THE PROMISE of POLYCENTRICITY in TWO U.S. PUBLIC WATER SYSTEMS

Karen J. Baehler
American University, Washington, DC

Jennifer C. Biddle
University of North Carolina Wilmington, Wilmington, NC

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ABSTRACT

This paper explores relationships between polycentricity and the processes through which social-ecological poverty and rigidity traps are built and dismantled. Two case studies are developed through process tracing and analyzed according to a four-phase model of social-ecological trap dynamics. Out of eight non-null hypotheses positing a variety of causal mechanisms in which polycentricity influences poverty and rigidity traps and traps influence polycentricity, evidence from the cases supports six. The paper concludes that the traps construct provides insights into various processes by which polycentricity contributes to adaptive capacity of social-ecological systems, while also highlighting potential weaknesses and limitations of polycentricity. For polycentricity to be effective in supporting adaptive capacity, this analysis suggests that two requirements must be present: a rough balance of power among the system's decision-making centers and assurance that one or more centers support the interests of resource users and the health of the resource itself.

INTRODUCTION

In nature, survival depends on a species' ability to adapt to changes in its surroundings by acquiring useful traits and shifting its behavior to cope with new stresses and take advantage of new opportunities. Humans are the only species with the power to choose, individually and collectively, among various adaptation strategies, including strategies to reengineer the environment itself to meet our purposes. We are also the species most likely to trigger rapid, large-scale environmental changes that require adaptation strategies, some of which may turn out to be maladaptive, leading to more and more complex interventions. To facilitate understanding of these complex, adaptive and maladaptive processes, scholars devised the concept of a linked social-ecological system (SES) (Berkes and Folke 1998), which refers to a single, interdependent and emergent entity in which humans, human organizations, and the built environment interact with the full range of objects and beings that constitute nature.

Drinking water systems offer examples of a type of system heavily dominated by human intervention and the social side of the SES construct. The Flint, Michigan water debacle of 2014-16 vividly illustrates one pathway by which a human-engineered crisis can tip the whole linked SES from a state of reasonable reliability to a state of public health emergency with long-term implications for government's credibility. The Flint case raises serious concerns about the deteriorating condition of water infrastructure in older cities as well as the unmitigated surface water quality problems that have been allowed to persist for decades in many former industrial centers. In addition, the patterns of decision making observed in Flint raise questions about the capacity of public institutions at multiple levels to recognize and respond to threats effectively and adaptively, and to learn from such experiences. By contrast, the city of New York has succeeded in managing threats to its drinking water system from multiple sources over many decades, and in the process has built a network of actors and institutions designed to advance learning and maximize responsiveness to shocks and stresses.

Social institutions that produce the kind of salutary results seen in New York City are often called resilient, meaning they can "absorb change and disturbance" in the short term without collapsing (Holling 1973, p 14); "learn, reorganize, and redevelop, preferably to an improved state, in the longer term" (Engle et al 2014, p 1296); and, where optimal, transform into a wholly new creation better suited to the changed environment (Carpenter, Westley, and Turner 2005). A recent variant of the concept, known as evolutionary resilience, encompasses all of these types of responses in settings characterized by constant change and no stable equilibria (Davoudi 2012; Simmie and Martin 2010). A related concept—adaptive capacity—underpins resilience and captures "a critical system property, for it describes the ability to

mobilize scarce resources to anticipate or respond to perceived or current stresses" (Engle 2011, p. 648), and thus determines the boundaries of a system's coping range (Yohe and Tol 2002). Systems with more adaptive capacity can increase their resilience and reduce their vulnerability by modulating exposure to sources of harm and sensitivity to harm once the exposure occurs (Engle 2011; Adger 2006). Adaptive capacity thus helps to operationalize resilience by focusing on the central mechanism—adaptation via reducing vulnerability—that seems to be at work in resilient systems.

The study of adaptive capacity also has begun to reveal the central mechanisms that plague systems with low resilience. Known as social-ecological traps, these are path-dependent processes in which self-reinforcing feedbacks lead to the "structural persistence" or "lock-in" of negative patterns such as inequality, authoritarian government, and environmental degradation (Laborde et al 2016, Boonstra and deBoer 2014). Traps qualify as one form of maladaptation (Sterelny 2007, Holling and Gunderson 2002). Scholarly work on traps and adaptive capacity aims to find formulas for how humans can best prepare for and respond to current and future threats to natural resources and ecosystems. Much of this exploration necessarily focuses on governance and institutions as the main vectors through which societies set rules, create incentives, and distribute powers that constrain and direct people's interactions with the environment. The literature to date has identified a growing list of governance traits associated with adaptive capacity and resilience (Berkes and Ross 2013; Brooks et al 2005; Clarvis and Engle 2015; Djalante et al 2011; Engle and Lemos 2010; Garmestani and Benson 2013; Huitema and Meijerink 2010; Huntjens et al 2012; Knieper and Pahl-Wostl 2016; Olsson et al 2006; Pahl-Wostl et al 2012, 2013).

One such trait is polycentricity, which refers to a set of multiple, formally independent power centers with overlapping jurisdictions at different scales (McGinnis & Ostrom 2012; V. Ostrom et al 1961). When those power centers "take each other into account" in coherent ways across scales, they tend to form interdependent, coordinated systems of governance that may or may not outperform other types of arrangements under various circumstances (V. Ostrom et al 1961, p 831). In the case of natural resources management, both theory and empirical research consistently have linked polycentric governance with better SES performance, as measured by both outputs in the form of policies and practices that reflect an adaptive approach (Koontz et al. 2015; Pahl-Wostl et al. 2012), and outcomes in the form of resource quality and quantity (da Silveira and Richards 2013).

More needs to be known about how, when, and why polycentricity works to build adaptive capacity (Koontz et al 2015). Yet, theory is not always easy to connect with empirical findings largely because the phenomenon of interest is more a process or pathway rather than a trait. Understanding processes and

pathways requires tracing them over time on a case by case basis, which makes both internal and external validity more difficult to achieve.

Where SES pathways are concerned, significant progress has been made using a construct known as a social-ecological trap to capture some of the most formidable obstacles facing actors in the Anthropocene era. Climate change, for example, perfectly illustrates the type of trap that involves a "mismatch between a fast-changing environment and a social system that is slow to respond" and the consequences of that mismatch, including "techno-institutional lock-in" in which institutions that have invested in and become habituated to a suboptimal technology—carbon-based fuels, for example—prevent other, better technologies from replacing it (Laborde et al 2016, p. 14). Traps such as these represent the dark side of social system stability, for they reinforce perverse incentives, entrench harmful habits, and resist self-correction. Over time, if left unbroken, these maladaptive patterns of behavior can lead to declining productivity of natural resources and subsequent human suffering, particularly in subsistence societies. Examples include fisheries and forests caught in persistent cycles of overharvesting and agricultural areas subjected to increasingly intensive cultivation (Enfors 2013; Boonstra and de Boer 2014).

In describing the vicious cycles that reinforce maladaptation, traps offer something like a photographic negative of adaptive capacity. As such, they offer insights into the original concept and may function as reverse proxies for adaptive pathways. If we learn more about how traps work, we may develop better ideas about how to prevent or interrupt them through adaptive governance. This paper seeks to contribute to that agenda by building on the logical association between traps and deficits of adaptive capacity, and the empirical relationship between polycentricity and adaptive capacity (Engle 2011; Walker et al. 2004). Given those two sets of relationships, it seems reasonable to posit a pathway that leads from polycentricity to adaptive capacity via mechanisms that prevent or interfere with traps. Based on the long-standing enthusiasm for polycentricity as an ingredient in adaptive capacity (Eakin & Luers 2006; Folke 2006; Smit & Wandel 2006; Walker et al. 2006), we might expect polycentric arrangements to be effective in blocking or interrupting entrapment processes. On the other hand, it is also possible that polycentricity might enable or exacerbate traps. Alternatively, causation might point in the other direction, meaning that traps might either increase or erode/undermine polycentricity. The general question seems ripe for investigation, and the full range of possible relationships needs to be examined.

A central purpose of much of the SES literature is to open the black box of adaptive capacity in order to find ways of supporting and developing this beneficial property, especially for systems facing immediate risks from climate change and other macro-stresses with catastrophic potential. Carpenter and

Brock (2008, p 11) describe a role for traps in the larger research agenda: "Understanding the pathways out of traps and how complex systems can be guided onto one pathway or another is an important topic for emerging research." This paper contributes to that understanding by identifying several processes in which polycentric governance appears to influence a system's pathway into or out of traps, and vice versa.

THEORETICAL BACKGROUND

Social-ecological traps refer to "path-dependent processes … causally produced through a conjunction of events" (Boonstra and de Boer 2014, p 260), and reinforced by "feedbacks between social and ecological systems, [which] lead toward an undesirable state that may be difficult or impossible to reverse" (Cinner 2011, p 835). Within each trap, emergent sets of perverse incentives, impacts on the ecosystem, and reactions to those impacts evolve in ways that tend to become spiraling harm multipliers due to short-term, individual rewards that mask or distract from longer-term, collective costs. Because traps tend to build strength over time, it is best to avoid them in the first place, when possible.

Holling and Gunderson (2002) explain how traps can interfere with a social-ecological system's ability to adapt to stresses and shocks. Their panarchy framework, also known as the adaptive cycle, posits a large-scale, repeated cycle of growth (r), conservation and consolidation (K), release (omega), and renewal (alpha) that shapes an SES's evolutionary path over the long run. The types of assets and capital to be grown and conserved during the growth (r) and conservation (K) phases include plant life, soil nutrients, water, and animal populations on the ecosystem side, in addition to financial wealth, social capital, technology, and information on the social side, among many others. Within the cycle, resilience is most clearly demonstrated in the renewal (alpha) phase, where success occurs when the SES reorganizes its released assets following an (omega) disruption, such as a natural disaster or political revolt, and does so in ways that improve its fitness for future circumstances. Successful reorganization (alpha) leads to a new cycle of growth (r), while failure to regroup may cause prolonged disaster as released assets are lost or wasted and efforts are dissipated.

Two types of traps imperil the adaptive cycle (Holling 2001, p 400). The first—**the poverty trap**—interferes with the system's ability to organize and mobilize resources to accomplish goals. Carpenter and Brock (2008) describe the poverty trap in terms of chronically low utilization, effort, and control. Under-used systems tend to be characterized by poor coordination, lack of mobilization, and unrealized potential. When this kind of inertia occurs in the renewal (alpha) phase, it blocks self-organization and re-

invention and prevents the system from advancing to the growth (r) phase. Inertia in the growth (r) phase, similarly, leads to feeble development at best, which reinforces shortages of natural or human-made capital that may have helped trigger the vicious cycle in the first place.

Systems with low levels of wealth tend to be victims of the poverty trap, although a poverty trap can exist in a system with abundant resources if those resources remain fragmented and uncoordinated and cannot be mobilized for productivity. Impoverished systems often have less to lose in a disaster scenario (omega phase) compared to wealthier systems, but they also have fewer resources that can be reorganized in the recovery (alpha) phase. Therefore, an SES caught in a poverty trap may have to deplete its savings in order to subsist, which could include overharvesting ecological or cultural wealth, which in turn reduces choice by leaving less stored potential for pursuing different futures. Escape from the poverty trap may occur if agents in the system can tap unknown or latent internal resources, or if outside resources are provided in sufficient quantities to flip the system from a state of chronic deprivation to one of self-reinforcing growth and development.

