Ecography

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Shackelford, N., Starzomski, B. M., Banning, N. C., Battaglia, L., Becker, A., Bellingham, P. J., Bestelmeyer, B., Catford, J. A., Dwyer, J. M., Dynesius, M., Gilmour, J., Hallett, L. M., Hobbs, R. J., Price, J., Sasaki, T., Tanner, E. V. J. and Standish, R. J. 2016. Isolation predicts compositional change after discrete disturbances in a global meta-study. – Ecography doi: 10.1111/ecog.02383

Supplementary material

Appendix 1: Individual study details

Ström, L., K. Hylander, and M. Dynesius. 2009. Different long-term and short-term responses of land snails to clear-cutting of boreal stream-side forests. Biological Conservation 142: 1580-1587.

Abstract We assessed relatively long-term effects of clear-cutting on litter dwelling land snails, a group with slow active dispersal and considered to be intolerant to microclimate changes. In a pair wise design we compared snail abundance, species density, and species composition between 13 old seminatural stream-side stands and 13 matched young stands developed up to 50 years after clear-cutting. Using a standardized semi-quantitative method, we identified all snail specimens in a 1.5 l subsample of a pooled litter sample collected from small patches within a 20x5 m plot in each stream-side stand. From the young stands a mean of 135 shells and 9.5 species was extracted which was significantly higher than the 58.1 shells and 6.9 species found in old forests. Only two of the 16 species encountered showed a stronger affinity to old than to young forests. In short-term studies of boreal stream-side forests land snail abundance is reduced by clear-cutting. Our results indicate that this decline is transient for most species and within a few decades replaced by an increase.

Latitude: 62°16′ N - 65°08′N
Longitude: 15°21′E - 20°04′E
Ecosystem: Boreal forest
Organism: Animal (snails)
Disturbance: Clear-cutting
Maximum time post-disturbance: 50 years

Åström, M., M. Dynesius, K. Hylander and C. Nilsson. 2007. Slope aspect modifies community responses to clear-cutting in boreal forests. Ecology 88: 749-758.

Abstract We compared bryophyte (liverwort and moss) communities in matched 0.02-ha plots of four boreal stand types in central Sweden: recently clear-felled and mature stands dominated by Norway spruce in south-facing and north-facing slopes. Differences between forests and clear-cuts were interpreted as effects of clear-cutting, and differences between south- and north-facing slopes as effects of aspect. In response to clear-cutting, bryophyte cover and composition changed more in south-facing slopes. Only one out of ten significantly declining species in south-facing slopes also declined significantly in north-facing slopes. North-facing slopes lost fewer bryophyte species, and among those, fewer forest species and fewer species associated with wood and bark. In north-facing slopes, the average proportions of mosses and liverworts shared between the forest and the clear-cut plot were 88% and 74%, respectively. Corresponding numbers for south-facing slopes were 79% and 33%. In addition, more bryophyte species were added in north- than south-facing slopes after clear-cutting, somewhat reducing the difference in compositional change between aspects. The smaller changes in bryophyte communities on north-facing slopes in response to clear-cutting have implications for ecosystem dynamics and management as high local survival may enhance landscape-level resilience.

Latitude: 63°40′N - 64°00′N
Longitude: 18°56′E - 19°26′E
Ecosystem: Boreal forest
Organism: Plant (bryophyte)
Disturbance: Clear-cutting
Maximum time post-disturbance: 22 years

Dynesius, M., K. Hylander and C. Nilsson. 2009. High resilience of bryophyte assemblages in streamside compared to upland forests. Ecology 90: 1042-1054.

