Supplementary Information for Governing Change: A Dynamical Systems Approach to Understanding the Stability of Environmental Governance

Nusrat Molla[1], John DeIonno[2], Thilo Gross[3], Jonathan Herman[2]

[1]Land, Air, and Water Resources, University of California, Davis, Davis CA 95616

[2]Civil and Environmental Engineering, University of California, Davis, Davis, CA 95616

[3]Helmholtz Institute for Functional Marine Biology, University of Oldenburg, Oldenburg, Germany

Contents

Parameter Values and Ranges

Parameters are derived from the Generalized Modeling approach described in the Methods.

Parameter	Interpretation	Range	Value
Scale Parameters			
ϕ	Rate of turnover in the resource, or inverse of characteristic time scale of resource	0 to 1	
ψ_n	Share of extraction of resource by user n	0 to 1, $\sum_n \psi_n = 1$	
α_n	Rate of turnover in the capacity of user n	0 to 1	
β_n	Share of actor n capacity gain in response to resource extraction	$\beta_n + \widehat{\beta}_n + \widetilde{\beta}_n + \overline{\beta}_n = 1$	
$\widehat{\beta}_n$	Share of actor n capacity gain in response to resource access conditions	$\beta_n + \widehat{\beta}_n + \widetilde{\beta}_n + \overline{\beta}_n = 1$	
$\widetilde{\beta}_n$	Share of actor n capacity gain from collaborations	$\beta_n + \widehat{\beta}_n + \widetilde{\beta}_n + \overline{\beta}_n = 1$	
$\overline{\beta}_n$	Share of actor n's capacity gain from "natural" gain (non-resource users only)	$\beta_n + \widehat{\beta}_n + \widetilde{\beta}_n + \overline{\beta}_n = 1$	
$\sigma_{k,n}$	Share of actor n's collaboration gain from collaborating with actor k	0 to 1	
η_n	Share of actor n's loss in capacity due to direct undermining by other actors	$1 - \overline{\eta}_n$	
$\lambda_{k,n}$	Share of actor n's loss from being undermined by other actors attributed to actor k	0 to 1	
$\overline{\eta}_n$	Share of actor n's loss in capacity due to "natural" decay	$1 - \eta_n$	
μ_m	Rate of turnover in decision center m's capacity	0 to 1	
Exponent Parameters			
$\frac{\partial s}{\partial r}$	Sensitivity of resource regeneration to resource state	-1 to 1	-0.5
$\frac{\partial e_n}{\partial r}$	Sensitivity of extraction by user n to resource state	1 to 2	1.5
$\frac{\partial e_n}{\partial g_{m,n}}$	Sensitivity of extraction by user n to intervention by decision center m (effectiveness of intervention)	-1 to 1	-
$\frac{\partial g_{m,n}}{\partial (F_{i,m,n} x_i)}$	Sensitivity of intervention in user n's extraction by decision center m to actions by actor i (effectiveness of actors' support/resistance)	0 to 2	1
$\frac{\partial g_{m,n}}{\partial y_m}$	Sensitivity of extraction intervention by decision center m to their own capacity	0 to 2	1
$\frac{\partial p_{m,n}}{\partial y_m}$	Sensitivity of resource access intervention by decision center m to their own capacity	0 to 2	1
$\frac{\partial b_n}{\partial e_n}$	Sensitivity of user n's gain in capacity based on extraction to the amount of extraction	-1 to 1	0.5
$\frac{\partial a_n}{\partial r}$	Sensitivity of access by user n to resource state	0 to 2	1
$\frac{\partial q_n}{\partial a_n}$	Sensitivity of user n's gain in capacity based on resource access to the level of resource access	-1 to 1	0.5
$\frac{\partial a_n}{\partial p_{m,n}}$	Effectiveness of intervention p by decision center m in changing access for resource user n	-1 to 1	-

$\frac{\partial p_{m,n}}{\partial(H_{i,m,n}x_i)}$	Sensitivity of intervention by decision center m to actions by actor i (effectiveness of actors' support/resistance)	0 to 2	1
$\frac{\partial c^+_{i,n}}{\partial(W^+_{i,n}x_i)}$	Sensitivity of actor n's gain from collaboration to actor i's collaboration efforts	0 to 2	1
$\frac{\partial c^-_{i,n}}{\partial(W^-_{i,n}x_i)}$	Sensitivity of actor n's loss in capacity to other actor i's efforts to undermine them	0 to 2	1
$\frac{\partial l_n}{\partial x_n}$	Sensitivity of actor n's "natural" decay in capacity l to their own capacity	0.5 to 1	1
$\frac{\partial u_n}{\partial x_n}$	Sensitivity of non-resource user actor n's self-growth in capacity to their own capacity	0 to 1	0.5
$\frac{\partial i^+_m}{\partial(K^+_{i,m}x_i)}$	Sensitivity of decision center m's gain in capacity to actor i's actions; likewise for $\frac{\partial i^-_m}{\partial(K^-_{i,m}x_i)}$	0 to 2	1
$\frac{\partial i^+_m}{\partial y_m}$	Sensitivity of decision center m's gain in capacity to their own capacity	0 to 1	0.5
$\frac{\partial i^-_m}{\partial y_m}$	Sensitivity of decision center m's loss in capacity to their own capacity	0 to 1	1