The second type of trap—**the rigidity trap**—refers to "increasing reliance on a specific configuration of system variables" that cause the system to become less pliable (Chaffin and Gunderson 2016, p 83). It is most likely to develop in the consolidation and conservation (K) phase when physical resources are becoming hardened (as through infrastructure construction) or social resources are becoming institutionalized. Rigidity reduces the SES's capacity to respond quickly and creatively to changing circumstances and increases its vulnerability to fluctuations and collapse. These patterns become self-reinforcing via physical feedback cycles as well as social phenomena such as force of habit, lack of exposure to other ways of doing things, and groupthink attitudes such as the TINA principle (there-is-no-alternative).

Because rigidity traps tend to resist smaller-scale disturbances and subsequent learning and adaptation (they are negatively resilient), they often lead to larger, more disruptive omega-phase shocks. Ideally, after the turbulent phases (omega and alpha) a new configuration of system components will emerge that includes less rigid, less brittle, and more adaptive forms of governance to replace those that have collapsed or lost their legitimacy (Chaffin and Gunderson 2016). In the worst-case scenario, the turbulent phases lead instead to long-term wastage and persistent decline via the poverty trap.

Systems stuck in a rigidity trap may have vast wealth, but those resources are locked up under strict controls (Holling 2001), such as conformance with maladaptive rules. Carpenter and Brock (2008)

describe the rigidity trap in terms of chronic overuse due to excessive control, leading to high levels of unrelieved stress—like a switch stuck in the "on" position. Think, for example, of subsistence fishers with no other livelihood alternatives who face declining fish stocks in the local fishery. A typical response to this scenario is to increase fishing effort at an accelerating rate to maintain income despite resource decline. Once established, such a pattern becomes difficult to change, especially if everyone is doing it, despite the likely increase in income instability and eventual collapse of the fishery.

According to the panarchy account, systems should expect to oscillate between periods of growth/exploitation and conservation/accumulation (r and K) and periods of disruption in which the system is forced to release its lock on resources and then regroup (omega and alpha). To the extent that a system responds intelligently to disruptions, they may function as opportunities for constructive change. The genius of the panarchy is its suggestion of a general pathway toward SES health and sustainability based on stimulating smaller, more frequent, and more compact cycles of release and renewal analogous to the common practice of controlled, prescribed burning of forest areas. Such burns act as deliberate omega events that reduce the probability of more serious forest fires later by reducing fuel build-up (a type of rigidity trap because the resources are locked and inaccessible) while also releasing minerals in the soil that stimulate germination of new trees in the subsequent renewal (alpha) phase.

Comparable opportunities for releasing and reorganizing social and biophysical assets (i.e., nutrients, water resources, financial wealth, and information, to mention just a few examples) in a wide variety of SES types may reduce the risks associated with unplanned, omega-phase disruptions, while also promoting cumulative learning within the system, all of which should improve resilience. Holling (2001) provides multiple examples of how well-governed social systems can avoid some of the larger disturbances associated with revolts and other destructive movements by designing smaller cycles of release and reorganization. Regular elections are a classic example of how to institutionalize smaller omega cycles. Elections allow the governance system to adapt to changing attitudes without having to wait for large build-ups of frustration and dissatisfaction (the rigidity trap of unhealthy politics) followed by sweeping, and often violent change.[1]

Understanding how perversities develop in human-dominated SES requires close attention to the micro-level system processes from which they emerge, particularly the incentives for collective action. Whenever individual resource users have strong incentives to consume as much of a common pool

[1] Even in well-functioning democracies, however, errors may be allowed to accumulate for long periods of time, in which case the punctuations of equilibrium may come as shocks (Baumgartner et al 2014).

resource (CPR) as they want before it is gone, sustainable levels of use will be difficult to achieve even when all users share strong motivations to protect the resource's future productivity. This is known as the tragedy of the commons (Hardin 1968), a concept that helped motivate Elinor Ostrom's early work on CPR problems. The tragedy-of-the-commons scenario links one example of a rigidity trap—a short-term mindset that leads each actor to engage in increasing levels of consumption—with a poverty trap induced by the resulting race to the bottom, which ultimately reduces the originally abundant resource to an impoverished resource. The two types of traps tend to feed each other in the tragedy of the commons. Other maladaptive cycles have been identified and named by Donella Meadows (2008) and others.

Instead of succumbing to the tragedy and other vicious cycles, SES actors nearly always have the option of committing to a cooperative plan for sustainable management and use of the common pool resource. To be successful, such a plan typically needs to establish incentives that reward responsible resource use. Such plans also should establish regular, controlled cycles of review and potential disruption to enable adaptive change via learning. The controlled cycles of disruption should be carefully calibrated, large enough to break rigidity traps but small enough to avoid throwing the whole system into chaos. Actors in the system also need incentives to reorganize productively following each disturbance in order to avoid poverty traps. Appropriate incentives have been shown to facilitate self-organization of governance organizations that bring significant human resources to the task of managing and coordinating natural resources (E. Ostrom 2007).

Polycentric governance may or may not be better suited to combatting traps and protecting against systemic atrophy and collapse than monocentric systems. Take the poverty trap. On one hand, polycentric systems are comprised of separate centers rather than just lone individuals, and each of those centers possesses some existing organizing capacity, which, however modest, could be pooled to address shared concerns. In addition, the modularity of the polycentric arrangement makes it possible for ad hoc networks or coalitions of centers to form and disband as needed to address shifting needs—an approach to coordination that is less likely to produce large, expensive coordinating bureaucracies. Moreover, multi-level, nested polycentricity creates opportunities for cross-scale subsidies and other types of cross-scale investments and interventions that may be capable of breaking a poverty trap at one scale (Andersson and Ostrom 2008; Erickson 2015).

On the other hand, as a multiplicity of overlapping power centers, polycentricity may dissipate energy across too many independent entities, leaving each of them too weak to accomplish anything. Especially in a system already struggling with poverty, the various centers may spend most of their available energy

competing for a small pool of resources, and then accomplishing little with what they receive. A highly dispersed arrangement also may struggle to marshal enough coordinated effort and energy to overcome inertia and launch effective initiatives.

The points above suggest two competing hypotheses:

H1: Polycentricity will prevent/disrupt poverty traps by providing opportunities for network organization at scale as well as cross-scale interventions in multi-level systems.

H2: Polycentric systems will enable/exacerbate poverty traps in SES by spurring unproductive competition and conflict among multiple power centers, or by perpetuating costly collaborative efforts beyond their useful lives.

With respect to the rigidity trap, the greater repertoire of ideas and approaches associated with polycentric governance seems particularly well suited to interrupting hegemonic thinking or routinized behavior. The benefits of this "requisite variety" (Ashby 1956), which refers to the number of possible states in a system, may manifest itself in SES as dissenting voices challenging an entrenched status quo or less directly as information based on experimentation by independent centers that may offer improvements on current practices. In their study of successful transformations toward adaptive governance of natural resources, Olsson et al (2006, p 29) describe the important role of informal or "shadow" networks "that help to facilitate information flows, identify knowledge gaps, and create nodes of expertise of significance for ecosystem management that can be drawn upon at critical times." Shadow networks contribute to increased polycentricity.

Polycentricity thus seems well placed to protect against rigidity traps, but opposite effects also can be imagined. When the subsystems of a polycentric system face similarly perverse incentives, for example, the separate parts of the system may find it difficult to alter their own out-of-date or dysfunctional status quo processes (Carpenter et al 2008). Reasons for such inertia may include various cognitive heuristics such as sunk-cost bias, risk aversion, and asymmetric sensitivity to gains and losses. Processes of socialization and group capture may spread throughout the various centers, thereby reducing diversity and shrinking the repertoire of solutions. Polycentric governance systems also may fail to break rigidity traps due to a sort of institutional bystander effect or free rider problem in which various centers stand by assuming that other centers will fill various roles. In the end, if no one fills those roles, important tasks will go undone, but blame will be difficult to apportion. Accountability thus becomes attenuated within a

polycentric system when key actors can "rely upon other actors who were assigned the same responsibilities," which creates "strong incentives to shirk responsibility" (Carlisle and Gruby 2017, p. 14).

The points above suggest two additional hypotheses:

> H3: Polycentric systems will prevent/disrupt rigidity traps by facilitating small-scale omega events capable of breaking hegemonic mindsets and behaviors through dissent, experimentation, and shadow networks.

> H4: Polycentric systems will enable/exacerbate rigidity traps by facilitating gridlock, groupthink, and bystanding.

Finally, it is important to ask whether causation also might flow in the other direction. An impoverished polycentric system might become more fragmented over time if the pressure of chasing scarce resources causes organizations to develop more irreconcilable differences, leading to splinters or cleavages. Alternatively, a system characterized by poverty could be expected to become more monocentric over time if centers choose to merge in order to pool their meager resources and build enough critical mass to overcome the poverty trap's dissipating forces.

Likewise, the presence of rigidity traps also might lead to increasing or decreasing polycentricity. The former effect is more likely if the rigidity trap triggers a disturbance that clearly illustrates the vulnerabilities associated with more monocentric systems and thus generates a more polycentric successor. It should be noted, however, that such a scenario requires effective reorganization in the alpha phase of the adaptive cycle. Alternatively, a rigidity trap characterized by groupthink may encourage mergers of power centers to consolidate the prevailing perspective.

Hypotheses associated with these scenarios are as follows:

> H5: Poverty traps will increase polycentricity by creating pressure for centers to split.

> H6: Poverty traps will reduce polycentricity by creating pressure for independent centers to merge or by allowing a single center to dominate the others, which creates functional monocentricity even if the system's formal structure does not change.

H7: Rigidity traps will increase polycentricity by generating crises that expose the maladaptive qualities of a more monocentric system.

H8: Rigidity traps will reduce polycentricity by creating pressure for independent centers to merge.

Finally, the null hypothesis must be considered:

H0: Polycentricity and traps operate independently of each other.

METHODS

Hypothesis testing at a system level is inherently fraught with difficulties. First, the sheer number of variables, and interactions among variables, that are needed to specify a dynamic SES model of moderate complexity tends to discourage formal modeling. The challenge becomes more daunting when the goal of the research goes beyond identifying and measuring impacts to explaining how those impacts occur. In lieu of statistical models, case studies can accommodate such complexity through rich description, but they may be vulnerable to conscious or unconscious confirmation bias, which raises a second type of difficulty. Confirmation bias arises because researchers choose which case details to collect and report, and they choose how to code each detail. Different researchers might choose different details or interpret them differently or both. Third, when the outcome variables of interest represent latent qualities, such as adaptive capacity, issues of measurement arise: unobservable qualities are difficult enough to identify, let alone measure (Engle 2011).

Such research dilemmas may help explain why, according to critics, “the SES resilience literature displays a dearth of … research designs that aim to produce generalizable results” and an excess of interpretive or sense-making-type case studies that tend to illustrate theories rather than testing them (Duit 2015, p 370). This paper addresses each of the challenges as follows.

