INSIGHT #2 REGIME SHIFTS

# Social-ecological systems contain various tipping points or thresholds that can trigger large-scale reorganization

**Understanding of regime shifts is important for ecosystem governance as they often have substantial impacts on human economies and societies, tend to occur unexpectedly, and are difficult, expensive and sometimes impossible to reverse.**

Sudden, large, long-lasting shifts in system structure and function as a consequence of human actions have been documented in a variety of ecosystems, including coral reefs, freshwater lakes, marine systems and savanna rangelands (Biggs et al. in press, Carpenter & Biggs 2009, Gordon et al. 2008, Norström et al. 2009, Rocha et al. in press, Österblom et al. 2007). Similar shifts linked to ecosystems have been documented in social, political and economic spheres (Biggs et al. 2010, Crépin 2007, Gelcich et al. 2010, Olsson et al. 2008).

Understanding of regime shifts derives from these empirical observations as well as from dynamical systems theory, a branch of mathematics that studies the behavior of complex systems. Mathematical models show that complex systems such as social-ecological systems (SES) can self-organize around different equilibrium points or attractors. This is because complex systems consist of many components linked by feedback loops, which can be configured in a limited number of different ways.

As the system evolves from some initial condition, a particular combination of feedbacks will tend to become dominant, leading the system to self-organize into a particular structure and function – or "regime". Dominant feedbacks tend to be self-reinforcing, creating conditions that enhance their persistence, and making regimes "sticky" once they form.

Regime shifts are large, persistent, often abrupt changes in the structure and function of social-ecological systems. A regime shift occurs when there is a switch in the dominant feedbacks, and is often associated with rapid non-linear change as the system reorganizes into a different structure and function. Such a switch can occur when a large shock (e.g. hurricane, political turbulence) or combination of shocks overwhelm the dominant system feedbacks. More commonly, a gradual change (e.g. habitat loss, accumulation of pollutants, emergent markets, changes in values) slowly erodes the strength of the dominant feedbacks until a threshold is reached at which a different set of feedbacks suddenly becomes dominant and the system rapidly reorganizes into a new regime (Biggs et al. in press, Folke et al. 2011). The slow erosion of feedbacks usually goes unnoticed until the actual regime shift occurs – hence regime shifts often occur as a surprise (Fig 1).

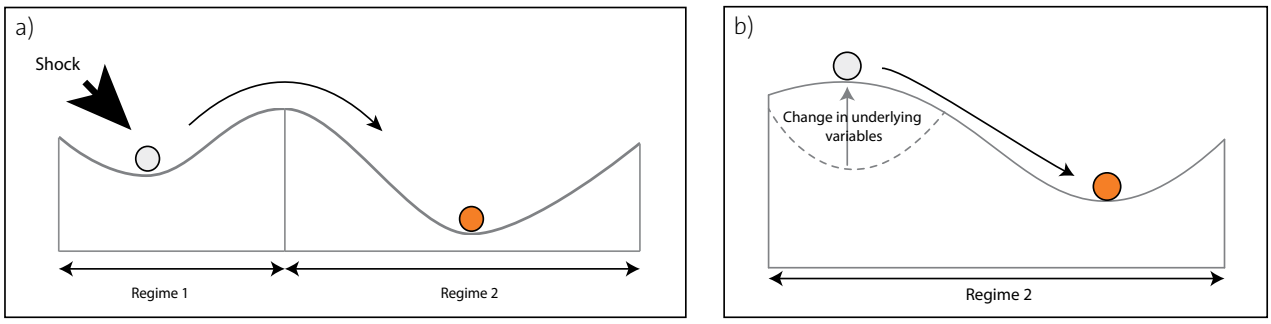


*Fig 1. The different possible regimes in a system can be metaphorically represented by a ball-and-cup diagram. The ball represents the current system state, and the cups or valleys represent the different possible regimes or domains of attraction in the system. A regime shift entails a shift from one domain of attraction to another. Regime shifts are usually due to a combination of a) a shock, and b) slow changes in external drivers and/or internal feedbacks that change the domain of attraction (or resilience) of the different regimes (Biggs et al. 2011).*



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# KEY FINDINGS:

**Regime shifts are typical features of SES, not rare, isolated phenomena**
Stockholm Resilience Centre has helped document regime shifts in a range of ecological and social-ecological systems, at a range of scales. In particular, the centre has documented regime shifts in coral reefs (Norström et al. 2009, Nyström et al. 2008), marine food webs (Öster-blom et al. 2007, Tomczak et al. 2009, Österblom 2010, Möllmann et al. 2011), and agricultural systems (Enfors and Gordon 2008, Gordon et al. 2008) and identified cascading effects that interact across scales and may lead to regime shifts (Folke et al. 2011, Galaz et al. 2010). Potential regime shifts have also been identified at the planetary scale (Rockström et al. 2009, Steffen et al. 2011). Stockholm Resilience Centre is also collating examples of different types of regime shifts that have been documented in social-ecological systems in the Regime Shifts Database – www.regimeshifts.org.

