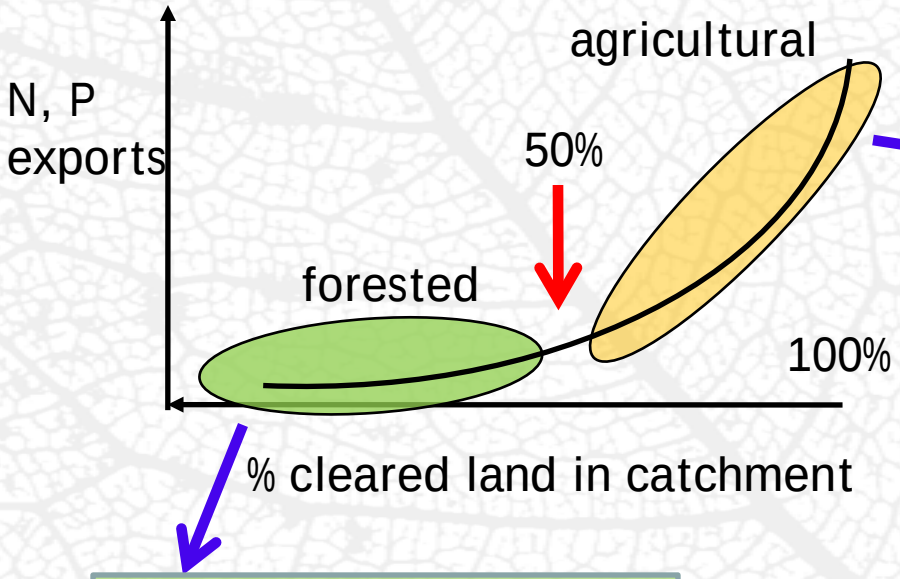
Catchments

- Catchments are messy because of ESE systems at a range of scales
  - Connectivity and complex interactions across time/space – advection by extreme events
- Coupled with human actions, values, markets – also across time/space
- Particularly difficult because of strong cross-scale interactions and causal thickets
  - Self organisation and multiple stressors



High exports
Surface sheet-flows
High suspended sediment loads
High DIN, DIP
High DIN:TN, DIP:TP
Low C:N, C:P
High in-stream production
Autochthonous production

Most catchments now in this state

Low exports, retention
Macropores, infiltration
Low suspended sediments
High DOC, DON, low P
High C:N and C:P
Low DIN:TN
Low in-stream production
Allochthonous C, N and P
Heterotrophic C balance

Characteristic catchment properties
Forested vs cleared

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Perturbed systems

- These are non-eq systems – spectrum of perturbations is critical (Kirchner)
  - HOT systems evolved for expected spectrum of perturbations – fragility in face of the unexpected (Csete and Doyle)
- Human attempts to "flat line" disturbances destroys ecosystem function (monocultures)
  - Inadequate data (aliasing) so we have no idea what has changed or how to go back
    - Weekly to monthly assessment data???

Multiple stressors: cross-scale effects

- Cross-scale effects in regions: causal thickets
  - Stocks connected by (multi-fractal) flows: transport, reach of capital – local to global
- Effects from both near and far
  - Multiple effects, stressors: non-equilibrium
- Adaptive (evolved) responses to frequency and magnitude of effects: fast to slow
  - Range of strategies, natural history critical
- Robustness and regime shifts: thresholds