Process Tracing to Map Complexity

The paper adopts an historical-institutionalist approach (Mahoney and Thelan 2009) to mapping the relationships between polycentricity and entrapment processes in order to capture as much of the systems' complexity as possible while also taking the dimension of time seriously (Durant 2014; Westley et al 2011). Process tracing—a social science method of within-case analysis for the evaluation of causal processes—is applied in order "to focus on the interdependent interactions between people and their natural environment, but also on the interdependency between episodes or phases within longitudinal social processes" (Boonstra and DeBoer 2014, p 263). By identifying linkages between independent and dependent variables in an historical sequence, process tracing can begin to explain how initial conditions or determinants, including larger social and political factors, are translated into outcomes (George and Bennett, 2005; George and McKeown, 1985; Goldstone, 1998; Hall 2003). When the outcomes of a process are undesirable and the process mechanisms identified take the form of self-reinforcing feedback loops, the presence of a social-ecological trap can be reasonably inferred.

The process tracing method thus facilitates the study of complex relationships inherent in social-ecological systems that involve multiple interdependencies, feedback loops, path dependencies, and interaction effects. By locating sequences of activity in time, it also allows the researcher to rule out some causal propositions: causes generally occur earlier in time than their effects. Each hypothesis above involves (1) identifying the direction (positive or negative) of polycentricity's apparent impact on traps and vice versa; and (2) to the extent possible, establishing a causal connection between polycentric features and the presence of traps by specifying the causal mechanism. Process tracing applies particularly to the second step.

Contrary Hypotheses and Parallel Processing to Reduce Confirmation Bias

The body of SES literature to date suggests that polycentricity often contributes to desirable system outcomes. It is, therefore, reasonable to expect the impacts of polycentricity on social-ecological traps to be beneficial, meaning that polycentricity will tend to counteract processes of entrapment. Hypotheses 1 and 3 above reflect this expectation. Rigor requires us also to entertain the opposite possibility, that polycentricity may aggravate or even cause traps. Simply by virtue of including contrary hypotheses (2 and 4) in the study, we force a search for evidence that might falsify the favored hypotheses (1 and 3), which should lead to a more thorough and less biased examination. Hypotheses 5-8 are included to add an

additional layer of rigor by requiring consideration of reverse causation. The null hypothesis also needs to be retained as a possible result: it posits no causal connections among polycentricity and traps.

Case study data was collected from primary and secondary sources, including reports of government inquiries, utility reports, white papers, news articles, emails released through Freedom of Information Act requests and made publicly available, law review articles, and published histories. Collection of case study materials was undertaken separately by each co-author with the expectation that a richer and more representative set of materials would be gathered than if either author had been assigned the task alone or if the two searches had been coordinated for efficiency. Each co-author also wrote up both cases independently, based on the combined material, in order to reduce bias associated with omitted variables or skewed interpretation. Although the two case write ups displayed meaningful differences, we cannot prove that our parallel-processing approach necessarily reduced confirmation bias.

We then organized the course material for each case according to Boonstra and deBoer's (2014, p 263) ideal-typical, temporal sequence for describing a series of interdependent social interactions propelled by "self-reinforcing feedback" acting as "the causal mechanism that creates path dependency" (Boonstra and DeBoer 2014, p 263). The first ideal-typical phase, known as **antecedent conditions**, encompasses an earlier period, prior to the key decision point, when background factors were present that made the key decision possible or probable. The focus of analysis in this phase is to describe relevant features of the time, place, and circumstances that preceded the key decisions. The second phase, known as the **critical juncture**, covers the period immediately before, after, and during the key decision(s) that allowed the entrapment process to unfold. **Structural persistence** is the third phase. It describes the self-reinforcing mechanisms generated by the key decision, their processes of reproduction, and how they make the future course of events more difficult to modify or reverse. In the fourth and final phase, **reactive mechanisms**, agents react to the previous events, often in ways that disturb or alter the self-reinforcing patterns established in the earlier phase. When traps are broken, evidence about the mechanisms involved typically surfaces in the fourth phase.

For purposes of this study, we assume that different parts of a system may be at different stages of trap-building and trap-breaking simultaneously.

Case Selection to Reduce Confirmation Bias

To avoid the "unfortunate propensity for choosing cases that confirm theoretical starting points" (Duit 2016, p 370), we selected a matched pair of cases with similar multi-level, polycentric governance arrangements—both are subsets of the U.S. system of regulatory federalism—but dramatically different outcomes in terms of water quality and social trust. Within the U.S. system of regulatory federalism, the federal government establishes the overarching rules for drinking water systems through the U.S. Safe Drinking Water Act and related regulations written and enforced by the U.S. Environmental Protection Agency (USEPA). The USEPA, in turn, operates through its regional offices, which are empowered to devolve authority and responsibility for national goals to state environmental agencies; the latter are mandated to coordinate with the EPA to enforce drinking water quality standards (Scheberle, 2004). The combination of decentralized independence, overlap, and interdependence that characterizes environmental protection in the U.S. should, in theory, produce good results. State governments are closer to communities than either the regional or national offices of the EPA, and, therefore, can respond in an agile fashion to shifting local needs and stresses. As so-called laboratories of democracy, states presumably can innovate in ways that advance learning throughout the larger system. In addition to setting policy, the federal government should serve as a backstop when states fail to meet their full responsibilities due to politics, lack of capability, or other reasons.

Our first case— New York City (NYC), New York's drinking water system—has enjoyed very high-quality drinking water for decades without anything like the crisis suffered in Flint. NYC's water system has a long-running history of polycentric governance operating within the U.S. framework of federalism, and it became more polycentric over the study period. In contrast, our second case—Flint, Michigan's drinking water system—experienced dramatic declines in drinking water quality during roughly a two-year period starting in April 2014 for reasons of bad human judgment followed by many months of absent accountability, despite an underlying structure of polycentricity.

Addressing Latent Properties

The methodological challenge associated with latency stems from adaptive capacity's nature as a potentiality rather than an observed action or outcome. As such, it can only be assumed based on actions or outcomes of the type that would be expected if such potential were present. The problem of observability is not helped by definitions that introduce other concepts equally elusive. For example, if adaptive capacity is understood as "the capacity of actors in the system to manage and influence

resilience" (Engle 2011, p. 650), then we face the additional challenge of trying to observe and verify resilience in advance of shocks and disturbances to the system, the impacts of which provide the only true test of any system's resilience.

Because adaptive capacity cannot be observed or measured directly, we equate system outcomes with adaptive capacity in this study on the assumption that robust systems with healthy outcomes must be adapting effectively to changes in their social and ecological environments. It is conceivable that healthy outcomes may result from interactions between confounding factors and not from direct actions taken in response to change. However, we see these examples as atypical and not the norm. Our approach assumes that evidence of adaptation counts as evidence of previously existing adaptive capacity. Thus, a system with consistently good water quality, like NYC, is credited with higher adaptive capacity than a system with the types of problems seen in Flint.

Unit of Analysis and Variables

Following Andersson and Ostrom (2008), we take as our unit of analysis the nested governance arrangement associated with each water system. Within that unit of analysis, we judge the degree of polycentricity separately at various points in time along the case trajectory. Our definition of polycentricity employs the conventional pair of criteria established originally by the Ostroms: (1) presence of multiple, quasi-independent power centers with overlapping jurisdiction, which we call the structural dimension of polycentricity; and (2) evidence that actors in the multiple centers take account of each other's activities when making decisions, which we call the behavioral dimension of polycentricity. Regarding criterion 1, we look for at least five separately identifiable centers with relevant authority. Any choice of a number for criterion 1 is arbitrary, of course, but we wanted to create a reasonably stringent threshold and one that cannot be satisfied by three-part federalism alone (local + state + federal government).

We identify traps based on the presence of self-reinforcing causal mechanisms leading to undesirable SES outcomes.

ANALYSIS

The following narratives organize the case material according to a social-ecological traps framework based on a four-phase time sequence and evidence of cyclical and self-reinforcing mechanisms. This analysis reveals that various types of traps were present at different phases in each case. Structural polycentricity varied somewhat between cases and also across time periods within each case. Table 1 at the end of the paper summarizes the results.

New York City, New York

Antecedents

New York City (NYC)[2] is home to the largest unfiltered water supply in the United States, servicing a population of approximately 8.4 million people (Grolleau & McCann, 2012). Early on in the City's development (1830-1905), proposals to use local surface waterbodies (i.e. the Hudson River) were rejected in favor of the installation of 125 miles of pipeline north of the City in the Croton and Catskill-Delaware watershed systems to collect abundant, pristine water from unspoiled rural watersheds. Through the first six decades of the 20th century, NYC's Board of Water Supply (BWS) focused almost exclusively on the task of continuously growing and protecting the city's water supply, a process that required land seizures to build reservoirs and restrictions on local activities to protect water quality from multiple sources of pollution. David Soll's (2013) comprehensive history of the NYC waterworks refers to this period as the era of "democratic resource imperialism" (p. 38) in which NYC exerted dominance over many dimensions of life in the Catskill-Delaware region, including "imposing its police powers on watershed residents" (p. 47).

Throughout this period, evidence can be found for both poverty and rigidity traps. In the Catskill-Delaware region, local residents had multiple complaints about the ways in which the BWS managed its source-water region. These included restricted access to areas for hunting and fishing, regulations on a wide variety of activities from construction to laundry, dam releases that degraded the ecological quality of tributaries downstream, inadequate maintenance of roads surrounding reservoirs, and many other impositions. The complaints tended to be varied and dispersed, however. Despite much common ground, local residents for decades failed to organize in sufficient numbers and with a sufficiently compelling case

[2] We refer to the State of New York as New York, and New York City as NYC.

to build leverage in the state capital of Albany. One of the obstacles to such organization was the political dominance of NYC in state matters of all types.

This antecedent incapacity to organize Upstate interests qualifies as a poverty trap—resources were available, but fragmented, uncoordinated, and therefore unproductive. As NYC continued to dominate the activities and discussions regarding Catskill-Delaware water and land use decade after decade, locals became acclimated to their powerlessness, which created further obstacles to effective organization. Although many citizens engaged with the issues, efforts never reached the scale needed to change policy.

Parallel to the poverty trap was a rigidity trap in NYC defined by the BWS's prevailing approach to Upstate water—a perspective or mindset that also pervaded official thinking in Albany. That mindset focused narrowly on building and maintaining infrastructure for water collection and delivery, and on controlling land use around the Upstate reservoirs to protect against point-source threats to water quality. It is worth noting that the BWS mindset—the rigidity trap—also made political organizing in the Catskill-Delaware region more difficult, thereby exacerbating the poverty trap.

By the early 1980s, however, NYC's 1970s fiscal woes and other factors began to reduce its power in Albany relative to more rural parts of the state. At the same time, the threat to water quality posed by nonpoint sources of pollution from rapid development and agricultural runoff in the Catskill attracted greater attention (Appleton, 2002). Following construction of a filtration plant in the Croton watershed to maintain compliance with safe drinking water standards[3], the possible necessity of building a $4-6 billion water filtration plant to treat Upstate water emerged.[4] The City faced powerful financial incentives to avoid additional filtration, but also serious questions about whether its administrative capacities were suited to the task. BWS tended to react to news of water quality problems by wanting to impose more regulations—the dominant tool in their toolbox. This ingrained approach to problems further illustrates the rigidity trap.