**Important regime shifts arise from the interaction of social and ecological factors**
Many regime shifts documented to date in SES have focused purely on the ecological feedback mechanisms that maintain them. Stockholm Resilience Centre is pioneering the application of regime shift concept to understanding regime shifts that are maintained purely by social-ecological feedbacks, for example poverty traps in dryland agricultural systems (Enfors and Gordon 2008, Gordon et al. 2008), guilded traps in coastal systems (Steneck et al. 2011) and unsustainable fisheries regimes (Österblom et al. 2011). Even "optimal management" can trigger regime shifts (Crépin 2007) and regime shifts can exacerbate tragedies of the commons (Crépin and Lindahl 2009).

**Regime shifts in SES have large impacts on ecosystem services and human well-being**
Immediate impacts are often felt through large effects on provisioning services (Crépin 2007, Crépin and Lindahl 2009), but many regime shifts also have substantial impacts on regulating services (Jansson and Polasky 2010, Nyström et al. 2008, Walker et al. 2010). See also www.regimeshifts.org.

**Regime shifts may take the form of social-ecological transformations**
Regime shifts can involve social-ecological transformations from unsustainable resource use to ecosystem stewardship (Chapin et al. 2010, Folke et al. 2010, Westley et al. 2011). Stockholm Resilience Centre has documented regime shifts in the form of transformations in ecosystem management practice and governance in Kristianstad (Olsson 2007, Olsson et al. 2010), Chilean fisheries (Gelcich et al. 2010) and the Great Barrier Reef (Olsson et al. 2008), amongst others (Biggs et al. 2010, Olsson et al. 2006, Österblom et al. 2010). See Insight Brief #1 for more information.

**Regime shifts are difficult to detect**
Due to lack of monitoring, sufficiently long time series data, use of improper metrics and the nature of complex SES it is difficult to detect regime shifts (Biggs et al. 2009a, Biggs et al. 2009b, Lokrantz et al. 2009, Mård Karlsson et al. 2011, Nyström et al. 2008, Tomczak et al. 2009, Möllmann et al. 2011). There is currently lack of indicators or measures that can provide "early-warning" of upcoming regime shifts. The condition is often assessed through metrics that poorly link to the loss of resilience or proximity to critical tipping points (Biggs et al. 2009a). For example, commonly used ecosystem-state metrics to gauge coral reef health (e.g. coral cover) remained unaffected on heavily fished reefs, whereas process-orientated indicators (abundance and size of herbivorous fish) suggested proximity to a critical threshold (Lokrantz et al. 2009). Preferably indicators need to capture resilience based on the present-day status of the system, since detailed time-series data are often lacking for most social-ecological systems (Nyström et al. 2008)

**Managing regime shifts requires different approaches than managing more gradual social-ecological change**
Coping with regime shifts is tightly linked to strategies to manage resilience of social-ecological systems. Adequate management requires substantial system specific knowledge about the characteristics of the different regimes, the particular dynamics leading to these regimes and the societal values associated with each regime and with possible transition between the regimes. (Fischer et al. 2009). When human actions influence the probability of an undesired shift precaution is motivated as an optimal strategy (Polasky et al. 2011). There is evidence that policy instruments to correct for externalities need to account for the possibility of regime shifts and some instruments like certain kinds of taxes may not be possible to use (Crépin et al. 2011).

**SRC work on regime shifts focuses on:**

1. Understanding, describing and modeling regime shifts and their implications;

2. Understanding how to manage and govern resilience of current social-ecological regimes in order to enhance adaptability within current trajectories of change;

3. Understanding how to break resilience of current social-ecological regimes to revive a previous regime (e.g. restoring cod stocks) or to transform into a new regime.

*A considerable proportion of the world's coral reefs are rapidly losing live coral cover. This is often associated with reefs undergoing regime shifts where they become dominated by macroalgae, sponges, soft corals, sea anemones and sea urchins. These regime shifts have substantial impacts on fisheries, coral reef tourism and other important ecosystem services. Coral regime shifts are problematic for managers and resource-users as the new, undesirable states can be "locked" in place by strong feedbacks. Bolstering the resilience of coral reefs involves breaking ecological feedbacks as they start to emerge by promoting herbivore abundances and improving water quality. Photo: Azote.se*

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