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Institutionalized Cooperation and Resilience in Transboundary Freshwater Allocation

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In the chapter, we consider the role of transboundary water agreements in the resilience of social-ecological systems to water shocks and stresses, where resilience is taken to mean the capacity of the system
to maintain functionality over a particular disturbance regime (Hol-ling 1973; Perrings 1998). Transboundary agreements take many forms, some being more effective than others at adapting to environmental and social change. Two attributes of a social-ecological system determine its resilience. One is the adaptive capacity of both components of the system (Carpenter et al. 1999; Elmqvist et al. 2003; Scheffer and Carpenter 2003; Kinzig et al. 2006). For freshwater ecosystems, this depends on the flow regimes, sediment and organic inputs, nutrient flows, and biotic assemblages (Baron et al. 2002). For the institutions governing trans-boundary freshwater systems, resilience depends on treaty mechanisms that account for fluctuations in the water cycle. A second important attribute of coupled systems is their robustness: the properties of the system that allow it to accommodate perturbations without additional adaptation (Webb and Levin 2005). Using the results of a content analysis, we evaluate these attributes in a sample of seventy-three international water treaties.

Formal management regimes governing shared river basins, as designed in international water treaties, are instrumental in mitigating potential conflicts and disputes between riparian states and in guiding societal interaction with water (Yoffe et al. 2003). Institutions complement ecosystem services by restricting consumptive use and contamination and through smoothing out variability via infrastructure at their disposal. However, analysis of resilience of institutions tends to focus on levels of conflict and cooperation over the shared resource, not the ecological impact of the management approach. Here, we attempt to bridge the divide between what treaty elements promote resilience for the institution, as measured by conflict, while also promoting resilience in the environment, as measured by the ecosystem's capacity to cope with disturbance while maintaining stability.

First, we give a brief summary of the principles guiding international water allocation. Second, three allocation frameworks are discussed and evaluated for their capacity to contain risk using the results of a content analysis of seventy-three water allocation treaties and how they contribute to international water-related conflict. Third, other mechanisms for treaty design are defined and their application assessed using the results of the same survey. Fourth, we discuss how treaties can integrate adaptive management principles in order to promote resilience to climatic...
shocks. We conclude that, to be resilient to environmental change, treaties must incorporate principles that promote institutional capacity to manage conflict and iterative governance strategies, most likely through establishment of joint water commissions bound to implementing adaptive management processes.

Principles of International Water Law

Numerous principles guide the development of international water law. Each treaty is unique in its application of principles, as each state has its own unique set of claims, rights, and needs, and each water body displays a unique set of characteristics. The particular mix of treaty provisions has profound implications for its capacity to enhance resilience of social-ecological systems (SES). Certain principles favor states based on hydrography (upstream versus downstream position), and others tend to favor states based on chronology (first to make claim or establish use). The constellation of riparians influences levels of cooperation and environmental impact. For example, an upstream riparian has little incentive to cooperate, because they can externalize the negative impacts of resource exploitation by flushing it all downstream. Thus, in a vacuum, upstream states prefer a unilateral order and are reluctant to engage in institutionalized cooperation, especially if they derive no benefits from downstream states (e.g., transportation, anadromous fish migration). Turkey exemplifies this sort of behavior along the Tigris–Euphrates basin. Conversely, downstream states tend to be more willing to institutionalize cooperation, because they experience the flushed externalities of upstream neighbors and therefore want some level of control over the resource upstream. For example, countries that have ratified the 1997 United Nations (UN) Convention on Non-Navigational Use of International Watercourses (UN Convention, described later in this chapter) are largely downstream states, such as Iraq. However, this trend may not hold true dependent on where power is concentrated in the basin. A hegemonic downstream state, such as Egypt on the Nile, is less likely to cooperate with its less powerful upstream neighbors, because those states may not make enough use of the resource to impact the downstream state, and because the more powerful state may be able to
limit that use by other means (intimidation; Zeitoun and Warner 2006). However, (benign) hegemons may also use their power to create incentives to cooperate, such as South Africa in the Southern African Development Community Protocol on Shared Water Resources (Turton and Funke 2008).

The end product usually reflects a compromise between extreme positions. Because negotiations are a give-and-take process, extreme claims rarely, if ever, take their pure form. Even more, some arguments have never been applied and only serve as extreme negotiation positions (LeMarquand 1976; Matthews 1984). The environmental impact of each claim is an important consideration, as some principles facilitate resource stewardship, while some arguments encourage unbounded exploitation. Below is a brief summary of these concepts and their potential environmental consequences. For a more detailed description of international water law concepts and their origins, see Dellapenna (1995, 2001) and Barberis (1991).