Abstract We asked whether the resilience of bryophyte (liverwort and moss) assemblages to clear-cutting differs between streamside and upland boreal forests in northern Sweden. In each of 17 sites, we compared two 0.1-ha plots (one streamside and one upland) located in old forest that had never been clear-cut with two matching plots in young stands established after clear-cutting of old forests 30–50 years earlier. We used the magnitude of the difference in assemblages between old and young stands as a measure of change and, therefore, resilience (large difference implying low resilience). Species assemblages were more resilient in streamside than in upland forests. Species composition changed significantly in upland but not in streamside forests. Reductions in species richness were more pronounced in upland forests for total richness and for eight subgroups of species. Two results indicated lower survival/recolonization in upland forests: (1) species had a stronger association with old stands in upland areas, and (2) among species present in both the old streamside and old upland plot in a site, fewer appeared in the young upland than in the corresponding streamside plot. Simultaneously, a higher proportion of species invaded streamside areas.

Latitude: 62°08′N - 66°16′N
Longitude: 14°48′N - 22°39′N
Ecosystem: Boreal forest
Organism: Plant (bryophyte)
Disturbance: Clear-cutting
Maximum time post-disturbance: 50 years

Becker, A., L.J.B. Laurenson and K. Bishop. 2009. Artificial mouth opening fosters anoxic conditions that kill small estuarine fish. Estuarine, Coastal and Shelf Science 82: 566-572.

Abstract Fish kills are a feature of intermittently open estuaries and are often associated with disturbances such as artificial mouth openings. Such a kill occurred in the Surrey Estuary in July 2005 resulting in the loss of thousands of fish within the system. At the time the Surrey was stratified with isolated waters below the halocline stagnated and anoxic. As a result only waters above the halocline contained oxygen concentrations capable of sustaining most fish. Fish within the estuary were sampled as part of an existing monitoring program and subsequent sampling was conducted three and six months after the fish kill. Three months after the kill few fish were collected within the estuary and included marine opportunists near the mouth and estuarine resident species in the far upper reaches of the system. However six months following the kill large numbers of estuarine resident species were collected throughout the Surrey Estuary. The high fecundity and rapid growth of these small, short lived species probably aided in their re-establishing populations within the estuary. The effects on larger, longer lived resident species are not known but likely to be more detrimental due to longer time required for them to reach sexual maturity.

Latitude: 38º15′ S
Longitude: 141º42′E
Ecosystem: Estuary
Organism: Animal (fish)
Disturbance: Anoxia
Maximum time post-disturbance: 9 months

Battaglia, Loretta L., Foster, M.A., unpublished

Abstract Coastal wetland mitigation banks are at the forefront forefront of climate change and are subject to regulatory requirements regarding plant community composition. If effects from climate change intensify, sea level rise and tropical storms may alter the composition of communities in the most flood-prone parts of the coastal landscape. We measured aspects of plant community structure and diversity at three wetland mitigation banks in coastal, southwest Mississippi in 2005-2012. Rapid monitoring assessments were conducted each year at pine savanna monitoring plots at each of the sites. The Lower Devil's Swamp site was in the eye-path of Hurricane Katrina and received more than 2.5 m of storm surge in August 2005. Although all sites were exposed to hurricane-force winds, multivariate analyses of the understory composition indicated that the high diversity, pre-Katrina community at Lower Devil's Swamp was the only community that diverged in terms of composition after the storm. Some recovery through time was evident at this site, although species composition had neither stabilized nor returned to ore-storm conditions by 2012. Diversity of savanna forbs dramatically declines following Hurricane Katrina and has not yet recovered. The assemblages have continued to shift in composition since Katrina, but it is not certain that they are returning to historic reference conditions. The reference species composition for a mitigation site is typically defined by regulatory requirements. As a result of tropical storm activity, these coastal ecosystems may be vulnerable to shifts away from fixed reference standards. If the effects of sea level rise and intensified tropical storm activity become more pronounced along the northern Gulf of Mexico, major vegetation community changes are likely to increase.

Latitude: 30º16′N - 30º 36′N
Longitude: 88º 30′W - 89º28′W
Ecosystem: Wetland
Organism: Plant (perennial)
Disturbance: Hurricane (Katrina)
Maximum time post-disturbance: 7 years

Battaglia, L.L., M.J. Abbott, A.D. Chupp, J. Fruchter, and D. Harshbarger. (in preparation) Resilience of coastal plant communities to storm surge pulses along an estuarine gradient.