Throughout this period, the governance system was structurally polycentric, but not always behaviorally so because the more dominant centers often did not take weaker centers into account: thus,

[3] Under the 1986 amendments to the Safe Drinking Water Act, USEPA promulgated the 1989 Surface Water Treatment Rule; the 1996 Interim and Enhanced Surface Water Treatment Rule that required unfiltered systems to meet additional provisions to retain unfiltered status; and the 2006 Long Term 2 Enhanced Surface Water Treatment Rules, which imposed requirements on filtered and unfiltered systems to increase disinfection.

[4] As early as 1905, engineers discussed filtering Catskill-Delaware water, but the BWS chose instead to make improvements to sanitation infrastructure and enforce multiple regulations on watershed residents (Soll, 2013).

inter-dependencies were lop-sided. The system included many weaker local power centers dispersed throughout the Catskill-Delaware region, the very powerful BWS, various other NYC officials, the governor's office, and the legislature in Albany, with some involvement by courts when various water management practices were being challenged. After 1970, the federal government's role increased. Not until the 1990s (next phase) did the power distribution begin to force more equality of inter-dependency within the polycentric system.

Critical Juncture

Consistent with the rise of environmentalism nationwide and its tendency toward greater polycentricity—as new civil society and government organizations proliferated—the BWS became the New York City Department of Environmental Protection (NYCDEP) in 1978. Although the organization's culture and mindset proved harder to change than its name, NYCDEP eventually adopted an ecosystem perspective, especially starting in 1990 with the appointment of new leadership in Commissioner Albert Appleton. Thus began a period of intensive negotiation between the two regions about how to protect water quality while also restoring Upstate residents' prerogatives.

NYC officials partnered with the New York Department of Agriculture to engage Catskill-Delaware residents, who had begun to organize more effectively in response to new draft watershed regulations released in 1990. Area farmers initially formed a Watershed Agricultural Council to coordinate their own activity and to manage a steady flow of financial payments from NYC to Upstate communities for implementation of Whole Farm Plans. The new, collaborative, and negotiated approach integrated farmers' business needs into the custom design of pollution control practices through innovative solutions that provided substantial ancillary benefits. For example, improved manure disposal proved not only to be effective at eliminating bacteria from the watershed; it also saved farmers precious time and energy. In addition, NYC funded sewage treatment upgrades and purchased conservation easements from willing sellers throughout Upstate communities. The NYC-Catskill-Delaware negotiations involved many hard-fought battles, but both parties had strong incentives to complete a deal and few good alternatives to cooperation. Thus, they stayed the course and did not defect from the negotiation game. Over time, the inter-dependencies between the regions were strengthened, leading to greater polycentricity.

With preliminary agreements in hand, NYCDEP applied to the EPA for long-term filtration avoidance, and in 1993 the EPA granted a conditional filtration avoidance determination (FAD) under the 1989 Surface Water Treatment Rule (see FN 3), which included over 150 conditions requiring

reconciliation before 1996. When negotiations with Upstate leaders restarted with the FAD in hand, progress waxed and waned. Catskill-Delaware groups found some of the EPA's FAD conditions unacceptable and continued to sue NYC over various impositions. Then in 1995, negotiations gained traction when the newly elected governor, George Pataki, chose to become personally involved and established his office as a center for constructive exchange.

The beginning of negotiations marked the beginning of the end for the previously entrenched poverty and rigidity traps. Both key parties—NYC and the Catskill-Delaware watershed communities—had powerful incentives to continue talks. Both groups had a major stake in maintaining the health of the source waters: NYC wished to avoid filtration costs and the Upstate communities valued the water for drinking, irrigation, fishing, recreation, inherent natural value, and other reasons. The Upstate groups also had a large stake in sustainable land use.

Cross-scale investment and intervention played a central role in breaking the traps. The USEPA not only demonstrated intent to enforce the U.S. Safe Drinking Water Act to ensure drinking water quality, but it also did so adaptively by allowing jurisdictions like NYC to find innovative, self-organized approaches to avoiding filtration requirements if they were able to protect water quality. In addition, state leadership—the governor, in particular—supplied a cross-scale forum for the negotiations and high-level support for resolving inter-regional tensions.

An agreement was finally reached in 1997 after years of deliberation between Catskill-Delaware landowners and farmers, environmental organizations, NYCDEP, and other city and state officials. The NYC Watershed Memorandum of Agreement (MOA) detailed a comprehensive watershed protection program that paid farmers and rural landowners to implement best management practices to preserve ecosystem services for all parties, and contracted with local farms and universities for training and implementation of best management practices and to conduct monitoring and research. The City paid both the program's operating costs and the capital costs of pollution control measures, while largely self-organized entities managed the multiple programs.

The MOA established its own new, coordinated, polycentric governance system with mechanisms designed to resolve conflicts before they could generate traps.

Structural Persistence

Under the MOA, NYCDEP spent over $1.5 billion to preserve the ecosystem health of the Upstate watershed by acquiring sensitive lands (easements of 130,000 acres), upgrading and building new wastewater plants, and partnering with farmers (NYCDEP, 2012). Funds continue to flow today.

Over two decades and many contentious renegotiations later, the NYC water system continues to operate in a desirable state. In exchange for a voluntary program, farmers committed to obtaining 85% participation in the Whole Farm Planning program within five years. By 1998, the program had achieved a 93% participation rate and nearly 500 dairy and livestock farms in the watershed had agreed to implement best management. Correspondingly, EPA issued a five-year FAD in 1997, followed by two ten-year renewals in 2007 (revised in 2014) and 2017.

The upper Delaware watershed has been protected through the National Wild and Scenic Rivers system since 1973 and over 100 miles of the river now are protected under various forms of federal protection (Stutz, 2015). Investment in natural filtration systems has enabled the Catskill-Delaware Watershed to maintain a near pristine state with minimal industrial activities. NYC water consumers pay moderate water rates for these outcomes, on average $464 per year for a household's drinking water bill (Board, 2018), which is around the median annual rate for public U.S. water systems (MacMillan, 2016).

Conflicts and disagreements large and small continue, of course, and no group in the City or Upstate or in Albany views the MOA as perfect. As of this writing, the agreement's conflict resolution mechanisms have prevented the key parties from defecting, and the EPA's regular reviews of the FAD have maintained pressure on all parties to cooperate while also leaving room for them to customize solutions. Payments from NYC to the Catskill-Delaware region have provided net benefits thus far to both regions. The result meets criteria for a virtuous cycle of polycentric inter-dependence and collaboration that is somewhat structurally persistent due to officials in both regions who increasingly assume that the arrangements will continue, and thus make future plans based on those expectations.

The MOA has not become an automatic process, however, in any sense. Considerable effort is required on a continuous basis to monitor progress, resolve conflicts, renegotiate terms, adjust to changing circumstances, and renew the FAD. The arrangement remains vulnerable to large shifts in attitudes, incentives, or power distributions in the future.

Reactive Mechanisms

Reactive mechanisms have power to disrupt a self-reinforcing cycle. In this case, the cycle to be disrupted is a virtuous one, as described above under the MOA, rather than a trap. Reactive threats to the MOA's virtuous cycle include coalitions of Upstate landowners who see the MOA as an obstacle to their vision of development in the region, or coalitions of City interests that see advantages in moving toward a filtration-based water system. Thus far, neither has amassed enough support to disrupt the MOA. Were the MOA to become highly institutionalized in ways that reduce its adaptiveness, a new rigidity trap could emerge followed by an omega event with destructive potential. As long as the MOA demonstrates agile responsiveness to threats, it may continue to absorb smaller omega disturbances, adapt, and persist. Time will tell.

Flint, Michigan

Antecedents

A once thriving city and home to the nation's largest General Motors plant, Flint enjoyed economic prosperity throughout the post-World War II era until GM began to downsize its industrial complex in the late 1970s. The 1950s were especially good for the "Motor City," but by 1962, manufacturing plants, landfills, and farms laden with pesticides and fertilizer had severely degraded the Flint River, the city's drinking water source, which forced officials to consider alternative sources. At the same time, a real estate scandal derailed plans to build a pipeline from Lake Huron to supply water directly to Flint and the surrounding county. With few other options available, Flint began purchasing its water supply through the Detroit Water and Sewerage Department (Detroit contract hereafter) in 1967.

By the early 2000's, decades of economic decline led the city to a fiscal crisis, which State of Michigan officials sought to resolve by appointing an emergency financial manager to make budget and fiscal decisions for the City of Flint from 2002-04. During that period, government officials again explored the possibility of building a pipeline from Lake Huron based on regional projected savings of $200 million over 25 years (Kennedy, April 20, 2016). In 2010, the Karegnondi Water Authority (KWA) was established as a municipal corporation to build the pipeline and supply water to Flint and surrounding areas.

The following year, Flint began its second period of state receivership after an audit projected a $25 million deficit, and the governor appointed another emergency manager (EM) under Michigan's recently revised Emergency Manager Law. The new law widened the authority of emergency city managers and effectively nullified the power of the city council and mayor (Fasenfest & Pride, 2016). It also required that all major spending projects be approved by the state treasurer.

Throughout the period of the Detroit water contract, Flint enjoyed reasonably trouble-free compliance with federal water quality requirements, as monitored and enforced by the key state agency, the Michigan Department of Environmental Quality, as well as the Region 5 office of the USEPA charged with implementation of national legislation—in this case, the Safe Drinking Water Act. The period was characterized by polycentricity, both in terms of the nested, inter-governmental system of U.S. federalism noted earlier and the additional power centers represented by the Detroit water supplier and the KWA. One unusual feature—the emergency management regimes of 2002-04 and 2011-15—reduced the polycentric nature of the system, because an EM supplants locally elected officials. EMs are appointed by the governor and report to the governor and treasurer, and therefore should be viewed as part of state government rather than genuine local officials, despite their focus on local budgets and issues. The system still retained status as polycentric after the receivership arrangement, however, due to continued roles for the federal EPA, the regional office of the federal EPA, involvement by multiple state agencies (Treasurer, MDEQ, and Department of Health), the Detroit agency that supplied the water, the KWA, and various environmental watchdog groups.

Flint's water system displayed no apparent traps during the antecedent period. The larger context of general city and state governance is a different story, however. The EM arrangement itself arose from a deep poverty trap triggered by the decline of GM starting in the late 1970s in Flint and larger forces of industrial shrinkage experienced throughout southeastern Michigan and across the American Rust Belt. Cross-scale investments and interventions were recommended and implemented here and there to break the trap, such as federal programs for retraining displaced workers and trade adjustment support. A few long-standing federal programs like Title I education funding, which provides additional resources to schools with high percentages of low-income students, helped areas in decline at the margins. State governments provided time-limited unemployment insurance and other safety net programs like Medicaid and Temporary Assistance for Needy Families (Aid to Families with Dependent Children in the years before 1996) at the individual and household level in partnership with the federal government. With respect to struggling communities, however, the state legislature responding by taking over local governments rather than assisting them with cross-subsidies. The EM laws operated on the apparent

theory that the fiscal crises experienced in these post-big-auto cities were caused by bad management. Given the pervasive presence of larger economic and social forces, including structural unemployment and structural racism—both of which represent poverty traps—the narrow focus on city management can be difficult to justify.