**Absolute Territorial Sovereignty**

Absolute territorial sovereignty, commonly referred to as the Harmon Doctrine after its founder, U.S. Attorney General Judson Harmon, claims that a state has an absolute right to all water flowing within its borders. This extreme position largely favors upstream claimants and is hydrographical in nature. Because of its grave consequences to downstream states and the environment, application of this claim is extremely rare and has only been applied in treaties relating to upstream tributaries (McCaffrey 1996). Harmon’s own successor rejected the theory, and the United States eventually repudiated this position in its negotiations with Mexico over the Rio Grande (McCaffrey 1996). Still, it lives on as an initial position for upstream users and as a rationale for the three nonsignatories of the UN Convention—Turkey, China, and Burundi—that are all upstream states. Interestingly, the concept is still argued domestically in the United States. The principle was recently invoked by the governor of Georgia in a statement claiming that Georgia was entitled to use all the water that falls within its borders, despite the U.S. Supreme Court’s rejection of the principle when Colorado invoked it for greater
rights to the Arkansas River against Kansas in 1902 (*Kansas v. Colorado* 1902; Gleick 2009).

With respect to the environment, pure application of the Harmon Doctrine could be devastating. Granting a state the right to divert all water within its territory creates exploitation incentives void of any incentive to conserve and could dry up the entire resource. For example, the U.S. state of Georgia, the upstream state on the Apalachicola–Chattahoochee–Flint river system has been embroiled in controversial litigation recently with its downstream states, Alabama and Florida. Georgia claims an absolute right to use all the water that flows within its borders. Alabama and Florida claim that Georgia's overuse has reduced instream flows and contaminated the system to a point that has decimated endangered downstream estuarine fisheries, especially shellfish beds (*Georgia v. U.S. Army Corps of Engineers* 2002; *In re Tri-State Water Rights Litigation* 2011).

**Absolute Riverain Integrity**

Absolute riverain integrity, also referred to as absolute territorial integrity, is the contrasting and equally extreme argument of international water law. States invoking this argument claim that each riparian has a right to the natural unobstructed flow of a river as it runs through its territory. This argument largely favors downstream states in humid climates and is hydrographical. Upstream states are prevented from diverting and consuming any flow, because the farthest downstream state is entitled to enjoy the entire flow. However, because the farthest downstream state has no obligation to another downstream state, they may be entitled to dewater. Much like the Harmon Doctrine, this argument is not integrated into treaties in practice and serves mostly as a strong initial position for negotiations (Odom and Wolf 2011).

The environmental impact of applying this principle may seem minimal, but restrictions against diverting flow may not curb instream development or restrict any consumption or development of the farthest downstream state. In addition, an upstream state may be entitled to install run-of-the-river hydropower dams that do not divert water but impede aquatic migration and alter sedimentation patterns, among
other effects. Likewise, upstream states may not be required to prevent contamination as long as the volume of flow is unaltered.

**Limited Territorial Sovereignty**

Limited territorial sovereignty, a hybrid of the extreme claims, provides for balanced use of a water body restricted by principles of equity (i.e., one state's use does not cause significant harm to another state's reasonable use). This doctrine is guided by vague principles catalogued in many international conventions, namely the UN Convention and the Helsinki Rules on the Uses of the Waters of International Rivers, and many of the factors are discussed below.

The UN Convention, adopted in 1997 by the UN General Assembly, specifically focuses on international transboundary water resources. The UN Convention codifies many of the principles deemed essential by the international community for the management of shared water resources, such as equitable and reasonable utilization of waters with specific attention to vital human needs, protection of the aquatic environment, and the promotion of cooperative management mechanisms. The convention also incorporates provisions concerning data and information exchange and mechanisms for conflict resolution. Once ratified, the UN Convention will oblige a legally binding framework, at least upon its signatories, for managing international watercourses. Even without ratification, its guidelines are being increasingly invoked in transboundary negotiations in which its general concepts are bolstered by basin-specific details to govern a particular watercourse.

Adopted by the International Law Association in 1966, the Helsinki Rules describe guidelines on how international surface waters and groundwater should be used. The Helsinki Rules led to the Berlin Rules on Water Resources of 2004, which address all freshwater resources (not limited to international waters). Both sets of rules emphasize sustainable management practices that minimize environmental harm. Interpretation of factors and the relative weight assigned to each varies dependent on the parties. Hydrohegemony scholars argue that the vagueness of these factors gives too much leeway for the more powerful states to grant disproportionate weight to those factors that favor themselves
(Zeitoun and Warner 2006). However, an equitable distribution of water requires that institutions not operate in favor of any particular state.

Guiding principles include equity in interpretation of law, restrictions on use to benefit other states, reciprocity in adherence to agreements, and peaceful dispute resolution. These principles guide water allocations based on equitable and reasonable use, the obligation to not cause harm, and past use (historic rights), but vague and occasionally contradictory language results in varied and conflicting interpretations of the principles (Biswas 1999). Each principle and its environmental impact is described below.