Abstract Coastal ecosystems along the northern Gulf of Mexico are subject to chronic sea level rise and ephemeral incursions of the sea when tropical storms make landfall. We hypothesized that hurricane-generated storm surge disassembles landward communities dominated by species intolerant of salinity pulses, enabling species from seaward positions to establish farther inland. In 2010, five transects were established at points spanning a tidal river ecosystem in northwest Florida. Each transect was surveyed for elevation and extended perpendicular to the river into upland habitat to include 1m, 2m, and 3m changes in relative elevation from the river's edge. In September 2010, nine 2 m x 1m plots were established in each of the zones along the five transects (n=135). Following an initial plant composition survey, six of the nine plots in each zone received a saline storm surge (28 ppt); three of those six were surged again in 2012. Species composition of plots was tracked for four years. Communities at the seaward end of the gradient did not exhibit significant changes in response to the treatment, suggesting that they are somewhat conditioned to these kinds of disturbances. In contrast, inland communities had pronounced compositional shifts and appeared to be quite sensitive to the storm surge treatment. Shifts were driven initially by marked losses in species. Over time, a few of those species recovered. Establishment of "new" species into these plots was rare, and most communities with high initial mortality remained depauperate. Many plots that received a second storm surge had little or no live vegetation by the end of 2013. These results partially support our

hypothesis in that landward communities were more disassembled than their seaward counterparts. We did not, however, find evidence that disassembly triggered establishment by seaward species in the short term. The footprint of these disturbances may be long-lived, thus providing an extended window for propagule interception and colonization by species from other parts of the coastal landscape.

Latitude: 30º26′N - 30º28′N
Longitude: 86º46′W - 86º57′W
Ecosystem: Wetland
Organism: Plant (perennial)
Disturbance: Saline flood
Maximum time post-disturbance: 3 years

<u>Bestelmeyer, B.T., M.C. Duniway, D.K. James, L.M. Burkett and K.M. Havstad. 2013. A test of critical thresholds and their indicators in a desertification-prone ecosystem: More resilience than we thought. Ecology Letters 16: 339-345.</u>

Abstract Theoretical models predict that drylands can cross critical thresholds, but experimental manipulations to evaluate them are non-existent. We used a long-term (13-year) pulse-perturbation experiment featuring heavy grazing and shrub removal to determine if critical thresholds and their determinants can be demonstrated in Chihuahuan Desert grasslands. We asked if cover values or patch-size metrics could predict vegetation recovery, supporting their use as early-warning indicators. We found that season of grazing, but not the presence of competing shrubs, mediated the severity of grazing impacts on dominant grasses. Recovery occurred at the same rate irrespective of grazing history, suggesting that critical thresholds were not crossed, even at low cover levels. Grass cover, but not patch size metrics, predicted variation in recovery rates. Some transition-prone ecosystems are surprisingly resilient; management of grazing impacts and simple cover measurements can be used to avert undesired transitions and initiate restoration.

Latitude: 32º35′N
Longitude: 106º51′W
Ecosystem: Arid/semi-arid grassland
Organism: Plant (perennial)
Disturbance: Grazing
Maximum time post-disturbance: 13 years

Tanner, E.V.J. & Bellingham, P.J. 2006. Less diverse forest is more resistant to hurricane damage: evidence from montane rain forests in Jamaica. Journal of Ecology 94 (5): 1003–1010