Supplementary Figures

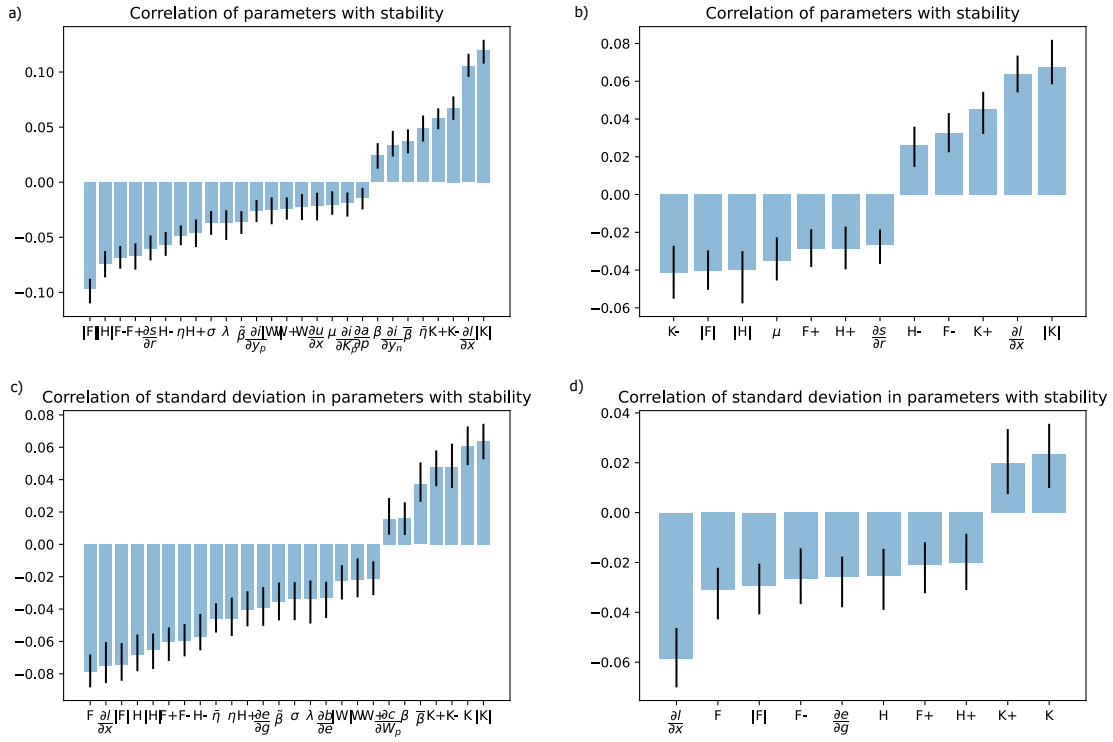

Figure S1: Correlation results including all forms of strategy parameters and all significant parameters. The inclusion of the different forms of strategy parameters allows for concluding that stability depends on the magnitude of effort allocated to the strategies rather than the sign or direction of the effort.

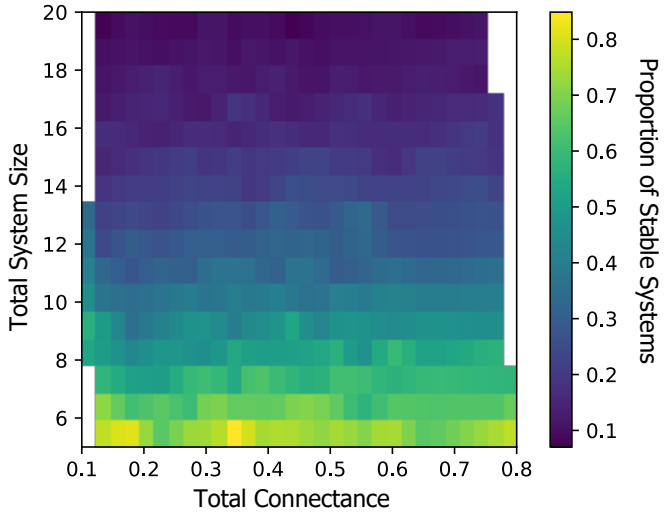

Figure S2: Effect of system size (number of actors and decision centers) and connectance on stability. The connectance shown is the total connectance, which is computed after the experiment rather than set beforehand due to the dependence of the connectance on actors' computed strategies. As a result, there is no data for some combinations of connectance and size.

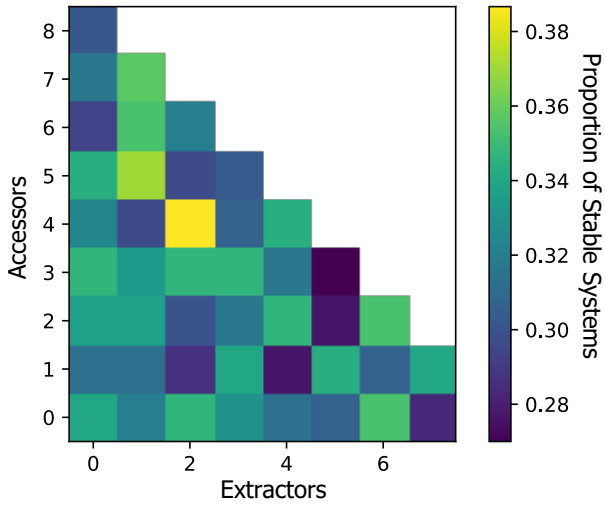

Figure S3: Effect of different types of resource users (extractors, accessors, and combined extractors and accessors) on stability. The color represents the proportion of stable systems for a given system composition. The total system size is 10, with 8 resource users and 2 decision centers. The proportion of extractors as compared to accessors or combined extractors and accessors has no effect on stability.