**EQUITABLE AND REASONABLE USE**

Equitable and reasonable use is a principle of customary international law accompanied by a long list of factors to determine what is equitable or reasonable. Its general acceptability stems from its vagueness. The UN Convention and the Helsinki Rules provide guidance on how the principle is to be implemented. Relevant factors, such as level of harm and demand, are identified and calculated, and the conclusion is reached on the basis of the sum or a cost–benefit analysis. Environmentally, this approach depends on the threshold of allowable harm or what level of harm is deemed “reasonable.” Typically, use is limited by an obligation to not prevent another state from enjoying its equitable use of the resource, discussed below.

**OBLIGATION TO NOT CAUSE HARM**

The obligation to not cause harm is normally qualified as the obligation to avoid significant harm and holds that riparian users must take all appropriate action to prevent causing significant harm to other riparian users, not necessarily the environment. Legitimate water projects that might negatively impact other riparian states and their development potential may be enjoined by this principle. Some scholars attribute its controversial implications as the reason the UN Convention has not been ratified (McCaffrey 2001). Typically, upstream states oppose this provision;
however, harm does not only flow downstream. A downstream state may cause significant harm to an upstream state by development projects that restrict upstream migration of anadromous species, impound flow, impact navigation, or cut off future plans for upstream development because that future development may harm the downstream project.

Environmentally, restriction on harming the environment seems to promote environmental integrity. However, what counts as harm turns on the interpretation of significant harm and on the parties' values. Environmental harm may not be of great concern, and thus, environmental degradation would not constitute a significant harm to be avoided.

HISTORIC RIGHTS

Historic rights grant priority to existing uses over proposed uses. Chronology is key. Prior uses are usually deemed inherently superior to proposed uses and granted the volume necessary to continue. This likely stems from the defensibility of prior uses as an expression of need, especially when protecting native rights. Downstream states in arid or exotic watersheds often invoke this principle in order to defend infrastructure. For example, Egypt has a long history of development on the Nile compared with the relatively recent projects begun upstream.

Environmentally, this approach can be harmful, because no regard is paid to the type of use, impacts, or benefits. While upstream development may be curbed in order to protect pre-existing downstream projects or uses, this doctrine also creates a strong incentive to develop first and fast. There is no incentive to cooperate on joint projects, which tend to take longer to build up. Instead, each state may develop similar projects, whereas a joint project with benefit sharing would have had less impact on the environment. In addition, strict adherence to priority by date leaves no room for changed values over time (Wilkinson 1989).

Prioritization of Uses

Prioritization of uses sets up a hierarchy of uses with those serving vital human needs above all others. Agriculture, energy production, and
industrial uses usually follow domestic use, depending on the weight given to certain hydrographic and sociopolitical factors and the values of the region. For example, the two sets of boundary waters agreements between the United States and Canada, and the United States and Mexico prioritize differently, due to the amount of water available along each border region and the dominant uses in the region: the former prioritizes first domestic and sanitary, then navigation, electricity generation, and irrigation; the latter gives descending weight to domestic, agriculture, electric power, other industry, navigation, fishing, and other beneficial uses.

Environmental concerns and instream flows may be included in the priority list, on par with environmentally harmful uses, but priority to instream use is rare. Generally, uses with the worst environmental record come after those with less harmful effects (domestic). However, relatively intensive uses, such as industrial and agricultural, are usually granted medium to high priority. The relatively low priority granted to environmental use is a reflection of the relatively recent change in societal values regarding instream flow.

Allocation Frameworks

Water allocation frameworks generally reflect (1) the rights of each party; (2) the wants and needs of each party; and (3) in some cases, an evaluation of benefits to be shared. Some treaties consist of a mix of the first two approaches, with some allocations based on territorial entitlements and others granted based on existing uses or other measurements of need. The third category may also influence the allocation scheme but requires a paradigm shift from the rights-based mentality, as political boundaries are lifted and parties become citizens of the watershed. Depending on how rights, needs, or benefits are defined, and how nature is valued and assessed, each allocation approach may fall anywhere along the resilience spectrum.

A content analysis was conducted using the Transboundary Freshwater Dispute Database (TFDD) of water-related treaties and events. The database is housed at Oregon State University under the direction of Dr. Aaron T. Wolf and is widely considered to be the most comprehensive
collection of water treaties, water-related events, and geospatial data of transboundary water resources. The full results of this survey, including detailed statistical analysis, are published in Dinar et al. (2010).

*Entitlement-Focused Negotiation*

Sovereigns argue over entitlements based on relative riparian position or past use. Claims based on absolute principles may seem easy to calculate, as they would constitute 100 percent of flow, either to be used as water flowing within borders as absolute territorial integrity dictates or to be kept instream as absolute riverain integrity requires. However, claims based on extreme principles are politically impossible to measure. As discussed above, the absolute principles rarely form the basis of an allocation, so the relative ease of calculation is negated by the difficulty in persuading the other side to grant full allocation of a stream. Thus, any allocation based on rights is necessarily tempered from the absolute.

