INSIGHTS

POLICY FORUM

GOVERNANCE

Tragedy revisited

"Freedom in a commons brings ruin to all." So argued ecologist Garrett Hardin in "The Tragedy of the Commons" in the 13 December 1968 issue of *Science* (*1*). Hardin questioned society's ability to manage shared resources and avoid an environmentally and socially calamitous free-for-all. In the 50 years since, the essay has influenced discussions ranging from climate change (see page 1217) to evolution, from infectious disease to the internet, and has reached far beyond academic literature—but not without criticism. Considerable work, notably by Nobelist Elinor Ostrom (*2*), has challenged Hardin, particularly his emphasis on property rights and government regulatory leviathans as solutions. Instead, research has documented contexts, cases, and principles that reflect the ability of groups to collectively govern common resources. To mark this anniversary and celebrate the richness of research and practice around commons and cooperation, *Science* invited experts to share some contemporary views on such tragedies and how to avert them. —**Brad Wible**

Collective actions, cultural norms

By **Robert Boyd**[1] *and* **Peter J. Richerson**[2]

The enduring influence of Hardin's essay testifies to the power of a clear argument. Should a selfish herdsman add animals to his flock? The benefit of additional animals flows to the herdsman, while the costs are spread among all who share the commons. Each herdsman decides to add animals, and the commons is over-grazed. Genes or ideas that encourage selflessness will be out-reproduced by those that encourage selfishness, so collective action problems can only be solved with coercive institutions such as police and courts.

This argument is clear and powerful, but wrong. Many village-scale human societies have organized hundreds of people to produce irrigation works and military action and solve commons problems, regulated not by formal coercive institutions but by informal, culturally evolved moral norms. Much evidence suggests that the propensity to be guided by culturally transmitted beliefs is a powerful adaptive tool that has been favored by natural selection (*3*). People in every human society acquire moral beliefs about what sorts of behaviors are right and wrong, and these beliefs can support solutions to collective action problems. For example, in the Turkana, an East African pastoral group, hundreds of warriors cooperate in cattle raids against other ethnic groups. The Turkana have no police, courts, or other formal coercive institutions, but cowards and deserters, tempted by selfish motives to free-ride, are punished by members of the community (*4*). Because norm violators suffer costs, those who adhere to the local norms do better than those who don't. Adherence to norms is self-interested, so genes and ideas that undermine successful norms do not spread.

This means that once they are established, very different norms can persist, even in similar environments. To understand why norms sometimes support collective action and sometimes don't, we need to understand the processes that shape norm content.

PHOTO: ALECTRUSLER2015/SHUTTERSTOCK

As R. Boyd and P. J. Richerson point out, "The enduring influence of Hardin's essay testifies to the power of a clear argument. Should a selfish herdsman add animals to his flock?"

Competition among culturally different groups is one such mechanism: Groups with norms that lead to economic success attract imitators, and norms that lead to military success spread through conquest (*5*). As societies become larger and more complex, political institutions play a major role in determining norm content and creating supporting formal institutions. However, there are many examples of norm shifts that cannot be explained as a consequence of group competition or deliberate political choices, such as the disappearance of norms supporting dueling in 19th-century Britain and shifts in norms regarding tobacco smoking, premarital sex, and same-sex marriage during the 20th century.

Although historians provide plausible narratives for particular norm shifts (*6*), plausible quantitative theory is scarce. Models based on drift-like random fluctuations make clear predictions but seem too slow to account for change in larger societies (*7*), whereas those based on self-reinforcing cascades (*8*) are fast but depend on an improbable balancing of processes. We think that developing such a theory is crucial for understanding human cooperation. Darwin argued in *The Descent of Man* that selection for cooperation in ancient tribes, acting over the long run, favored prosocial emotions such as sympathy and patriotism. These emotions, coupled with "approbation of our fellow men," contributed to changes in norms, which in turn supported legal initiatives such as the end of slavery in the British Empire in 1833. We have argued for a modern version of his idea (*3*, *5*).