Abstract Are more diverse ecosystems more or less resistant to disturbance? Does diversity increase in a forest after being hit by a hurricane? We answer these questions using a 30-year study of four Jamaican forests, which differ in soil fertility and diversity, and which were hit by Hurricane Gilbert in 1988; the decades were: pre-Gilbert (1974–84), Gilbert (1984–94), and post-Gilbert (1994–2004). Diversity (Shannon index) was always higher in the three forests (Col H′ 3.00, Mull H′ 2.91 and Slope H′ 2.99) on more fertile soils (C:N ratios 10–13, N:P 16–24), and significantly lower in the Mor forest (H′ 2.26) with the least fertile soil (C:N ratio 24, N:P ratio 44). Diversity increased during the Gilbert decade in two of the more diverse forests (Mull and Slope), it did not increase in the least diverse, Mor forest. The overall increase in diversity during the Gilbert decade was due to the recruitment of eight, mostly light-demanding, species and the increased abundance of uncommon species.
We used turnover rates (the average of mortality and recruitment of stems) as a measure of resistance. We equate low turnover with high resistance to hurricane damage. Turnover increased during the Gilbert decade in all forests, but increased more in the three more diverse forests (Mull 1.5% year^{-1} 1974–84 to 3.1% year^{-1} 1984–94; Slope 1.3–2.6; Col 1.5–3.2); than in the least diverse Mor forest (1.2–1.9). Stem diameter growth rates pre-Gilbert were very low in all forests and were lowest in the Mor forest (Mor 0.3 mm year^{-1}, Mull 0.4, Slope 0.5, Col 0.6). They increased during the Gilbert decade and remained, in the post-Gilbert decade, double those of the pre-Gilbert decade (Mor 0.6 mm year^{-1}, Mull 0.6, Slope 0.8, Col 1.1). Smaller stems increased growth more than larger stems. The stems recruited during the Gilbert and post-Gilbert decades grew faster than those present in 1974. Thus, in montane forest in Jamaica the least diverse forest was most resistant to hurricane damage, and although there was a strong similarity in species rank abundances over 30 years including a hurricane, the hurricane increased diversity.

Latitude: 18º5′N
Longitude: 76º39′W
Ecosystem: Tropical forest
Organism: Plant (forest)
Disturbance: Hurricane (Gilbert)
Maximum time post-disturbance: 15 years

Dwyer, J. M., R. Fensham and Y.M. Buckley. 2010. Restoration thinning accelerates structural development and carbon sequestration in an endangered Australian ecosystem. Journal of Applied Ecology 47(3): 681–691.

Abstract Restoration thinning involves the selective removal of stems in woody ecosystems to restore historical or ecologically desirable ecosystem structure and processes. Thinning may also accelerate carbon sequestration in dense regenerating forests. This study considers restoration thinning effects on both structural development and carbon sequestration in a regenerating forest ecosystem. An experimental thinning trial was established in dense *Acacia harpophylla* regrowth in southern Queensland, Australia. The mean stem density prior to thinning was 17 000 stems ha^{-1}. Four treatments (no thinning and thinning down to 1000, 2000 and 4000 stems ha^{-1}) were applied in a randomized block design. Growth and mortality of a subset of stems was monitored for 2 years. Mixed-effects models and hierarchical Bayesian models (HBMs) were used to test for treatment effects and to explore relationships between neighbourhood density variables and the growth and mortality of stems. The HBMs were subsequently used to parameterise an individual-based simulation model of stand

structural development and biomass accumulation over 50 years. The circumference growth rates of stems in thinning treatments were significantly higher than in the control. Woody species diversity and grass cover were also significantly higher in thinning treatments and were strongly negatively correlated with canopy cover. The HBMs confirmed that both growth and mortality were density dependent to some extent. The simulation model predicted a net gain in living above-ground biomass in some thinning treatments (compared with the control treatment) within 20 years after thinning. The 6000 stems ha^{-1} treatment was predicted to be the optimal thinning density for structural development towards the structure of a nearby mature reference forest. Naturally regenerating woody vegetation provides important habitat for native fauna in fragmented landscapes and represents an efficient means to reinstate habitat connectivity and increase forest area. Many regrowth ecosystems also have considerable potential as land-based carbon sinks. This study demonstrates that restoration thinning can be applied to accelerate stem growth and woody species recruitment and may also accelerate structural development and carbon sequestration in this extensive regrowth ecosystem. The application of restoration thinning to provide dual restoration and carbon benefits should be explored for a wider range of naturally regenerating woody ecosystems.