Institutions that allocate based on property rights tend to generate less conflict, but also are less adaptive to changing conditions. India and Pakistan, for example, divide the tributaries of the Indus River according to territory, as agreed in the Indus Waters Treaty of 1960 between Pakistan and India, brokered by International Bank for Reconstruction and Development (World Bank). India is entitled to 100 percent of the eastern tributaries; Pakistan enjoys unrestricted use of 100 percent of the western tributaries, and India agrees to allow those western tributaries to flow unimpeded through Indian territory (with some minor exceptions). Scholars note the resilience of this institution by pointing out that the terms were honored in the midst of armed conflict (Kirmani 1990; Alam 2002). However, as the international community trends toward integrated watershed management and catastrophic flooding in Pakistan in 2010 spurred calls for increased storage upstream (Kiani 2011), this rigid allocation scheme hinders the institution's ability to adjust to changed values and demand. See, for example, the difficulty in agreeing on development of the Kishanganga Dam. The states could not agree on the construction of a hydropower facility on a western tributary in India, invoking the intervention of the International Court
of Arbitration, which recently enjoined the project (The Nation 2008, 2011). Indian development plans also commonly prompt accusations of violative flow impoundment, especially during drought (Jamil 2008).

Ecologically, decades of relative peace over the Indus River led to many large-scale developments in a river valley already known for its vast network of canals. Without any environmental protection provisions, both states have been free to utilize their full entitlements, which are 100 percent of flow. Dewatering, contamination, and instream infrastructure has led to ecological collapse, including endangerment of the charismatic Indus River dolphin (Reeves et al. 1991; Braulik 2006). In this instance, an institution capable of containing the level of conflict/number of grievances expressed has nevertheless led to a loss of ecological resilience.

**Need (Current Use)-Based Allocation**

Need-based or current use–based allocation is the most common approach applied in international negotiations. Of the water allocation agreements that explain why water is to be allocated a certain way (fifty treaties of a sample of seventy-three treaties), most base allocations on current use (mostly for irrigation, domestic uses, and hydropower generation) and project that use based on growth predictions. Current use is the more sensible unit of measurement once negotiators have moved past abstract absolute rights, because it can be concretely measured based on irrigable acreage, population, use, environmental requirement, or any other mutually agreeable parameter. Historic uses are typically granted the necessary water to continue, because they are simple to quantify. This approach may include a discussion of priorities, beneficial and reasonable use, environmental harm, and equity.

The resilience of need-based allocation mechanisms depends on the characterization and prioritization of need and the inclusion of adaptability mechanisms (discussed below). Calculations limited to irrigable acreage or population are vulnerable against even foreseeable changes in population and demand, and exhibit much less resilience with respect to less predictable disturbances, such as climate change, natural disaster, epidemic, or regulation (e.g., species protection that requires increased
instream flow à la the U.S. Endangered Species Act of 1973). Content analysis of the water allocation data set reveals that most need-based treaties are not so rigid as to require an allocation made based on a certain need to be used strictly for that purpose. Need is typically used to quantify the distribution, and once the distribution is agreed upon, the states have flexibility in utilization, within reason. For example, the treaty governing the Incomati/Inkomati River between Swaziland and South Africa allocates a specific amount for afforestation in both states based on the amount of land to be planted, a rare nod to environmental need in a water treaty. Using that water for any purpose other than afforestation would violate the spirit and terms of the allocation provision. On the other hand, an allocation based on population and per capita consumption would not necessarily be violated if the allocation is distributed among other uses.

**Benefit Sharing**

Benefit sharing requires that the basin be managed as a single unit, the aggregate benefits then being distributed to each country according to some negotiated principle of proportionality. Such an approach shifts the analysis from the resource itself to the benefits of utilization. Thus, the product to be shared or allocated expands beyond water to include goods and commodities, such as agricultural products, hydroelectricity, and, conceivably, benefits from nonuse, such as conservation, instream flows, and improved water quality (Sadoff and Grey 2002).

Consider the following example. By lifting the border between the upstream and downstream states, water managers can collaborate on the optimal location for a reservoir. Consider a downstream state that experiences frequent flooding and seeks to construct a reservoir, but the state's territory is mostly floodplain, so any reservoir would be shallow, have a large footprint, and store less water than a reservoir with a smaller footprint in a deep valley in the headwaters. In addition, downstream development would impede the migration of anadromous fish. At the same time, a canyon in an upstream state may be a more suitable location for a storage facility that would benefit the downstream state in the form of flood protection without imposing downstream physical
barriers to fish migration. Upstream development would also cause significant environmental harm, harm which must be addressed if the SES is to be resilient. The upstream facility may be able to provide greater benefit (i.e., store more water) with potentially less cost (i.e., flooded land and evaporation). Then, whatever benefits the downstream state reaps can be paid forward to the upstream state, perhaps in collaborative measures to protect upstream migration or as financial side payments. For instance, as part of the Columbia River Treaty, the United States pays Canada for the benefits of flood control and Canada diverts water between the Columbia and Kootenai for hydropower purposes as part of a larger scheme of sharing hydropower benefits, whereby Canada releases water for hydropower production in the United States. Half of the electricity is either delivered to Canada, or the United States pays Canada for its value (Wolf 1999).