When societies are small, and collective action problems are local, group beneficial norms often spread. The most difficult problems are those such as climate change that spill over into many different societies and require people from societies that share few norms or political institutions to create new norms. On the time scale of a century, progress in solving global commons problems has been impressive. It is not clear that for some problems we have another century to spare.

TOMORROW'S EARTH

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Playing games in a common pool

By **Ruth Meinzen-Dick**[3]

Water is a classic common pool resource: What one person consumes is not available for others, and water's mobility makes it costly to exclude other users. But classic studies of irrigation institutions (*9*) showing that people can and do cooperate to sustainably manage water have been instrumental in refuting the notion of an inevitable tragedy of the commons (*2*). Yet cooperation does not always emerge or survive, particularly in large irrigation systems built and managed by government agencies. Community organizers have been able to strengthen irrigation institutions, but this is generally time- and labor-intensive and difficult to scale up. Millions of dollars have been invested in large-scale programs to introduce, formalize, or strengthen water users' associations, but success in such programs has been limited (*10*). Groundwater is particularly problematic because it is a mostly invisible resource and it is difficult to understand the boundaries of the aquifers and how one person's use affects others.

What then can increase collective action over water? A strong tradition of interdisciplinary and transdisciplinary research brings together social sciences with irrigation engineering and hydrology, using case studies and comparative studies (*2*, *10*). Elinor Ostrom identified design principles underlying effective governance of common resources: clearly defined boundaries, rules adapted to local needs, with users' participation and respected by outsiders, monitoring, graduated sanctions, dispute resolution, and nested layers of governance that fit the resource system (*2*). In addition to these, water scarcity, type of infrastructure, market integration, and social ties among users can all affect cooperation over water. For example, when many farmers in India get wells and no longer depend on surface irrigation for all their water, they stop contributing to the irrigation organizations. Or those at the head end

ILLUSTRATION: ADAM SIMPSON/HEART AGENCY

of canals, who get water first, may take too much unless they also depend on the tail enders for other things, such as contributions to maintain the whole system.

Behavioral experiments, originally designed as games simulating commons dilemmas in the laboratories, have been adapted to be played with real commoners in the field. These games have shown the importance of communication, repeated interactions, information, and perceived fairness of the distribution of costs and benefits in influencing collective action. We are testing whether these games could be adapted from a research instrument to a tool that can also help water users understand the trade-offs and potential value of cooperation. In our groundwater game, players choose between crops with different water consumption and profitability and see the simulated effects on aquifer sustainability, showing that short-term profits by some come at long-term costs borne by all. In India, sites where this game was played were significantly more likely to adopt rules governing groundwater use, compared with control communities (*11*).

At a larger scale, multistakeholder participatory processes can sometimes create common understanding and consensus about opportunities for improving the complex governance of multiple water uses and users in river basins, including water quality improvement and reservoir reoperation for restoring more natural flow regimes in rivers (*12*). Ostrom's concepts of polycentric governance (*4*) and the rich literature on multistakeholder platforms and comanagement arrangements between the state and communities (*10*) provide insights—though not blueprints—for ways to better manage water commons in the future. Payment for environmental services financed by downstream users such as municipal water systems can encourage upstream conservation, such as seen in the Delaware County watershed that feeds New York City, but building trust between government agencies and different types of water users is key.

Revealing historical resilience

By **Tine De Moor**[4]

The practice of managing and using land and other natural resources in common—what the term "commons" originally referred to—has a long history. "Commoners" exercised rights to use resources over large expanses of permanently uncultivated, or only temporarily cultivated, open country such as heathland, rough pasture, or woodland. Commons were an essential component of early modern agriculture in many parts of Europe until the 19th century; their disappearance (through enclosures) was a key political issue at the time and has been the subject of considerable historiographical debate since. Historians, whose work on commons was for a long time mainly descriptive, have provided evidence that—contrary to Hardin's assumption—historical commons were dynamic institutions, with continuous rule-making, changing, intensive communication between the commoners and with effective monitoring mechanisms (*13*). Contrary to arguments in favor of their dissolution, common resources were used in an efficient manner, and improvements associated with enclosing common land and limiting access to commoners were probably not as large as originally thought by reformers (*14*).