A(R-D) problems

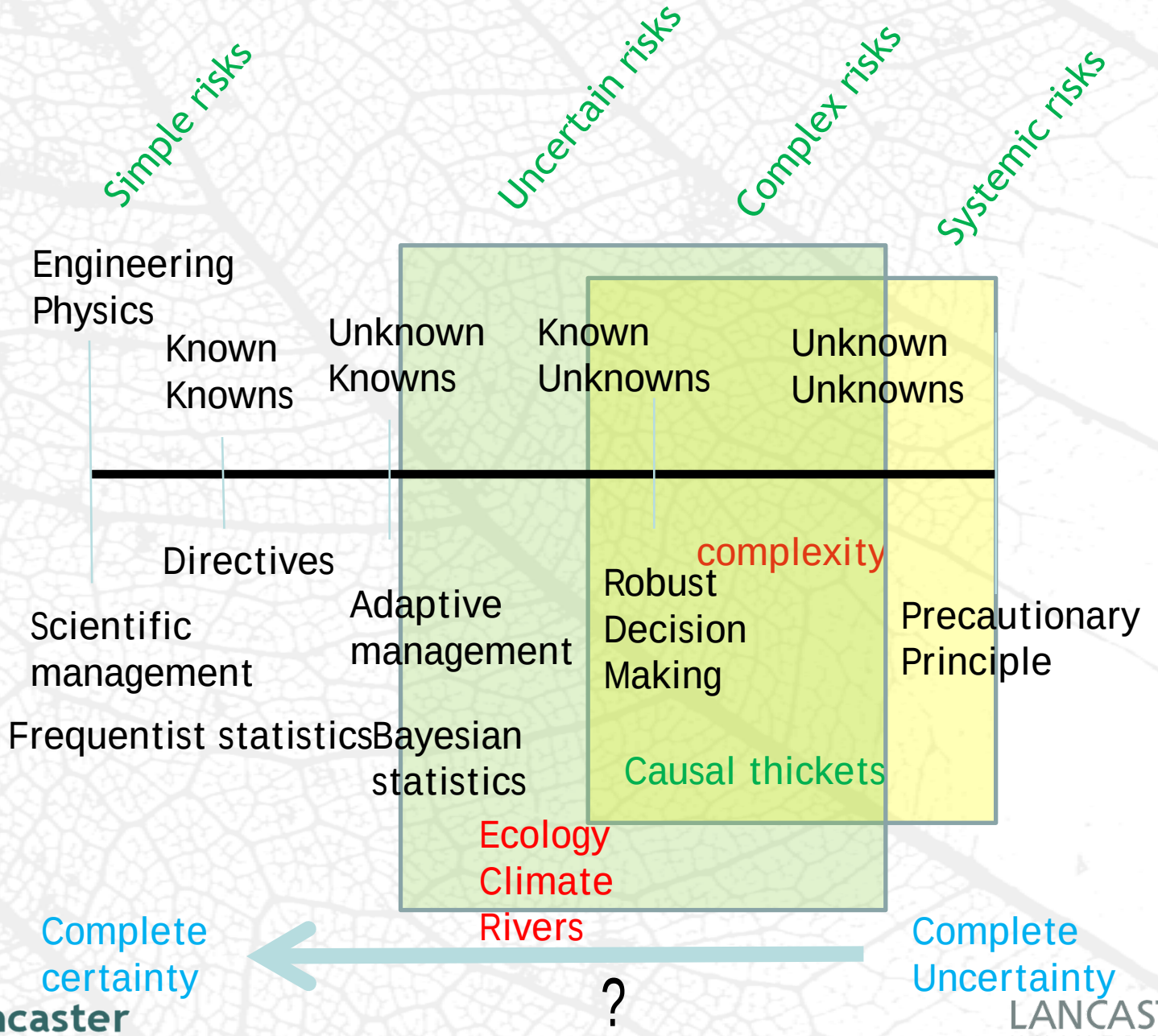
- So it is (Reaction-Dispersion) locally
  - Therefore require measures to define local properties and interactions: thresholds etc
  - Characteristics, invariants, order parameters
- Advection across scales (Harris et al. 1980s)
  - Connectivity, flows, linkages: S^2 spectrum?
  - Hydrology, critical source areas, hot spots
- And the interaction between the two
  - Emergence, connecting the small and large

Degrees of uncertainty

- 1. Complete certainty – Newton
- 2. Risk without uncertainty
  - Randomness governed by known probability
- 3. Fully reducible uncertainty
  - Given enough data…..
- 4. Partially reducible uncertainty
  - Poor data, non-linear, non-stationary, complex, adaptive, emergent, time varying generating functions, dependence on initial conditions
- 5. Irreducible uncertainty – suffering!

In the context of ICM/IWRM…

- What is "knowable" and what, maybe, isn't
- How to deal with this (particularly science)
- Institutional resistance
- Rethink of approaches to policy and risk
  - Data resolution, change undefined, Nyquist freq., complexity means no reference sites!
- Restoration of what to what? (Walker et al.)
- Social engagement and values



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Uncertainty

- Acknowledging incomplete knowledge and that things are complex and incomputable means robust decision-making techniques are required
  - Lempert et al. "no regrets" policies and actions (no idea what we have changed!)
- Recognition of lack of ability to restore to "remembered" states – hysteresis and novel "non-homologous" ecosystems (Hobbs)