The assumption that the benefits of river basin management are shared between countries implies a cooperative approach on the part of participating countries. The conditions in which countries will cooperate are quite limited, as are conditions in which international agreements are self-enforcing (Barrett 2003; Wu and Whittington 2006; Touza and Perrings 2011). Where they exist, however, self-enforcement mechanisms have been shown to correlate with a reduction in conflict over the resource (Dinar et al. 2010). Integration of various elements of water resource planning across multiple scales, known as integrated water resource management, tends to be decentralized and more legitimate, as it incorporates an array of stakeholder interests (Blomquist et al. 2005). However, recent research has shown that integrated water resource management may be at odds with the flexibility required of adaptive management practices (Engle et al. 2011) (but see Chapters 4 and 5, this volume). Of water quantity–related treaties (a broader group than those that outline allocations), ten move beyond needs and discuss sharing benefits from and beyond the river in an equitable allocation of water, hydraulic development, reforestation, flood control, capital, and other commodities—their “basket of benefits” or “benefit-shed.” Governance of the Aral Sea is a prime example.

The 1998 treaty over the Naryn Syr Darya Cascade Reservoirs in the Aral Sea basin reflects the heterogeneous distribution of natural resources in the region and attempts to share them equitably through
integrating regional fuel, energy, agriculture, and water economies. The Naryn River originates in the Tian Shan Mountains of Kyrgyzstan, where opportunities for storage and hydropower generation are greater than in the broader, downstream valleys of Uzbekistan and Kazakhstan, where cotton production is vital to the regional economy. Kyrgyzstan and Tajikistan store water over the winter and forgo potential hydropower generation from winter releases in order to provide Uzbekistan and Kazakhstan with a dependable source of irrigation in the growing season. In exchange for the agricultural and flood control benefits provided from the storage and release of water from Kyrgyzstan’s Toktogul Reservoir (the largest storage facility on the Naryn River) and electricity provided from hydropower generation in the growing season, Uzbekistan provides electric power, natural gas, and fuel oil, while Kazakhstan provides electric power and thousands of tons of coal to Kyrgyzstan during the season of storage. Additionally, Kyrgyzstan agrees to reduce its national energy consumption by 10 percent in order to reduce demand on the energy sector. Tajikistan was later added in an effort to create a single economic zone addressed to water and energy issues in 1999.

Although many may still question the resilience of the current resource allocation in the area, the institution is a marked improvement from the nonintegrated, independent exploitation and historic Soviet misuse. The collapse of the Aral Sea, one of the world’s most shocking man-made environmental disasters, decimated the region in both ecological and economic terms. Integrated development has tempered the dewatering, and the self-enforcing aspects of the arrangement constitute institutionalized cooperation between states. States continue to disagree over development projects and impacts (The Telegraph 2010), but the presence of the treaty has increased the institutional capacity of the states to cope with change and conflict (Yoffe et al. 2003). In addition, the physical Aral may be better off, because increased storage in winter may keep more water instream during irrigation season. Increased fossil fuel consumption in lieu of hydropower production may tip the environmental footprint of this arrangement into a less stable state (albeit hydropower has its own set of impacts that can erode resilience), but the agreed 10 percent consumption reduction signals some degree of conservation awareness.
Resilient Treaty Design

The unique hydrology, climate, economics, and politics of each international basin preclude blueprints for building resilient institutions, and each water treaty comprises a unique set of provisions to govern the resource. Water can be distributed in many different ways, some simple, some complex, some resilient, some not. Management regimes can be iterative, information shared, conflicts foreseen, extreme events planned for, systems monitored, and joint commissions formed. Or not. Treaty design, not the mere presence of a treaty, is paramount to the stability of the institution (Dinar et al. 2010).

While blueprints may not exist, patterns emerge indicating that assemblage of certain provisions correlate with institutional resilience and adaptive capacity (Dinar et al. 2010). An institution’s adaptive capacity can be forecast by the presence of certain provisions and, equally important, the institution’s ability to effectively mobilize these mechanisms in response to disturbance (Adger et al. 2011). Adaptive capacity provisions require resources such as information, learning capacity, and human and social capital, all of which may be accounted for in treaty design (Tol and Yohe 2007).