Economic homogeneity in southeastern Michigan also created a type of general rigidity trap during the post-war period due to the region's over-reliance on a single industry. One might have expected the shock of the GM closures to release that trap and create opportunities for new, more diversified investments, and some of that did occur, but not nearly enough for places like Flint, Pontiac, and Detroit to bounce back. Holling's (2001) concept of "persistent collapse" well describes Flint's post-GM economy.

Critical Juncture

Plans for the KWA pipeline were approved in 2013 (Gross, 2016), and almost immediately the EM and other local officials began to argue for shifting the city's drinking water source to the Flint River rather than renewing the Detroit contract. The proposal was designed to save money while waiting for the new pipeline. It is worth noting that a similar suggestion had been made in 2004 and again in 2012—to blend Detroit water with Flint River water and/or shift the intake completely—as part of overall strategies to balance the city's budget, but objections were raised by MDEQ officials in these previous episodes, based on water quality concerns.

The chief alternative to the Flint River was an interim contract with Detroit for the 2013-14 period to fill the gap between expiration of the previous contract and completion of the new KWA pipeline. Although Flint officials entered into negotiations with Detroit over an interim arrangement, and the Detroit supplier offered lower rates, agreement was never reached (Lynch, 2016).

The EM ultimately chose to switch the intake in early 2014, with approval from the governor's and treasurer's offices and despite warnings from the city laboratory and the water quality supervisor at the water treatment plant on the Flint River. In early April of 2014, Flint Water Treatment Plant Supervisor Michael Glasgow sent memos to supervisors at the Michigan Department of Environmental Quality (MDEQ) stating that the water treatment plant would not be ready to begin treating water by the April 25 deadline. These memos went unanswered, and on April 25 Flint residents drew their drinking water from the Flint River for the first time in 40 years.

Within one month, residents began complaining about the smell and color of the water. Three months after the changeover, the city was forced to issue a series of boil water advisories after detecting high fecal coliform bacteria levels. During the two-years following the switch, 87 cases of Legionnaires' disease developed in Genesee County, compared to 6 and 13 cases in the previous two years (*Genesee County*, 2016). Per MDEQ recommendations the city responded with flushing and addition of chlorine as a disinfectant, which then combined with accumulation of road salts to make the river water 19 times more corrosive than water from Lake Huron (Edwards).

Two traps are notable here. First is the general poverty trap established in the antecedent period of industrial decline and still unbroken in the 2010s, where it is manifest in the lack of dialogue between state officials and Flint residents—many of them members of vulnerable population groups with reason to suspect problems with their water, but little organized power. Second is a rigidity trap associated with how emergency managers and the state government view cities like Flint: namely, through a strictly fiscal lens with the laser-focused goal of cutting spending and increasing revenue sources rather than investing in local economic and social development capacity.

Regarding the shift to the Flint River in 2014, how could such a decision be taken, given the many warnings against it since 2004? Although we could not find a direct answer to that question, the findings of the State of Michigan's own post-crisis task force report identified a "minimalist approach to regulatory and oversight responsibilities" on the part of MDEQ under the Snyder Administration (Davis et al 2014). Members of the task force assessed that approach to be "unacceptable and simply insufficient to the task of public protection." The minimalist approach to public health and environmental protection, which may qualify as its own groupthink-type rigidity trap, becomes an important part of the Flint story in the next phase.

Would the decisions have been different in the absence of the EM, with the elected local government (mayor and city council) still in place? This counterfactual deserves attention, for it bears on the question of whether reduced system polycentricity (due to the EM imposition) influenced the course of events, and if so, how much.

Structural Persistence

In June of 2014, Glasgow contacted MDEQ officials to inquire whether he should be adding corrosion inhibitors to the water. They responded that this should not be done until six months of water quality data is collected (Ridley, March 2016)—a gross misreading of the federal Lead and Copper Rule. In the absence of anti-corrosives, lead predictably leached from pipes into the water supply in some homes, but elevated lead levels found in the summer of 2014 were dismissed as merely seasonal fluctuations by state officials. Although the governor's own chief legal counsel warned about the Flint River situation in October 2014, efforts to deflect criticism and defend earlier decisions continued. The issue of corrosion inhibitors was raised again in February 2015—this time by Regulations Manager Miguel del Toral in the Region 5 office of the USEPA. In response, state MDEQ officials gave false information that the additives were being used and declined an offer of technical assistance from USEPA. As late as March 2015, state officials were still arguing about what federal rules require. Even after the state removed the EM and restored authority to local officials the following month, Flint's own mayor held a press conference to declare the water safe to drink despite residents' many objections.

In this blame-avoidance phase, three rigidity traps converged to produce structural persistence and maladaptive results. First was the propensity of EMs and state officials to focus narrowly on cost-cutting and revenue raising when considering decisions in cities like Flint. That approach was expected and rewarded, and thus became structurally persistent. Second was the mindset of regulatory minimalism that had taken hold in MDEQ and the Snyder Administration more generally, which also became business as usual and thus showed resistance to alternatives. Third was the EPA Region 5's excessive attachment to the idea of deferring to state agencies and its fear of federal overreach. National regulations were in place to protect against the kind of mistakes made in Flint, particularly the Lead and Copper Rule (LCR, a product of the 1986 Safe Drinking Water Act (SDWA) amendments), but norms proved more powerful than rules. By the 2010s, the doctrine of granting primacy to state environmental agencies had become a well-established practice in all EPA regions; it operated as the default mode and created an expectations barrier to federal intervention. Had the warnings of EPA Region 5's del Toral prevailed, Flint's lead crisis may have been prevented, or at least ended many months sooner. As the EPA inspector general's report on the Flint events noted, "The EPA and its regional offices must understand their oversight tools and authorities, and not be reluctant to use them to protect public health" (USEPA 2018, p. 27). EPA could have exercised its powers under Section 1414 and Section 1431 of the Safe Drinking Water Act or under the LCR, 40 CFR 141.82(i) in 2014. Instead it waited until January 2016 to issue an emergency order and take control of lead monitoring.

The convergence of these mindsets occurred despite the presence of formal polycentric governance structures. It took additional forces of polycentricity—voices of dissent from civil society power centers, as described in the next section—to break through the rigidity traps that had prevented adaptive responses to the public's demands for clean water. The highly persistent poverty trap associated with Flint's long period of economic decline and dormancy likely contributed to the extended crisis period. Citizens who tried to organize fellow residents apparently could not build enough critical mass of protesters to overcome the rigidities of official thinking. That inability to organize represents another manifestation of Flint's poverty trap and its roots in structural racism (Hammer 2016) and neglect of the poor.

Reactive Mechanisms

In April 2015, the governor's office lifted the emergency management order and put authority back in the hands of Flint's mayor and city council, while also prohibiting the city from rejoining the Detroit water contract. Polycentricity thus increased, although local authority was hobbled somewhat. At the same time, MDEQ corrected the false information submitted in February to the USEPA, and announced that corrosion inhibitors were not being used in Flint, which prompted del Toral to send a detailed warning about serious health risks to state and federal authorities.

At roughly the same time, researchers from Virginia Tech and Dr. Mona Hanna-Attisha, a local pediatrician, were beginning to find evidence of elevated lead levels in water at some homes (which MDEQ's faulty testing procedures had not caught earlier) as well as elevated blood lead levels in children. That information finally captured the sustained attention of the media and then government officials. The arrival of external civil society forces and the emergence of new internal voices expanded polycentricity by increasing the number of functioning centers with influence. Those new centers, in turn, forced other centers to take each other into account in more adaptive ways.

Still, despite acknowledgements by all parties of the health risks, and despite mobilization of the National Guard to distribute bottled water in September, the USEPA Region 5 office leadership—who should have issued an emergency order in June under the Safe Drinking Water Act—continued to insist that the state was managing the situation competently. The rigidity trap was proving highly resistant to self-correction. In October, Flint's elected officials closed the Flint River intake and returned to the Detroit contract. Not until January 2016 did the USEPA finally issue an emergency order and take responsibility for lead testing in Flint, thus interrupting the remaining rigidity trap.

Ultimately, it was pressure from non-governmental activism, amplified by the national and international media, that forced state officials to reverse their earlier decisions about the Flint River and undertake belated remedial activities. The decision to remove the EM restored power to Flint's mayor and city council and placed demands on those local bodies to implement additional follow-up activities such as replacing lead pipes. The cumulative effect of public and media pressure eventually increased the net costs to elected officials of continued denial and motivated higher levels of intervention to address the problems. Increased polycentricity thus contributed to interrupting the rigidity traps.

Flint remains in a difficult state. Although the water treatment plant began adding phosphates to build up pipe lining to prevent further lead leaching in December 2015, the additives were not reaching all lead pipes because of a shrinking population and a water distribution system built for greater volume (Kennedy, April 20, 2016). In addition, extensive damage to drinking water infrastructure prevented usage of Lake Huron water from the completed KWA pipeline, and necessitated a continued reliance on the Detroit contractor (now known as the Great Lakes Water Authority) (City of Flint, 2018). Scandals surrounding the crisis resulted in a major trust deficit between the Flint community and local, state, and federal officials. A survey of the largest U.S. water systems found Flint residents were paying the highest water rates, almost double the national average and almost four times as much as Detroit residents (Food and Water Watch, 2016).

RESULTS

The results in Table 1 point to preliminary evidence of relationships between the two key variables in this study: polycentricity and traps. Results are clearest with respect to rigidity traps, which show the strongest relationships with polycentricity as well as bi-directionality in both cases.

In the New York case, gradually increasing polycentricity in the antecedent phase helped make negotiations possible, which succeeded in breaking both poverty and rigidity traps at the critical juncture. Deliberate increases in polycentricity, particularly those that empowered watershed communities, helped turn these developments into virtuous cycles in New York's structural persistence phase. In the Flint case, a long legacy of general poverty traps resulted from economic decline in the antecedent phase. Poverty traps contributed to rigidity traps, which reduced functional polycentricity and eventually triggered a crisis that interrupted the rigidity traps, at least temporarily.

Six of the eight non-null hypotheses receive some support from the case analysis, as described below and summarized in Table 2 at the end of the paper. These results suggest a complex multitude of possible relationships between polycentricity and social-ecological traps that may influence a system's pathway toward adaptation or maladaptation.

H0: Polycentric systems have no effect on traps and vice versa.

We observed effects of polycentricity at many phases associated with both the building up of traps and their dismantling. In addition, traps appear to have impacts on polycentricity under some circumstances. The various effects are discussed in detail below and suggest a highly complex set of relationships among the phenomena of traps and polycentricity. If the relationships observed are spurious, then the null hypothesis may remain in tact, but the evidence presented here for multiple types of relationships and mechanisms leads us to reject H0.

H1: Polycentricity will prevent/disrupt poverty traps by providing opportunities for network organization at scale as well as cross-scale interventions in multi-level systems.