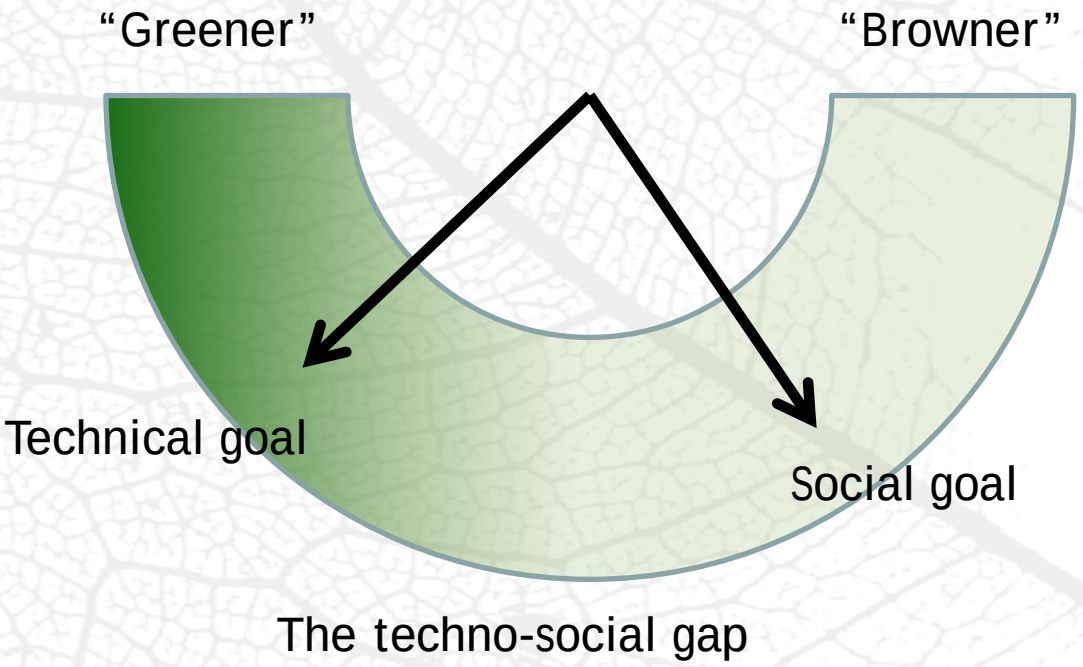
Environmental management

- Environmental management means:
  - analytical tools to understand risk and the behaviour of complex natural and man made systems and…
  - participatory tools to deal with beliefs and values, debate options, communicate risk and act (bench to bedside….)
- All in the context of culture and values: semiotics (yes, in science too!)
  - What is good? And how do we define it?

Where to from here?

- Progress indicators
  - Better evidence – recognising uncertainty
- New measures of good – system invariants?
  - (R-D) Order parameters, patterns (Rietkirk), (A) connectivity, flows, sources, sinks
- No regrets management actions: context
  - Is "natural" good? What is natural anyway?
- Investment under uncertainty
  - Pick a goal; will any goal will do? (complexity)

What kind of goal?



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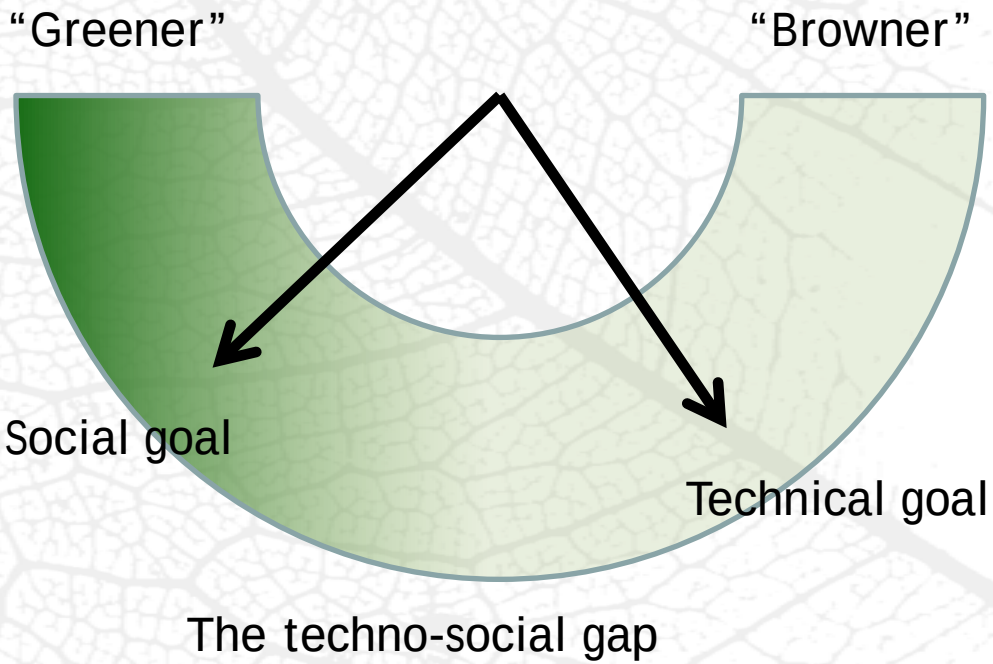
What kind of goal?