Since 1820, more than 450 water treaties and other water-related agreements have been signed, more than half of which were concluded after 1950. Despite growth in treaty formation and increased calls for resilience, a review of treaties from the last sixty years reveals an overall lack of mechanisms designed to enhance resilience to water shocks. For example, states rarely explicitly delineate water allocations, the most conflictive and volatile issue area between co-riparian states (Giordano and Wolf 2003). Further, the treaties that do specify quantities often do by fixed volumes, ignoring dynamic hydrology, values, and needs. Likewise, water quality provisions play a minor role in co-riparian agreements historically (Giordano 2003). Enforcement mechanisms are also absent in a large percentage of the treaties. Thus, even if a treaty acknowledges the need to be resilient facing variable water availability, there may not be any means of ensuring each state will respond to disturbance according to treaty principles.
Water Allocation Method

The method of water allocation embodied in a treaty has profound implications for the resilience of the social-ecological system served by the treaty to both climatic and other shocks (Dinar et al. 2010; Odom and Wolf 2011). States share water by many means, often as a reflection of the negotiation process and historic relations, and the degree to which the environment is considered varies greatly. Methods of allocation vary from simple volumes to a complex calculus of flows, availability, and time of year. Disturbingly, the treaty record is replete with allocations that do not allow for the vagaries of nature and the scientific unknown and that often lead to tense political standoffs and environmental degradation.

Most commonly, states divide water based on fixed volumes, the least adaptive form of allocation. Rigid entitlements leave no flexibility to account for hydrologic variability, and the IPCC predicts such rigidity will lead to increased international tension:

One major implication of climate change for agreements between competing users (within a region or upstream versus downstream) is that allocating rights in absolute terms may lead to further disputes in years to come when the total absolute amount of water available may be different. (McCarthy et al. 2001, 225)

In low-water years, if states divert their full entitlement, water levels fall, perhaps to the point of dewatering, and strain the aquatic ecosystem. Another likely drought scenario challenges institutional resilience when an upstream state diverts its full allotment, leaving insufficient flow for the downstream state to satisfy its entitlement. Without flexibility in allotments or flow requirements at some downstream point (e.g., the upper basin states of the Colorado River must release enough water from Glen Canyon Dam so that 7.5 MAF/year flows to the lower basin at Lees Ferry), allocation by strict volume leads to vulnerability in institutions and social-ecological systems.

Of the sample of water allocation treaties \((n = 73)\), twenty-eight treaties allocated water based on fixed quantities, with sixteen of those not
providing flexibility in the allocation mechanism. Of the twelve remaining treaties, nine acknowledge variability and base the fixed quantity on availability. For example, the 1994 treaty between Lebanon and Syria over the Al-Asi River (Orontes) provides 80 MCM to Lebanon when the amount of water in Lebanon is 400 MCM or greater. When the annual quantity falls below 400 MCM, the year is considered "rainless," and the Lebanese share is reduced by 20 percent. The remaining three treaties in the data set allocate fixed quantities that may be recouped over a particular period of time. The adaptability of this method depends in part on the period of time. In low-water periods, recoupment over a course of days does not account for seasonal variation. In prolonged drought, more generous recoupment periods of several years may still result in failure to meet treaty obligations.

Agreements that reduce diversions during low-water years provide for more adaptable institutions and are less likely to dewater a stream. However, states must agree on what constitutes a low-water year and utilize accurate assessment methods (Kilgour and Dinar 2001). For example, the dry season immediately after the 1996 treaty between Bangladesh and India over the Ganges River, a treaty that allocates quantities and percentages according to the water level at Farakka Barrage and took 35 years to negotiate, the water level fell below the minimum accounted for in the treaty, partly due to the data used to establish minimum flows, and the institution was strained. The parties used historical hydrological data that did not account for increased upstream diversions or changing climate patterns. As a result, the institution faltered, and Bangladesh, the downstream state, faced water scarcity. By relying on historical data and past trends to predict future patterns, the institution failed to appreciate the complexity of the social-ecological system along with its tipping points (Liu et al. 2007; Lenton 2011).

Most treaties (55 percent or forty out of seventy-three) allocate based on fixed quantities, percentages, or both. Percentages account for changes in availability due to physical or social disturbance, and unless the entire flow is allocated to states (e.g., 50/50), grant proportional protection to instream flow. Whether that protection is adequate to support a resilient social-ecological system depends on hydrology and the reserved amount. If 30 percent of flow is reserved instream, that may not be adequate for habitat, even in a wet year. On the other hand,
leaving 100 percent of flow instream may not be sufficient in a severe drought. Institutionally, allocation by percentage is less likely to lead to state grievances (Dinar et al. 2010).

**Extreme Events Provision**

While the resilience of a system is measured by its ability to cope with change (Yoffe et al. 2003), water allocation treaties regularly ignore the inevitability of extreme events, especially drought, despite research demonstrating that the intensity of state grievances is robustly correlated with the degree of flow variability in the basin (Dinar et al. 2010). Extreme fluctuations in flow variability can be built into the allocation mechanism or dealt with in separate provisions or through separate treaties. Only twelve treaties in the TFDD collection of water quantity, flood protection, and hydropower treaties ($n = 102$) contain drought adaptability mechanisms. These mechanisms range from vague provisions to consult and cooperate in the event of drought (e.g., Agreement between the Governments of the Republic of Portugal, the People's Republic of Mozambique and the Republic of South Africa Relative to the Cahora Bassa Project, signed May 2, 1984) to more specific pledges to cease all irrigation pumping if flow falls below certain levels (e.g., Complementary Settlement to the Agreement of Cooperation between the Government of the Eastern Republic of Uruguay and the Government of the Federal Republic of Brazil for the Use of Natural Resources and the Development of the Cuareim River Basin, signed May 6, 1997). Presence of an adaptability mechanism to drought has been shown to affect the intensity of state grievances (Dinar et al. 2010). Notably absent are provisions to protect the environment in times of drought.