Evidence of this trap-breaking process may be seen in New York's critical juncture period and afterward. As networks of farmers, other landowners, and various interested actors began to develop and ripen in the Catskill-Delaware region, they managed to overcome the self-reinforcing mechanisms that had generated a poverty trap in the antecedent period. The process was enabled by a gradual balancing of power in Albany (thanks to NYC's fiscal problems in the 1970s), facilitative leadership in the governor's mansion and NYCDEP, and a growing understanding that NYC was being pushed to the negotiating table by cross-scale pressures and pulled by cross-scale facilitation. These factors increased polycentricity by requiring that the system's various centers take account of each other rather than riding roughshod over each other as in the past. The power shift and leadership infusion across the system increased potential for Upstate interests to exert influence over policy developments, and thus helped encourage individuals in the Catskill-Delaware region to mobilize and escape the poverty trap. It should be noted that both parties in this case—NYC officials and key actors in the source-water region—had a deep interest in protecting the health of the water resource, which provided a focus for organizing and common ground for negotiating. Increased polycentricity on the system level helped break the poverty trap in one subsystem.

Turning to the Flint case, the converse of H1 receives some speculative support insofar as the reduction of polycentricity via the EM arrangement contributed to the City of Flint's poverty trap by

creating fewer opportunities for local residents' voices to be heard. It is worth noting a dearth of cross-scale investments within the polycentric arrangement known as U.S. federalism throughout most of the Flint study period. Cities like Flint with long histories of economic struggle, arguably would have benefitted from multiple types of assistance and investment across scale during the antecedent period. As Carpenter et al (2001, p 767) observe, "The history of human cultural evolution has been the story of cross-scale subsidies." Yet the State of Michigan responded to the problem of structural decline as if it were rooted in managerial incompetence, and the federal government generally left such challenges to be addressed by states (apart from the federal safety net programs available to eligible individuals). Not until the period of structural persistence, when the water crisis became breaking news, did aid begin to flow from the state and federal levels to Flint. Such aid was earmarked for dealing with the water crisis, however; not for general economic development.

During Flint's critical juncture and later periods, it is also worth noting again the obstacles to organizing resource users at a scale large enough to overcome rigidity traps. The contrast with Catskill-Delaware residents is notable. If water consumers in Flint had operated in a setting similar to that of Upstate New York in the early 1990s—with power rebalancing in the state capital, leadership changes, and more forceful intervention by the EPA—their poverty trap might have been overcome and outcomes might have been different.

H2: Polycentric systems will enable/exacerbate poverty traps in SES by spurring unproductive competition and conflict among multiple power centers, or by perpetuating costly collaborative efforts beyond their useful lives.

If H2 receives support, it will reveal weaknesses and limitations of polycentricity, particularly its second feature: inter-dependency between centers. Certain types of inter-dependency—conflict, competition, and unproductive partnerships and collaborations—may contribute to poverty traps and maladaptation. Though plausible, this proposition did not receive support from either of the two cases that we examined.

In the antecedent period of the New York case, Catskill-Delaware communities were caught in a poverty trap as noted under H1. Efforts to organize around community interests never managed to build quite enough energy to overcome obstacles (including the predominant obstacle—the BWS rigidity trap), despite motivation, resources, and a structurally polycentric governance arrangement. The watershed region's organizing problem can be traced to a system-wide lack of polycentricity's second feature—i.e.,

power centers in NYC, Albany, and other parts of the state were not taking the Catskill-Delaware centers into account—due to asymmetric power distribution. Thus, more polycentricity (in terms of interdependency) appears to have been needed rather than less.

Development of a deeply rooted poverty trap also can be traced through much of Michigan's antecedent period with effects that flowed into the later periods and up to the present. Since the 1980s, the problem of economic decline in industrial states has fallen through the cracks of the U.S. federal system, with perverse incentives operating at each level. Local mayors are often motivated to focus on downtown development and policies that favor areas that pay higher property taxes, rather than addressing poverty. State governments similarly have little incentive to undertake redistributive policies because they compete with each other to attract the wealthy and repel the poor in what has often been called a race to the bottom with respect to state safety net provisions. The federal government historically has maintained residual safety nets, but where economic development aid is concerned, efforts to target it to areas of need have always failed due to political pressure to distribute program benefits as broadly as possible to build nationwide coalitions of support. Those affected most by economic decline have in many cases been unable to organize effectively, which describes a pure poverty trap. Forces of institutional racism cannot be ignored when talking about southeastern Michigan generally and Flint especially: they contribute in significant ways to the structural persistence of the poverty trap (Hammer 2016).

It is difficult to characterize southeastern Michigan's poverty trap as a product of polycentricity. We found no clear evidence of that mechanism. Instead, the key drivers of the poverty trap in this case were asymmetric power and lack of cross-scale investments and interventions.

H3: Polycentric systems will prevent/disrupt rigidity traps by facilitating small-scale omega events capable of breaking hegemonic mindsets and behaviors through dissent, experimentation, and shadow networks.

Evidence of this effect can be seen in different phases of each case. In New York's critical juncture phase, the rise of the environmental movement, as manifest in a blossoming of environmental organizations inside and outside of government, contributed to a change in culture at BWS by giving voice to the health of the ecosystem. So did the EPA's cross-scale intervention. Indeed, by threatening to enforce filtration requirements if the City did not fulfill requirements for a FAD, the EPA laid the foundation for the MOA and its continuance through periodic FAD reviews. NYC overcame the antecedent period's rigidity traps in the 1990s due to the FAD's powerful incentives combined with the

new mental models associated with society-wide environmental awareness raising, dynamic leadership at both the local and state levels, and effective self-organization in the Catskill-Delaware region that corrected long-running power imbalances in Albany. The system that broke the traps and generated the MOA was thoroughly polycentric, with multiple centers (several Upstate interest groups, NYCDEP and other City officials, federal EPA, state government agencies, the governor's office, and others) operating at different scales in different sectors (local, state, and federal as well as civil society and government) and taking each other into account, especially across the negotiating table.

The New York case offers an example of how cross-scale incentives (the EPA's threat of filtration) can themselves function as shocks to a system to initiate an (omega) disruption, leading to an (alpha) renewal and reorganization phase such as that which produced New York's MOA. Such disruptions need to be well-timed and proportionate to the changes needed. The EPA's FAD was particularly effective because it set clear outcome targets and specified the costs associated with not meeting the targets, but it allowed the New York parties to self-organize in innovative ways to achieve the outcomes.

In New York's antecedent case, the groupthink rigidity trap was able to establish itself despite structural polycentricity (the presence of many centers) due to a lack of behavioral polycentricity; i.e., more powerful centers were able to ignore weaker ones.

In Michigan, late in the crisis period (the reactive mechanism phase), it took persistent local voices and outside help from civil society to finally break through the rigid mindsets in evidence among state officials. Although we will never know if the people in power truly changed their minds or if they learned anything about avoiding social-ecological traps in the future, they were forced to change their behavior in that instance, which in turn enabled more adaptive responses to the water crisis. In the Flint case, in contrast with the New York case, the rigidity traps may have only been interrupted rather than broken.

H4: Polycentric systems will enable/exacerbate rigidity traps by facilitating gridlock, groupthink, or bystanding.

If H4 receives support, it will reveal a different type of weakness in polycentricity other than that represented by H2. All three of H4's manifestations—gridlock, groupthink, and bystanding—indicate that multiple centers are taking each other into account, as required by the behavioral dimension of polycentricity, and yet they are doing so in maladaptive ways due to perverse incentives that favor blame avoidance over problem solving.

In the antecedent phase of the New York case, NYC was able to dominate Catskill-Delaware actors due to decentralized authority within the U.S. system of federalism, acquiescence by the powers in Albany to NYC's wealth and influence, and lack of federal jurisdiction over many environmental matters prior to the 1970s. Groupthink appears to have been a central feature of New York's antecedent phase, but it occurred during a period of relatively weak polycentricity within the SES. Although the existence of many centers satisfied the criterion of structural polycentricity during this phase, those centers did not take each other into account equally, which violates the behavioral dimension of the polycentricity definition. We found no clear evidence that structural polycentricity contributed to this rigidity trap, but it also did not protect against the emergence and persistence of the trap (as per H3) due to weak behavioral polycentricity.

In Flint, the most familiar model of a cross-scale polycentric structural arrangement—federalism—facilitated behaviors associated with blame avoidance ("passing the buck") rather than deliberation and learning, and ultimately created orphan problems for which no one accepted responsibility. The Flint case thus offers some evidence supporting H4 in its structural persistence phase.

A key determining factor in Flint's blame-avoidance process was the convergence of a trio of ideas consisting of USEPA's deference to state primacy, MDEQ's regulatory minimalism, and the EMs focus on cost-cutting. Any one of these norms on its own may not have been problematic if other parts of the system were operating properly as backstops or checks and balances. As it happened, all three reinforced a pattern of unresponsiveness to warning signals. By masking the problem at every level, the three norms also failed to lever cross-scale interventions that might have interrupted, or at least mitigated the effects of rigidity traps at other levels. Accountability was difficult to assign amidst collective efforts to defend the bad decisions made during the critical juncture (shifting intake to the Flint River and foregoing anti-corrosive additives). As a result, the central problem—lead in drinking water—fell between the cracks of a polycentric, but dysfunctional, governance system for many months.

The Flint case offers a reminder that a system with many different power centers may deliver undesirable outcomes if none of those centers is speaking for the health of the ecosystem and the resource users. In addition, the Flint case highlights the interacting effects of poverty and rigidity traps when power distributions are skewed toward elites. When actors who are harmed by rigidity traps cannot generate enough organizing energy to mobilize other actors, prevailing mindsets (of those with power) are more likely to become entrenched and rigid. These two points—a voice for the ecosystem and reasonable

balance of power—draw a sharp contrast between the two cases examined in this paper. In New York, unlike Flint, the major actors (City government, Catskill-Delaware landowners and residents) cared very much about the health of the source-water ecosystem, albeit for different reasons, and acted accordingly. In addition, the power imbalance that characterized New York's antecedent phase became less skewed immediately prior to the critical juncture at which traps were disrupted.

H5: Poverty traps will increase polycentricity by creating pressure for centers to split.

We found no evidence of this effect in either case.

H6: Poverty traps will reduce polycentricity by creating pressure for independent centers to merge or by allowing a single center to dominate the others, which creates functional monocentricity even if the system's formal structure does not change.

In New York, influence may flow in both directions between the Catskill-Delaware poverty trap (inability to organize in the antecedent period) and the polycentricity of the whole water governance system. To the extent that Upstate interests found it difficult to organize for internal reasons, it could be argued that the Upstate poverty trap helped to create the BWS's somewhat monocentric lock on water policy and politics, which then in turn reinforced the Upstate poverty trap. Separating the various threads of cause and effect is difficult in this case, but H6 has plausibility as an explanation via the second mechanism—dominance by a single center.

Turning to Michigan, evidence of H6 is clearer. When viewed on a state-wide scale, introduction of the EM law was a direct response to the antecedent phase's poverty trap and related fiscal crises in cities abandoned by the auto industry. Cities that are placed under an EM order experience a loss of polycentricity temporarily because their local governmental power centers are disabled and replaced by an official appointed by the governor. This arrangement significantly strengthens the power held at the state level. By virtue of the Snyder Administration's laser focus on local cost cutting and its ideological aversion to regulation, imposition of a state-appointed EM also reduced the number of organizations within the SES that were representing the interests of resource users and the water resource itself.

H7: Rigidity traps will increase polycentricity by generating crises that expose the maladaptive qualities of a more monocentric system.