*Latitude: 2*8º2′S
Longitude: 150º55′E
Ecosystem: Subtropical forest
Organism: Plant (forest)
Disturbance: Ringbarking
Maximum time post-disturbance: 40 years

Hobbs, R. J. And H.A. Mooney. 1991. Effects of rainfall variability and gopher disturbance on serpentine annual grassland dynamics. Ecology 72(1): 59–68.

Abstract: We studied the dynamics of a serpentine annual grassland in northern California in relation to disturbance by pocket gophers (*Thomomys bottae*) and interannual variation in rainfall over the period 1982—1988. Mapping of gopher mound formation indicated that the probability that gophers would disturb any given area during the 6 yr study period had a near normal distribution with a peak at two disturbances during that period. Disturbance levels varied considerably from year to year and spatially, and thus the disturbance regime is complex. Exclosure experiments indicated that gopher disturbance had a significant effect on the abundances of many of the grassland annuals, perennial grasses, and cormaceous species. Aboveground herbivores had no detectable effects. Over the period of the study annual rainfall varied threehold and plant community dynamics were strongly affected by this. In particular, *Plantago erecta* decreased and Lasthenia californica increased in abundance with increasing rainfall. Abnormally high rainfall in 1982—1984 allowed the buildup of populations of *Bromus mollis*, the only nonnative species that invades the serpentine significantly. *B. mollis* was, however, subsequently virtually eliminated from the serpentine grassland by two consective years of severe drought. Invasion of *B. mollis* was found only on gopher mounds formed in 1983. In subsequent years recolonization of gopher mounds was predominantly by other species, in particular *Lotus subpinnatus*. Interannual variability in species abundances was most apparent on disturbed microsites. Our results provide a longer term perspective from which to view shorter term experimental and modelling work and highlight the need for long—term observations of ecological systems.

Latitude: 36°25′N
Longitude: 122°12′W
Ecosystem: Prairie
Organism: Plant (annual-perennial)

Disturbance: Gopher disturbance
Maximum time post-disturbance: 3 years

Sasaki, T., T. Ohkuro, K. Kakinuma, T. Okayasu, U. Jamsran and K. Takeuchi. 2013. Vegetation in a post-ecological threshold state may not recover after short-term livestock exclusion in Mongolian rangelands. Arid Land Research and Management 27: 101-110.

Abstract: We tested the potential irreversibility of vegetation dynamics in Mongolian rangelands using well-studied plant communities that exist along grazing gradients, in which ecological thresholds (defined as the points or zones at which disturbance should be limited to prevent drastic changes in ecological conditions) exist in terms of the compositional changes along these gradients. To accomplish this, we removed livestock grazing impacts by establishing exclosures along a grazing gradient at two study sites located in Mandalgobi and Bulgan, Mongolia. Each exclosure was established in the summer of 2004 at a location with either a post-ecological threshold state or a pre-ecological threshold state. We examined general patterns of temporal change in vegetation for the permanent plots inside and outside each exclosure at each site between 2005 and 2010. The trajectories of floristic composition in the permanent plots outside and inside each exclosure were similar from 2005 to 2010, indicating that the trajectories were mainly associated with annual rainfall and annual phenological changes in the plant communities. Post-threshold states at both sites did not reach their respective target community for restoration, indicating the lack of restorability despite livestock exclusion. Moreover, ordination separated the trajectories of floristic composition for the permanent plots inside exclosure in the post-threshold state from those in the pre-threshold state. Thus, our results suggest that vegetation in a post-threshold state may not recover after short-term livestock exclusion in Mongolian rangelands.