Societal goals and the “licence to operate” of industries



Risk assessment and management is a major issue

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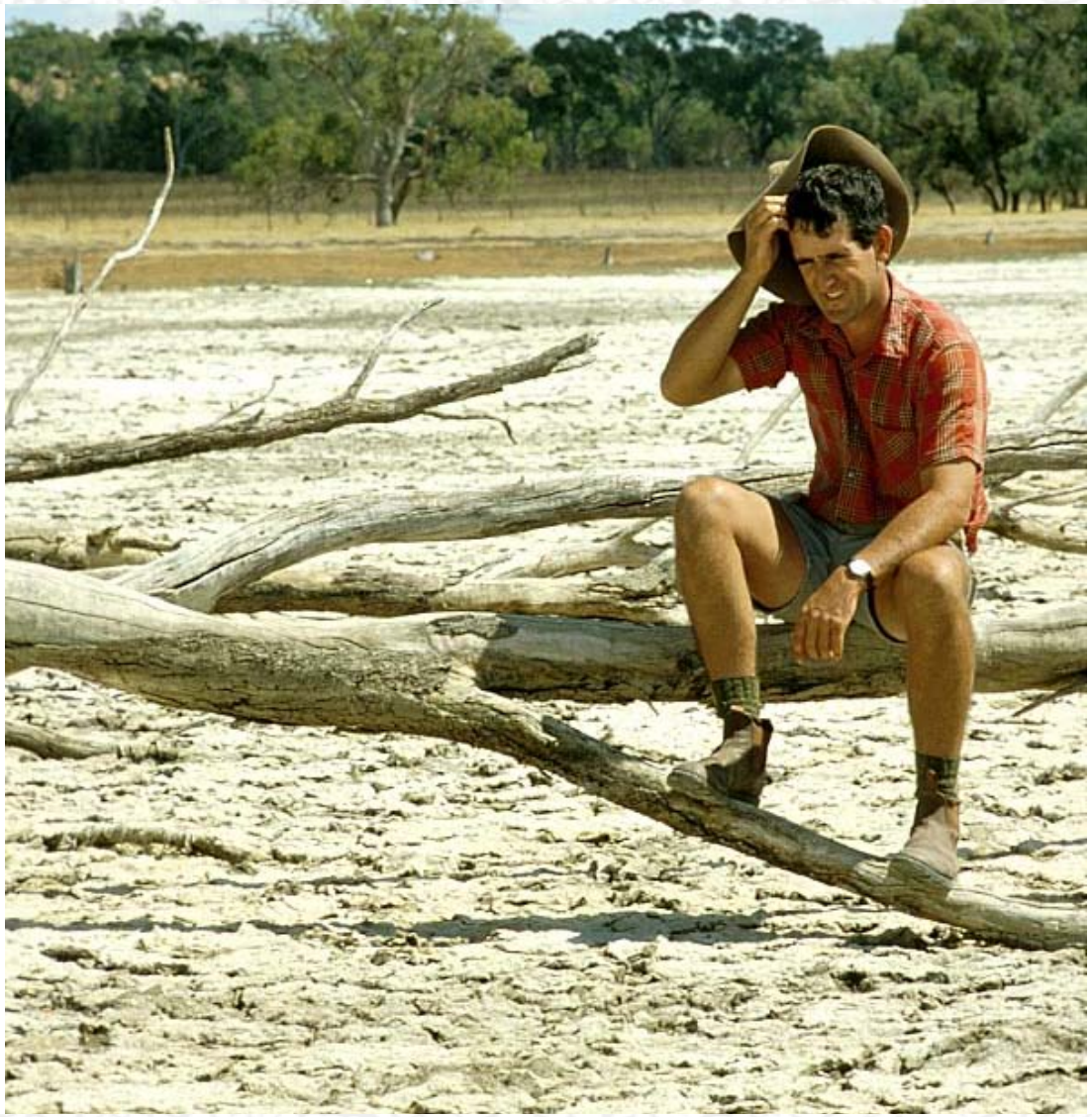

We need to do some hard thinking about what we are doing