There appears to be abundant evidence of this effect. In the New York case, both BWS and its successor NYCDEP found it difficult to shift focus away from the rigid engineering, infrastructure, and top-down-control perspective on drinking water that had prevailed for 80 years toward a more collaborative, ecosystem-centered approach in tune with the late 20th century environmental ethos. Not until the EPA threatened filtration—an appropriate-scale (omega) disruption—did the rigidities become obvious enough to require dramatic change. New leadership helped effect the needed changes in the (alpha) renewal phase that followed. NYCDEP adopted a new perspective, which helped lay the foundation for the MOA. The MOA in turn helped reinforce NYCDEP's more systemic approach.

In Flint, a combination of poverty and rigidity traps led to the central public health crisis that defines the case, as anticipated by H7. That crisis constituted an (omega) disturbance much larger and more damaging than the one that spurred constructive creativity in New York. Flint's water debacle clearly exposed the maladaptive convergence of governance structure (the polycentricity-reducing EM arrangement) and governance norms (state primacy, regulatory minimalism, and fiscal orientation, which further concentrated power at the state level, focused it on cost-cutting, and left the resource users and the water system itself largely unrepresented in decision making). That combination reduced the benefits of polycentricity and caused the crisis to persist rather than self-correct. Whether Flint experienced a true renewal and reorganization (alpha) phase following the crisis remains to be seen.

H8: Rigidity traps will reduce polycentricity by creating pressure for independent centers to merge.

Rigidity traps associated with groupthink may have a natural tendency to move toward monocentricity as an expression of the system's homogeneity. In New York, this could be seen in the antecedent period as the BWS's way of doing things expanded and eventually dominated thinking in Albany, thereby reducing the behavioral dimension of polycentricity. Although the effects did not include actual, structural mergers of power centers, the merging of ideas and practices may have the functional effect of reducing polycentricity. BWS dominance meant that other, weaker voices—particularly those from the Catskill-Delaware communities—were not taken into account.

Similarly in Michigan's critical juncture and structural persistence phase, evidence of H8 may be found in the convergence of governance norms mentioned earlier, the dearth of channels for effective dissent, and the decisions by state and federal actors to defer to other authorities.

DISCUSSION and CONCLUSION

The traps framework captures the toughest obstacles to collective action on ecosystem health and sustainability. The poverty trap is a potent reminder that collective action requires resources and also that resources need to be coordinated and mobilized in order to effect results. The rigidity trap further reminds us that the existence and coordination of resources may not be enough: agility and heterogeneity are also needed. If and when resources become locked up in social processes characterized by inertia and maladaptation, they will be virtually useless for building adaptive capacity. The two cases examined in this study show extensive evidence of both poverty and rigidity traps. In the case of NYC's water system, processes of breaking traps are clearly evident. In the Flint water case, the poverty trap is a constant presence through the four phases, while the rigidity traps emerge most clearly in the critical juncture phase when they converge to create a sort of perfect storm of bad decision making.

The NYC and Flint cases also demonstrate important ways in which poverty and rigidity traps interact. In particular, when rigidity traps are present, the parts of a system that are caught in a poverty trap may need larger amounts of energy and effort to organize at a scale that can overcome the rigidity traps elsewhere. In other words, poverty traps may be more resistant to change in the presence of rigidity traps.

The panarchy model offers a larger vision of how to escape from traps. The core idea is that shocks can be salutary and constructive if they are calibrated to release locked-up resources without collapsing the whole. The goal of governance, from the panarchy perspective, is to enable smaller, less disruptive cycles of release and renewal within an SES. These processes are clearly evident in the NYC case, especially in the EPA's dynamic and responsive approach to water filtration enforcement, and in the leadership role of state leaders in making negotiation possible—both cross-scale interventions. Dispersion of power appears to have been a key factor in creative problem-solving in the New York case. By contrast, Michigan's EM arrangement, combined with the regulatory minimalism philosophy of the Snyder Administration and the federal EPA's excessive attachment to state primacy, shut off the usual avenues for small-scale disruptions.

Governance is not typically defined as a process of negotiation among interests to address problems, but that characterization fits both of these cases. Polycentricity by definition requires that power centers take account of each other. And beyond simply taking account, entering into direct negotiations to take action (or at least not to block others from taking action) requires acknowledgement of inter-dependency and rough equivalence of power. Mechanisms of negotiation worked well in the NYC case, whereas in Flint, the concerns and interests of the resource users—the water consumers—never received the attention they were due. Officials actively avoided engagement, let alone negotiation, with those most directly affected by their decisions. Theory predicts that traps will entrench power imbalances and mask interdependency, and the Flint case appears to bear that out.

The NYC case indicates that ordinary, contested, democratic politics can lead to collaborative and adaptive governance if strong, balanced incentives are sufficient to bring parties to the table and if those interests depend upon and thus focus on protecting the health of the ecosystem. Another way to say this is that parties to a negotiation need to have weak BATNAs (best alternative to a negotiated agreement) in order to stay involved in the negotiation. When parties' BATNAs are equally weak, a balanced results is more likely. Cross-scale interventions like those of the EPA with respect to filtration enforcement can shape the negotiating parties' BATNAs. Thus, processes of negotiation are facilitated by nested, polycentric, and representative arrangements. The Flint case offers a further reminder (this one negative) that those with a strong interest in the health of the ecosystem may be excluded from the negotiating table due to either a reduction in polycentricity, as when one level of government is sidelined, or a failure of polycentricity itself, as when each center thinks the other centers should act.

This study highlights obstacles to polycentricity's good impacts on SES adaptiveness. Results from the cases suggest at least two additional dimensions to those identified by Carlisle and Gruby (2017) for capturing polycentricity's contributions to desirable SES outcomes. In addition to the idea that polycentricity requires multiple centers and coordination between those centers (in the sense that they take each other into account, in V. Ostrom's words), we would add two further requirements:

(1) There must be a reasonable balance of power—formal or informal—among the system's decision-making centers. If some centers are able to dominate others, polycentricity's benefits may be quickly lost.
(2) One or more power centers must represent resource users' interests in sustaining ecological services and values. In other words a generic multiplicity of centers and diversity of institutions

is not enough if all of the centers and institutions are promoting various forms of exploitative activities.

This paper's results are too preliminary to suggest that the polycentricity-traps relationship contains predictive power. As Table 1 shows, it is not always easy to peg effects in time, which makes causality difficult to establish. Short of predictive theory, these results suggest that, with further empirical work to build on the insights from NYC and Flint, typologies of how polycentricity influences traps, and how traps influence polycentricity, may contribute to practical strategies for avoiding and breaking traps in order to advance the cause of adaptive capacity, beneficial resilience, robustness, and sustainability of social-ecological systems.

Table 1. Polycentricity and Traps in Case Studies

CASES & PHASES	MECHANISMS PRESENT		
	POLYCENTRICITY	**TRAP BUILDING and REINFORCING**	**TRAP PREVENTION or DISRUPTION**
NYC			
Antecedent conditions	Many centers, but not equally inter-dependent; BWS dominance waned later in this phase	*__Poverty trap__ (difficulty organizing) Upstate *__Rigidity trap__ (BWS mindset) in NYC	Prerequisites: rebalancing of regional power + increasing incentives for key actors to change course
Critical juncture	More inter-dependency due to cross-scale intervention		*Rebalancing of power **weakened poverty trap** *Cross-scale interventions **weakened rigidity trap**
Structural persistence	MOA increased numbers of centers and inter-dependencies		MOA created opportunities for self-correction, which should help prevent traps from reemerging
Reactive mechanisms	No changes evident yet	*Threat of new **poverty trap** if Upstate interests fracture *Threat of new **rigidity trap** if MOA institutionalized	If future threats materialize, reactions will depend on incentives and
FLINT			
Antecedent conditions	Many centers with reasonable inter-dependence; imposition of EM reduced polycentricity by disabling local actors	*No traps in water system, but City and region suffered both … *__Poverty trap__ due to economic decline, and *__Rigidity trap__ associated with one-industry legacy	Note lack of adaptiveness-enhancing interventions across scales; main cross-scale move (by State of Michigan) was receivership
Critical juncture	No change	*__Poverty trap__ persisted *Additional **rigidity traps** formed due to governance norms that enabled negligence	Lack of beneficial cross-scale intervention/disruption
Structural persistence	No change	*Officials' lack of responsiveness exacerbated **poverty trap** *Blame avoidance reinforced **rigid** mindsets	Lack of beneficial cross-scale intervention/disruption
Reactive mechanisms	Entrance of civil society groups and lifting of EM order increased both dimensions of polycentricity	No evident change in **poverty trap**	**Potential weakening of rigidity traps** as state and federal officials were forced to respond to crisis; but may be temporary

Table 2. Results

HYPOTHESES	CASES	
	NEW YORK CITY	FLINT
H1: Polycentricity prevents/disrupts poverty traps	Moderately supportive evidence in Upstate communities in critical juncture phase; cross scale activity was an important factor	Speculative evidence of converse: less polycentricity may have exacerbated poverty trap; note lack of cross-scale investments until post-crisis
H2: Polycentricity enables/exacerbates poverty traps	No supportive evidence	No supportive evidence
H3: Polycentricity prevents/disrupts rigidity traps	Strongly supportive evidence system-wide in critical juncture phase; cross scale activity was an important factor	Moderately supportive evidence in reactive mechanism phase; civil society was an important factor
H4: Polycentricity enables/exacerbates rigidity traps	Not applicable: SES met only one of two criteria for polycentricity in phase when traps developed	Moderately supportive evidence in structural persistence phase
H5: Poverty traps increase polycentricity	No supportive evidence	No supportive evidence
H6: Poverty traps reduce polycentricity	Speculative evidence in antecedent phase	Moderately supportive evidence insofar as the poverty trap led to the imposition of EM in antecedent phase
H7: Rigidity traps increase polycentricity	Strongly supportive evidence: Rigidity traps led to disruptions that produced increased polycentricity in critical juncture phase	Strongly supportive evidence: Rigidity traps led to disruptions that produced increased polycentricity in reactive mechanism phase
H8: Rigidity traps reduce polycentricity	Moderately supportive evidence in antecedent period	Moderately supportive evidence in critical juncture and structural persistence phases
H0: Null hypothesis	No supportive evidence	No supportive evidence

REFERENCES

Adger, W., 2006. Vulnerability. *Global Environmental Change*, 16:268.

Anderies, J.M., et al, 2007. Panaceas, uncertainty, and the robust control framework in sustainability science. *Proceedings of the National Academy of Sciences*, 104:39:15194.

Andersson, K.P. & Ostrom, E., 2008. Analyzing Decentralized Resource Regimes from a Polycentric Perspective. *Policy Sciences*, 41:1:71.

Appleton, A.F., 2002. How New York City Used an Ecosystem Services Strategy Carried Out Through an Urban-Rural Partnership to Preserve the Pristine Quality of Its Drinking Water and Save Billions of Dollars.

Ashby, W.R. 1958, Requisite Variety and its implications for the control of complex systems, Cybernetica (Namur) 1(2).

Baumgartner, Frank R., Bryan D. Jones, and Peter B. Mortenson (2014). "Punctuated Equilibrium Theory: Explaining Stability and Change in Public Policymaking." In *Theories of the Policy Process,* 3rd Edition, edited by Paul A. Sabatier and Christopher M. Weible. Boulder, CO: Westview Press.

Berkes, F., and C. Folke, editors. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press, New York.