Latitude: 45°47′N (Mandalgobi), 43°54′N (Bulgan)
Longitude: 106°11′E (Mandalgobi), 103°30′E (Bulgan)
Ecosystem: Arid/semi-arid grasslands
Organism: Plant (perennial)
Disturbance: Grazing
Maximum time post-disturbance: 9 years

Price, J.N., Berney, P.J., Ryder, D., Whalley, R.D.B. and Gross, C.L. (2011) Disturbance governs dominance of an invasive forb in a temporary wetland. Oecologia 167: 759-769

Abstract Dominance of invasive species is often assumed to be due to a superior ability to acquire resources. However, dominance in plant communities can arise through multiple interacting mechanisms, including disturbance. Inter-specific competition can be strongly affected by abiotic conditions, which can determine the outcome of competitive interactions. We evaluated competition and disturbance as mechanisms governing dominance of *Phyla canescens* (hereafter lippia), an invasive perennial forb from South America, in *Paspalum distichum* (perennial grass, hereafter water couch) meadows in floodplain wetlands of eastern Australia. Water couch meadows (in the study area) are listed under the Ramsar Convention due to their significance as habitat for migratory waterbirds. In the field, we monitored patterns of vegetation boundaries between the two species in response to flooding. Under controlled glasshouse conditions, we explored competitive interactions between the native water couch and lippia subject to different soil moisture/inundation regimes. We did this using a pairwise factorial glasshouse experiment that manipulated neighbour density (9 treatments) and soil moisture/inundation (4 treatments). In the field trial, inundation increased the cover of water couch. Under more controlled conditions, the invader had a competitive effect on the native species only under dry soil conditions, and was strongly inhibited by inundation. This suggests that dry conditions favor

the growth of the invader and wetter (more historical) conditions favor the native grass. In this system, invader dominance is governed by altered disturbance regimes which give the invader a competitive advantage over the native species.

Latitude: 29º21′S,
Longitude: 149º19′E
Ecosystem: Wetlands
Organism: Plant (annual-perennial)
Disturbance: Flooding
Maximum time post-disturbance: 2 months

<u>Gilmour, J. P., L. D. Smith, A. J. Heyward, A. H. Baird and M. S. Pratchett. 2013. Recovery of an isolated coral reef system following severe disturbance. Science 340: 69-71.</u>

Abstract Coral reef recovery from major disturbance is hypothesized to depend on the arrival of propagules from nearby undisturbed reefs. Therefore, reefs isolated by distance or current patterns are thought to be highly vulnerable to catastrophic disturbance. We found that on an isolated reef system in north Western Australia, coral cover increased from 9% to 44% within 12 years of a coral bleaching event, despite a 94% reduction in larval supply for 6 years after the bleaching.
The initial increase in coral cover was the result of high rates of growth and survival of remnant colonies, followed by a rapid increase in juvenile recruitment as colonies matured. We show that isolated reefs can recover from major disturbance, and that the benefits of their isolation from chronic anthropogenic pressures can outweigh the costs of limited connectivity.

Latitude: 13°36′S - 14°13′S
Longitude: 14°48′E - 22°39′E
Ecosystem: Coral reef
Organism: Animal (coral)
Disturbance: Bleaching
Maximum time post-disturbance: 12 years

<u>Starzomski, B. M. and D.S. Srivastava. 2007. Landscape geometry determines community response to disturbance. Oikos 116(4): 690–699.</u>

Abstract Ecological communities are impacted by anthropogenic changes in both habitat geometry (i.e. amount, shape, fragmentation and connectivity of habitat) and disturbance regime. Although the effect of each of these drivers on diversity is well-documented, few studies have considered how habitat geometry and disturbance interact to affect diversity. We used a miniature landscape of moss patches to experimentally manipulate both habitat geometry and disturbance frequency on microarthropod communities. Species richness and abundance in local patches declined linearly with disturbance rate in all experimental landscapes, but the speed of this decline (a measure of ecological resilience) depended on the size and connectivity of the surrounding region. Reductions in region size had little effect on community resilience to disturbance until habitat loss resulted in complete loss of connectivity between patches, suggesting a threshold in community response to habitat loss. Beyond this threshold, repeated disturbance resulted in rapid declines in patch species richness and abundance and substantial changes in community composition. These effects of habitat geometry and disturbance on diversity were scale-dependent. Gamma (regional-scale) diversity was unaffected by habitat geometry, suggesting experimental reductions in alpha (local-scale) diversity were offset by increases in beta diversity. There was no effect of body size, abundance, or trophic position in determining species response to disturbance. Taxonomic grouping had a weak effect, with oribatids less affected by drought. We conclude that, in this system, dispersal from the surrounding metacommunity is vital in allowing recovery of local communities from disturbance. When habitat loss and fragmentation disrupt this process, extinctions result. Studies that examine separately the effects of habitat alterations and disturbance on diversity may therefore underestimate their combined effects.