A more analytic approach to commons' history, using archival records for many commons dating back to medieval times (in Europe), can provide insights about what makes a self-governing institution resilient for major crises and external shocks. After all, true resilience can take multiple generations and even centuries to surface. Historical sources are often still available, in the form of extensive written rulebooks, in many cases for commons with a lifetime of several hundreds of years during which rules changed frequently (*15*, *16*). The reconstruction of these rules demonstrates that regulation often adapted to changing circumstances, and that survival over many centuries was not an exception, but the norm. Those rule books provide essentially the same type of data as collected through fieldwork by Ostrom and colleagues (*2*), but whereas Ostrom's list of design principles is the common denominator of a large set of commons studied at a specific moment in time, the historical data allow for a longitudinal study of the temporal dynamics of a common, of governance that needed to adapt or else collapse. An ongoing study of large datasets of 30 historical commons across the Netherlands, Spain, and the United Kingdom (15) is suggesting some ways in which Ostrom's list, and work building on it, may need to be updated. For example, sanctioning—in particular, graduated sanction, incrementally based on the repetition of violations—has been seen as an essential component to make self-governing commons work, yet graduated sanctioning is hardly ever found in commons surviving more than 200 years (the minimum years of survival as set in the study) (*17*). This suggests that in order to achieve long-term survival, this particular type of sanctioning may have been less essential than suggested in Ostrom's principles, and that those commons with graduated sanctioning in Ostrom's database may have been through a severe period, with many trials and errors of sanctioning, with the graduated version as the very last resort. Futhermore, analyzing rules and sanctions over the lifetime of several commons, there appears to be an inverse correlation between the effort put into developing sanctions (expressed as the number of rules accompanied by a sanction) and the longevity of a common (expressed as the number of years between emergence and dissolution), suggesting that commons that managed to survive longest invested least in designing and applying sanctions (*18*). This counterintuitive result may be explained by the longer-lasting commons investing more time and effort in (compulsory) commoners' meetings, leading to a more thorough understanding by commoners of why rules—and changes thereof—were necessary, and possibly, as a consequence, leading to less free-riding. Historical analysis can add unexpected insights to our understanding of which methods can be used to keep commons functioning in the long run, steering them away from a tragedy.

Couple issues to address conflict

By **Matthew O. Jackson**[5,6,7]

Over the past five decades, we have come to a deep understanding of commons problems and how to solve them: They are not zero-sum games, but instead offer substantial gains from cooperation. Game theory and market design have helped us understand how to provide appropriate incentives (*19*–*21*). For instance, taxes as well as cap-and-trade systems can be designed to make the price of emitting carbon include its ultimate social/climate cost, and subsidies can make the prices of alternative technologies reflect their ultimate social benefit. However, a challenge with global commons problems is that solving the incentive problems often leads the collective gains to be distributed very unevenly (*22*); the costs can even outweigh the benefits for some parties. There are many players with enormous differences in wealth and interests around the planet—both within and across countries—facing different consequences from commons problems and abilities to pay for them. Yet, universal cooperation is needed, including coordinated limits and the willingness and the ability to enforce those limits. Thus, the main challenges that we face are political. Crafting a policy that addresses everyone's needs becomes an even bigger challenge when combined with constantly changing political leadership with short-term perspectives and impatient citizens who make it difficult to incur large costs today for

Uncoordinated management of fishing, shipping, and seabed mining challenges the health, productivity, and resilience of the global ocean commons.