Berkes F., H. Ross. 2013. Community resilience: toward an integrated approach. *Society and Natural Resources* 26(1):5-20.

Boonstra, W.J. & de Boer, F.W., 2014. The historical dynamics of social-ecological traps. *Ambio*, 43:3:260.

Brooks N., W. N. Adger, and M. P. Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change* 15:151–163.

Brown, R. R. 2008. Local institutional development and organizational change for advancing sustainable urban water futures. *Environmental Management* 41:221-233.

Carlisle, K. & Gruby, R.L., 2017. Polycentric Systems of Governance: A Theoretical Model for the Commons. *Policy Studies Journal*, 00:1.

Carpenter, S., et al, 2001. From Metaphor to Measurement: Resilience of What to What? *Ecosystems*, 4:8:765.

Carpenter, S., Westley, F. & Turner, M., 2005. Surrogates for Resilience of Social-Ecological Systems. *Ecosystems*, 8:8:941.

Carpenter, S. R., and W. A. Brock. 2008. Adaptive capacity and traps. *Ecology and Society* **13**:2: 40. URL: http://www.ecologyandsociety.org/vol13/iss2/art40/

Chaffin, B.C. & Gunderson, L.H., 2016. Emergence, institutionalization and renewal: Rhythms of adaptive governance in complex social-ecological systems. *Journal of Environmental Management*, 165:81.

Cinner, J.E., et al, 2012. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, 22:1:12.

City of Flint, M., 2018. Water Treatment Plant. <https://www.cityofflint.com/public-works/utilitieswater/water-treatment-plant/>.

Clarvis, M. H. and N. L. Engle. 2015. Adaptive capacity of water governance arrangements: a comparative study of barriers and opportunities in Swiss and US states. *Regional Environmental Change* 15:517-527.

da Silveira, A. & Richards, K., 2013. The Link Between Polycentrism and Adaptive Capacity in River Basin Governance Systems: Insights from the River Rhine and the Zhujiang (Pearl River) Basin. *Annals of the Association of American Geographers*, 103:2:319.

Dahl, R., 1957. The Concept of Power. *Behavioral Science*, 2:3:201.

Davis, Matthew M., Chris Kolb, Lawrence Reynolds, Eric Rothstein, and Ken Sykkema. 2014. Final Report of the Flint Water Advisory Task Force, Office of Governor Rick Snyder, March. Retrieved from: https://www.michigan.gov/documents/snyder/FWATF_FINAL_REPORT_21March2016_517805_7.pdf

Davoudi, S., et al, 2012. Resilience: A Bridging Concept or a Dead End? "Reframing" Resilience: Challenges for Planning Theory and Practice Interacting Traps: Resilience Assessment of a Pasture Management System in Northern Afghanistan Urban Resilience: What Does it Mean in Planning Practice? Resilience as a useful Concept for Climate Change Adaptation? The Politics of Resilience for Planning: A Cautionary Note. *Planning Theory and Practice*, 13:2:299.

Djalante R., C. Holley, and F. Thomalla. 2011. Adaptive governance and managing resilience to natural hazards. *International Journal of Disaster Risk Reduction* 2(4):1-14.

Duit, A., 2016. RESILIENCE THINKING: LESSONS FOR PUBLIC ADMINISTRATION. *Public Administration*, 94:2:364.

Durant, R., 2014. Taking Time Seriously: Progressivism, the Business-Social Science Nexus, and the Paradox of American Administrative Reform. *The 2013 John Gaus Lecture*:8.

Eakin, H. & Luers, A.L., 2006. Assessing the Vulnerability of Social-Environmental Systems. *Annual Review of Environment and Resources*, 31:1:365.

Enfors, E., 2013. Social–ecological traps and transformations in dryland agro-ecosystems: Using water system innovations to change the trajectory of development. *Global Environmental Change*, 23:1:51.

Engle, N.L., 2011. Adaptive Capacity and its Assessment. *Global Environmental Change*, 21:647.

Engle, N.L., et al, 2014. Towards a resilience indicator framework for making climate-change adaptation decisions. *Mitigation and Adaptation Strategies for Global Change*, 19:8:1295.

Engle, N. L., M. C. Lemos. 2010. Unpacking governance: building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change* 20:4-13.

Fasenfest, D. & Pride, T., 2016. Emergency Management in Michigan: Race, Class, and the Limits of Liberal Democracy [Editorial. *Critical Sociology*, 42:3:331.

Folke, C., 2006. Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses. *Global Environmental Change*, 16:253.

Garmestani, A. S. and M. H. Benson. 2013. A framework for resilience-based governance of social-ecological systems. *Ecology and Society* 18(1):9 [online].

Genesee County Health Department. (2016). Legionellosis Outbreak-Genesee County, June, 2014 – March, 2015. Retrieved from https://www.michigan.gov/documents/mdhhs/6-14_to_3-15_Legionellosis_Report_Full_Analysis_Results_511708_7.pdf

George, A.L. & Bennett, A., 2005. *Case Studies and Theory Development in the Social Sciences*. MIT Press.

Goldstone, J.A., 1998. Comparative Historical Analysis and Knowledge Accumulation in the Study of Revolutions. *Comparative Historical Analysis in the Social Sciences*:41.

Grolleau, G. & McCann, L.M., 2012. Designing Watershed Programs to Pay Farmers for Water Quality Services: Case Studies of Munich and New York City. *Economic Economics*, 76:87.

Gross, A. (February 13, 2016). Emails reveal Flint AM and state advised not to join the KWA- it was never about saving money. Detroit Metro Times. Retrieved from: http://www.metrotimes.com/Blogs/archives/2016/02/13/emails-reveal-flint-should-never-have-joined-kwa-andnbspit-was-never-saving-money

Hall, P., 2013. Tracing the Progress of Process Tracing. *European Political Science*, 12:1:20.

Hammer, Peter J. 2016. The Flint Water Crisis, KWA, and Strategic-Structural Racism. Written Testimony Submitted to the Michigan Civil Rights Commission Hearings on the Flint Water Crisis. Retrieved from: https://www.michigan.gov/documents/mdcr/Hammer_Peter_Flint_water_and_strategic-structural_racism_final_552225_7.pdf

Hanna-Attisha, M., et al, 2016. Elevated Blood Lead Levels in Children Associated With the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response. *American Journal of Public Health*, 106:2:283.

Holling, C., 2001. Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems*, 4:5:390.

Holling, C. (1973). Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics, 4, 1-23.

Holling, C. S. and L. H. Gunderson. 2002. Resilience and adaptive cycles. In L. H. Gunderson and C. S. Holling, editors. *Panarchy: understanding transformations in human and natural systems*. Island Press, Washington, DC, USA, pp. 25-62.

Huitema, D. and S. Meijerink. 2010. Realizing water transitions: the role of policy entrepreneurs in water policy change. *Ecology and Society* 15(2):26 [online].

Huntjens, P., L. Lebel, C. Pahl-Wostl, J. Camkin, R. Schulze, and N. Kranz. 2012. Institutional design propositions for the governance of adaptation to climate change in the water sector. *Global Environmental Change* 22:67- 81.

Knieper C. and C. Pahl-Wostl. 2016. A comparative analysis of water governance, water management, and environmental performance in river basins. *Water Resources Management* 30:2161-2177.

Koontz, T.M., et al, 2015. Adaptive Institutions in Social-Ecological Systems Governance: A Synthesis Frame. *Environmental Science and Policy*, 53:139.

Laborde, S., et al, 2016. Social-Ecological Feedbacks Lead to Unsustainable Lock-In in an Inland Fishery. *Global Environmental Change*, 41:13.

Lynch, J. (2016, February 2, 2016). Late bid failed to avert Flint-Detroit water deal. The Detroit News. Retrieved from: http://www.detroitnews.com/story/news/michigan/flint-water

McGinnis, M.D. & Ostrom, E., 2012. Reflections on Vincent Ostrom, Public Administration, and Polycentricity. *Public Administration Review*, 72:1:15.

Mahoney, J. L., & Thelen, K. (2009). A theory of gradual institutional change. In Explaining Institutional Change: Ambiguity, Agency, and Power (pp. 1-37). Cambridge University Press. https://doi.org/10.1017/CBO9780511806414.003

Meadows, D.H., 2008. *Thinking in Systems*. Chelsea Green Publishing Company, White River Junction, VT.

Mimura, N.R., Pulwarty, S., Duc, D.M. et al. Adaptation planning and implementation IPCC (Ed.), Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York, NY, USA (2014), pp. 869-898

Olsson, P., L.H. Gunderson, S.R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C.S. Holling. 2006. Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. Ecology and Society 11(1): 18.

Ostrom, E., 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences*, 104:39:15181.

Ostrom, V., Tiebout, C. & Warren, R., 1961. The Organization of Government in Metropolitan Areas: A Theoretical Inquiry. *The American Political Science Review*, 55:4:831.

Pahl-Wostl, C., 2015. *Water Governance in the Face of Global Change: From Understanding to Transformation*. Switzerland: Springer International Publishing.

Pahl-Wostl, C., 2009. A Conceptual Framework for Analysing Adaptive Capacity and Multi-level Learning Processes in Resource Governance Regimes. *Global Environmental Change*, 19:3:354.

Pahl-Wostl, C. & Knieper, C., 2014. The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change-Human and Policy Dimensions*, 29:139.

Pahl-Wostl, W., Claudia., et al, 2013. Missing Links in Global Water Governance: A Processes-Oriented Analysis. *Ecology and Society*, 18:2.

Pahl-Wostl, C., et al, 2012. From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. *Environmental Science & Policy*, 23:24.

Ridley, G. (April 20, 2016). More Flint water crisis charges guaranteed, attorney general says. Michigan Live Media. Retrieved from: http://www.mlive.com/news/flint/index.ssf/2016/04/

Scheberle, D., 2004. *Federalism and Environmental Policy: Trust and the Politics of Implementation*. Georgetown University Press, Washington, DC.

Simmie, J. & Martin, R., 2010. The Economic Resilience of Regions: Towards an Evolutionary Approach. *Cambridge Journal of Regions, Economy and Society*, 3:27.

Smit, B. & Wandel, J., 2006. Adaptation, Adaptive Capacity and Vulnerability. *Global Environmental Change*, 16:282.

Soll, D., 2013. *Empire of Water: An Environmental and Political History of the New York City Water Supply*. Cornell University Press, New York, New York.

Walker, B. H., J. M. Anderies, A. P. Kinzig, and P. Ryan. 2006. Exploring resilience in social-ecological systems through comparative studies and theory development: introduction to the special issue. Ecology and Society 11(1): 12. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art12/

Walker, B., et al, 2004. Resilience, Adaptability and Transformability in Social–ecological Systems. *Ecology and Society*, 9:2.

Westley, F., P. Olsson, C. Folke, T. Homer-Dixon, H. Vredenburg, D. Loorbach, J. Thompson, M. Nilsson, E. Lambin, J. Sendzimir, B. Banarjee, V. Galaz, and S. van der Leeuw. 2011. Tipping toward sustainability: emerging pathways of transformation. *AMBIO* 40(7):762-780.

Woolcock, M. & Narayan, D., 2000. Social Capital: Implications for Development Theory, Research, and Policy. *The World Bank Research Observer*, 15:2:225.

Yohe, G. & Tol, R.S.J., 2002. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12:1:25.