Latitude: 42°13′N
Longitude: 122°31′W
Ecosystem: Moss microcosm
Organism: Animal (microarthropods)
Disturbance: Drought/heat
Maximum time post-disturbance: 4 months

Appendix 2: Variables collected

There were two steps of variable processing to arrive at the final variables used in the modeling. The first was a session in which as much information on each study fitting our hypotheses was collected from each author. Some of these were discarded before the analysis began due to lack of data, lack of transparency in their calculation, or lack of relevance to our primary hypotheses. Once complete, the remaining variables were assessed for relevance and covariance/collinearity.

All variable data is available by request to the corresponding author.

1. Variables used in final modeling – range values at end detail the range of that variable in the meta-dataset
   - Time since disturbance – Time since disturbance in the study (in years). There were multiple time since disturbances within most studies; these were treated as separate data points. *Range: 0 – 50 years.* This was weighted by:
     - Population turnover time – This is a very general estimate of the population turnover (in years). It is an estimate of the average generation time of the majority of life forms in the system. For example, annual and perennial species characterize grassland systems. Thus, the generation speed might be three years, halfway between one year (annual) and five years (perennial). *Range: 0.01 – 50 years*
   - Species richness – Total pooled species (or species analogue) richness of the controls. *Range: 1 – 201 species*
   - Relative disturbance intensity – if the disturbance has historical precedence, this is how intense it was relative to similar disturbances (*e.g.* 1/100 year flooding event, 3X the average hurricane wind speed, 2X the usual stocking rates, etc.). If the disturbance is novel, it is given the dummy variable value of the maximum relative disturbance intensity in the meta-data * ~1.5. *Range: 0 – 60; 100*
   - Connectivity – whether the entire extent of habitat was covered by the disturbance or not; captures whether the community is isolated or connected to potential propagule sources. This was calculated as the disturbance extent (below) transformed into a binary variable of 0 for total extent (isolated communities) and 1 for less than total extent (connected communities).
2. Variables considered but discarded for relevance and collinearity issues:
   - Temperature – Average annual ambient temperature; atmospheric for terrestrial systems and water temperature for aquatic systems. *Range: 1.5 – 28.6°C*
   - Abiotic change – This captures if there has been an abiotic impact of the disturbance on the ecosystem. It is the percentage difference in the primary impacted abiotic variable to the control immediately after the disturbance (or as near to that point as possible). *Range: 0 – 10 (proportion)*
   - Disturbance extent – This is the areal coverage of the disturbance relative to the estimated amount of available habitat in the contiguous habitat. Specifically, given a landscape of size *A* that is contained in a reserve, for example, or area *A* that is covered by similar habitat but may not be in a reserve, the 'extent' of the disturbance is the percentage of *A* that is disturbed; it will be a value between 0 and 1. This particular variable encompasses a measure of connectivity. *Range: 0.01 – 1 (proportion)*
   - Disturbance duration – Estimated length of the pulse disturbance event (in days). For clearing events, it might be one day; for heavy grazing, it might be 90 days; etc. *Range: 1 – 18250 days*