Floods that cross boundaries tend to account for a disproportionate share of casualties and are more severe in magnitude of loss (Bakker 2009a). Many treaties in the TFDD collection concern flood control, mostly in the form of joint infrastructure projects (e.g., reservoirs, levees, river straightening), and these treaties tend to be single-issue agreements that outline specifics of flood control mechanisms, not vague references. However, agreement over flood control mechanisms does not robustly correlate with fewer state grievances (Dinar et al. 2010).
In addition, Bakker (2009a) found that international river basins with water institutions experienced higher flood magnitudes than those basins without institutions.

**Data Sharing, Joint Monitoring, and Information Exchange**

Monitoring and data sharing is crucial for iterative governance of a dynamic resource. In contentious basins, agreements to exchange data can be the first step in building a cooperative governance structure (Sadoff et al. 2008). When ecosystem knowledge is shared among a variety of stakeholders, institutions enable responsive and flexible solutions at the appropriate scale (Brown 2002). To ward off the tendency to “hunker down,” whereby states are less willing to share information when facing disturbance, the agreement to share must be institutionalized (Anderies et al. 2004; Putnam 2007).

Unfortunately, though many treaties include monitoring and data-sharing provisions, information sharing among states is relatively low (Grossman 2006). Whether caused by a lack of monitoring or technology, incompatibility between databases, or a lack of willingness to share, restricted data sharing has exacerbated the ecosystem harm of water system infrastructure, such as the effect of dams on the Senegal River (Grossman 2006). The Senegal River is managed by a joint commission that is responsible for operating a database of flow information. One contributing factor to the data-related problems of the Senegal is that an upstream riparian, Guinea, is not a member of the joint commission and does not contribute inflow data, resulting in data gaps. Data gaps weakened the capacity of dam operation models to optimize both water allocations and environmental health as designed. As a result, additional agreements are necessary to define the roles of all contributing organizations and to create a central river basin information system (Grossman 2006).

**Joint Commission**

Recognizing the restraints of the negotiation process, treaties often establish joint commissions to manage shared resources. Of the world's
276 transboundary river basins, 78 are represented by an international commission and even within these, few include all nations riparian to the affected basins, precluding the integrated basin-wide management advocated by the international community (Bakker 2009b). The scale of operations ranges from day-to-day decisions concerning operation of infrastructure to occasional discussion of new development projects. In some cases, joint commissions enjoy some degree of independence from their respective national governments and may be less bound by political relations and realities. For example, the Joint Water Committee, established by the Israel–Jordan Treaty of Peace to resolve conflict without amending the treaty, to monitor water quality, and to share data, mitigated a rhetorically heated conflict between the riparian states during the severe drought of 1998–1999 by modifying allocations (Odom and Wolf 2011). The treaty provides for Jordanian water storage (winter) and release (summer) in the Sea of Galilee/Kinneret/Lake Tiberias/Lake of Gennesaret system, which lies completely within Israel. In return, Israel secured fifty-year leases for wells and agricultural land in Jordan. The treaty also allocates fixed volumes of the Jordan and Yarmouk Rivers. When Israel threatened to renege on its delivery schedule, protests erupted in Amman and the King of Jordan issued harsh words, challenging the stability of peace between the nations. The treaty was silent with respect to flow variability, especially such extreme fluctuations as those experienced during a drought. Likewise, the Joint Water Committee did not have expressed authority to modify allocations. Nonetheless, the committee intervened to mitigate the conflict, exhibiting institutional capacity to manage the disturbance (Odom and Wolf 2011).

International river management organizations that attempt to tackle multiple collective-action problems, such as environmental conservation and water allocation, face increased challenges to their effectiveness, but many argue that integration of all related problems is necessary for effective governance (Kliot et al. 2001; Dombrowsky 2007; Sadoff et al. 2008). Thus, an organization that focuses solely on how to allocate water and has no jurisdiction to mitigate or even monitor environmental impacts of withdrawals can only be effective to a limited extent. Conceivably (and perhaps even likely), withdrawals made without concern for environmental harm will decimate the source and render the organization ineffective. If addressing multiple issues reduces the effectiveness
of an organization but a singular focus leads to exacerbation of related problems, there must be a trade-off made whereby the most important related problems, such as sustainability and ecosystem resilience, are addressed along with resource distribution (Schmeier 2010).