3. Variables excluded during correlation analysis – reason for exclusion is included at the end of each description
   - Organism – Type of organism studied: plant (vascular plant, liverworts, mosses), animal (microarthropods, fish, coral, terrestrial invertebrates), fungi, or microbe (bacteria). *Reason for exclusion – correlated with relative intensity (-0.62) and isolated portions of data for which we had few datapoints (e.g. only eight fungi datapoints)*
   - Rainfall – Average annual rainfall; irrelevant for deep water marine systems. *Reason for exclusion – capture abiotic character of sites similar to temperature but excluded all marine datasets*
   - *Abiotic Resistance* – This is a binary variable that applies only to a subset of the data. In these cases, there were either *a priori* or logically derived assumptions about which sites would be less impacted and/or recover more quickly from the disturbance based on their abiotic setting. For instance, streamside sites were expected to recover more quickly (*abiotic resistance* = 1) than upland sites (*abotic resistance* = 0); sandy sites (*abiotic resistance* = 1) are more resistant to shrub invasion than non-sandy sites (*abiotic resistance* = 0). *Reason for exclusion – applied to only a small subset of datapoints*
   - *Abiotic difference* – This attempts to capture the 'abiotic resilience' of the system: does the abiotic environment need to return to the control conditions for the system to recover? This is only applicable in instances when the abiotic conditions are altered by the disturbance. It measures the proportional difference in the important abiotic variables to the control. This is intended to be a univariate measure so should focus on the single most important variable or the variable that most represents abiotic change. For example, storm surge can lead to increased soil salinity. Thus, abiotic change would be the average percent difference in salinity between the control and disturbed plots at each time step during the recovery process. *Reason for exclusion – captured in part by 'abiotic change'; data was sparse or unavailable for many studies at timesteps subsequent to the initial post-disturbance measurement*
   - *Disturbance intensity* – A numeric estimate of the intensity of the disturbance. This is a univariate measure of a value of the disturbance as compared to the 'average' of that value without disturbance. The dataset to calculate the 'average' will depend on the author's judgement. *Reason for exclusion – measured similar variable to relative intensity but was more difficult to estimate accurately*
   - *Disturbance timing* – This is a binary variable that captures whether the disturbance was 'in season' The value will be 0, 1, or 2, with 0 meaning 'in season', 1 meaning 'on either side of the season' (so an autumn burn in a region with historically summer fires), and 2 meaning 'opposite season' (so winter instead of summer) or novel. *Reason for exclusion – highly correlated with relative disturbance intensity (0.93); excluded because of categorical nature and correlation*
   - *Disturbance novelty* – 1 if the disturbance is novel, 0 if it has historical precedence. *Reason for exclusion – highly correlated with relative disturbance intensity (0.94); excluded because of categorical nature and correlation*
   - *Disturbance frequency* – This is a value from capturing the probability of occurrence of the disturbance in a single 'time step'. For most, this would be probability of occurrence in a year: flooding (of any level, not just that measured in the study) every 20 years (*disturbance frequency* = 1/20); fire every three years (*disturbance frequency* = 1/3); etc. For novel disturbances, this data is missing. *Reason for exclusion – highly correlated with temperature (-0.81) and disturbance duration (0.68); excluded because of categorical nature and double correlation*

4. Variables excluded prior to correlation analysis
    - *Location* – For larger countries, location is identified to state-level. For smaller countries, it is identified to country-level. This might eventually be scaled up to identification at the continent-level only.
    - *Latitude/Longitude* – Coordinates of the approximate centerpoint of the study area.
    - *Ecosystem type* – Ecosystem type could be any of the following: tropical rainforest, tropical seasonal forest, woodland, grassland, boreal, subtropical forest, temperate rainforest, temperate seasonal forest, tundra, alpine, polar, estuary, reef, intertidal, subtidal, multiple
    - *Land-use history (in the decade prior to disturbance)* – This is a 0 or 1 value, 0 for sites without a history of human land-use and 1 for sites with a history of human land-use. Examples of unused = offshore coral reefs, unutilized coastal wetlands. Examples of used = sites with a long history of grazing or other land-use (e.g., cultivation).
    - *Disturbance* – Disturbance type could be any of the following: agriculture, clearing, eutrophication, windthrow, biomass removal, chemistry stress, anoxia, temperature stress, surface stress, grazing, fire, flood, outbreak, landslide, drought, poison, pollution, mining, nutrient pulse
    - *Spatial scale* – Scale of observation relative to approximate scale of ecosystem. This is similar to the disturbance extent, except instead of the percentage disturbed, this variable focuses on the percentage of A that is sampled.