**Dispute Resolution Mechanism**

If all other treaty mechanisms fail to avoid conflict, a previously agreed upon method of dispute resolution will, at the very least, provide some guarantee of cooperation. How dispute resolution influences the effectiveness of an institution varies by basin and method. Disputes may be solved by consultation, arbitration through a neutral third party (e.g., UN, World Bank, International Court of Arbitration/Justice), diplomatic channels, or a joint commission, among other means. This mechanism may act as a fail-safe against defection and may provide states with at least a minimal incentive to cooperate, depending on where a dispute may ultimately be settled. For example, if a state is only bound to vague commitments to resolve conflict diplomatically, they may stall or act uncooperatively with little penalty. On the other hand, if disputes are to be settled on the world stage by a neutral arbitrator, the stakes for acting in bad faith may be higher.

**Treaties to Promote Resilience in Social-Ecological Systems**

Since the 1992 UN Rio Declaration on Environment and Development proclaimed twenty-seven principles to guide sustainable development, states have increasingly incorporated environmental protection into treaties, but many of the recent environmentally conscious treaties merely establish a spirit of cooperation over ecosystem protection without obligating riparians to fulfill any specific ecological threshold or dictating any particular process for protection or monitoring.

Of the water quantity–related treaties in the TFDD collection, eleven include explicit provisions for environmental protection, and eight of these were signed in the past twenty years. These treaties have the primary purpose of either allocating water or establishing a framework to
allocate water while protecting ecosystems. In our survey of water allocation mechanisms, only three treaties justified allocations for environmental reasons, compared with twenty-three (32 percent) that gave no justification, and thirteen (18 percent) and eleven (15 percent) that justified allocations for irrigation and hydropower, respectively. For example, the 1992 agreement between South Africa and Swaziland over the Incomati/Inkomati allocates fixed quantities of water that vary according to availability, with additional allocations reserved for afforestation based on the area of land to be planted. It should be noted that the environmentally related justification is for only one aspect of the allocation.

It follows that adaptive management principles in international agreements are required if they are to accommodate the effects of changing climate on variability in water availability. However, few treaties actually spell out iterative processes (Wolf 2007; Drieschova et al. 2008, 2011; Eckstein 2010). Political difficulties prevent treaties themselves from being iterative. While open, negotiations may go back and forth, and there may be room for iterative give and take as information is exchanged. However, once closed, treaties may be effectively locked until they expire, often a period of decades. Another challenge for integrating adaptive management practices would be convincing state water ministers to leave room for flexibility and error in the management of a vital resource. Given the scrutiny under which negotiations proceed, negotiators would likely prefer to leave experimentation in the hands of the trusted technocrats they appoint (Arvai et al. 2006; Gregory et al. 2006). Thus, for iterative processes to influence governance of international watercourses, the process must be built into the organization established to jointly manage the resource. Mechanisms such as monitoring and information sharing must be institutionalized to bind the river basin organization to these procedures.

Unlike U.S. administrative law, which requires detailed front-end procedures, treaties are typically brief and lack long descriptions of process. Instead, they often establish a joint management commission that could (at least in theory) be mandated to operate according to resilience principles. This would require the regulatory structure to be adaptive—to be an experimentation-based learning process consisting of continuous monitoring of the transboundary water body (i.e., the social-ecological system), data review, and the regulatory adjustments needed to promote
the desired goal, all at the appropriate scale (Ruhl 2005; Bruch 2009). Many of these principles, such as data accumulation, information sharing, and cooperative management are not foreign to the international water community. By mandating an adaptive management approach through monitoring, assessment, and adjustment provisions, treaties may increase their institutional capacity to cope with societal and ecological change.

Modern technology, especially information-gathering technologies such as those prescribed in iterative approaches, can change the law. International water law scholar Joseph Dellapenna contends that technology changes the problems international law must address, the range of solutions, and the intellectual structures of international legal institutions (Dellapenna 2000). Institutionalizing adaptive management techniques may change the law by identifying new problems posed by international water development, as data accumulation may reveal a problem in water development that was previously unknown, present new solutions as continuous experimentation results in surprising results, and change the structure of treaties as joint commissions are structured to operate based on iterative processes.

Conclusion

To manage a transboundary water body for resilience in a social-ecological system, an institution must be capable of coping with change. There is no ideal model for this. However, certain principles have been shown to reduce conflict over shared natural resources—flexible allocations that reflect the variability of availability, joint commissions that cooperatively manage the resource, dispute resolution mechanisms that give certainty to the process of conflict, and provisions that proactively determine operational adjustments in times of extreme disturbance and stress. These provisions and their application vary in how they protect the environment, and environmental protection should not be traded away for institutional stability.

As such, institutions must be designed to cope with or reduce conflict, while also maintaining ecological integrity. After all, what good is a peaceful water organization that has no water to manage? To this end,
collaborative management should integrate iterative processes so that as
social and ecological systems alter one another, they also coevolve into
more resilient regimes.

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