PHOTO: BRUSINI AURÉLIEN/HEMIS.FR/HEMIS/ALAMY STOCK PHOTO

benefits that may not accrue for decades and involve considerable uncertainty and may affect others more than themselves. A natural reaction to this is to try to simplify things by concentrating on one issue at a time. Although this may seem sensible at first blush, the key to crafting policies that address a multitude of conflicting interests is actually to couple issues together (*23*). If there is an issue on which a group has little to gain and much to lose, then one gets their consent by including some other issue on which they have much to gain and little to lose. This is a principle underlying omnibus legislation: the packaging of unrelated issues into one large bill (*24*). Global organizations such as the United Nations have wide scope and can envision such compromise, but they are funded at a handful of billions of dollars when tens of trillions are at stake, and they lack full international buy-in and trust. The exception is the World Trade Organization (WTO); more than half of world gross domestic product crosses country borders. However, the WTO's scope is limited to trade agreements. In the absence of a world organization with sufficient jurisdiction and large enough carrots and sticks, there is a need for the leadership of key countries to step up and craft an omnibus agreement that couples commons problems with other issues, with something for everyone. Packaging issues produces an attractive agreement that entices participation, rather than coercing it by threatening nonparticipants with trade sanctions that may run afoul of existing treaties, fuel a trade war, or be costly to follow through with. Coupling global commons problems with other large issues will complicate our lives, but it is the only way to forge and enforce agreements at an appropriate scale, which everyone will sign onto. Without powerful international leadership, large global commons problems will continue to be ceded to humanitarian organizations and the voluntary behaviors of groups here and there.

An ocean of opportunity

By **Kristina M. Gjerde**[8] *and* **Harriet Harden-Davies**[9]

In many ways, the global ocean beyond national boundaries—two-thirds of the ocean's surface—epitomises the tragedy of the commons. Access remains difficult to control, resources are declining, and pollution pervades the deepest abyss (*25*). Combined with ocean warming, deoxygenation, and acidification, these impacts undermine ocean health, productivity, and resilience, exacerbating the challenge of achieving equitable and sustainable management of our shared ocean (*26*).

Since Hardin in 1968, the concept of the global ocean commons has evolved. The 1982 United Nations Convention on the Law of the Sea (UNCLOS) tempered the right of States to access resources of the high seas and international seabed ("the Area") with obligations to build capacity, advance scientific knowledge, and protect the environment. UNCLOS further designated the Area and its mineral resources as the "common heritage of mankind" to be managed by the International Seabed Authority for "the benefit of mankind as a whole." In the 1990s, States acknowledged that biodiversity loss and climate change were "common concerns" (*27*). More recently, concepts such as precaution, ecosystem-based approaches, and marine protected areas (MPAs) have been incorporated into international commitments (*27*), including United Nations (UN) Sustainable Development Goal 14.

However, global ocean health remains under threat because mechanisms to enable and enforce existing UNCLOS obligations remain weak (*25*). Despite new technologies to monitor activities and impacts (*28*), the current system of managing fishing, shipping, and seabed mining separately begets inconsistent, conflicting, and frequently unsustainable results (*25*). For example, illegal fishing is worse in some places than others; mineral exploration rights are being granted atop important fishing, scientific research, and cable sites; and biodiversity values are frequently ignored (*25*). Meanwhile, the lack of centralized reporting hinders efforts to hold accountable the few that block conservation measures despite treaty requirements (*27*, *29*) and compelling evidence of need (*26*). In the Southern Ocean, for instance, compromises made to secure consensus for the Ross Sea MPA (*29*) highlighted the power of a very few states to weaken protections.

Conversely, on the rare occasions that the UN has called on sectoral bodies to implement specific requirements to tackle threats to biodiversity, substantial progress has been made. A 2006 UN resolution requiring states sponsoring bottom fishing to conduct prior assessments, adopt measures to avoid substantial impacts, and crucially, report to the UN has protected vast areas of the deep seabed. However, as ocean stressors multiply, the UN has recognized the need for a more comprehensive approach to biodiversity conservation and use (*25*).

In September, the UN convened the first intergovernmental conference to negotiate a legally binding agreement under UNCLOS for conservation and sustainable use of marine biodiversity beyond national jurisdiction. The negotiations present an opportunity to elaborate and modernize existing requirements to conduct environmental impact assessments; proactively adopt conservation measures, including MPAs; avoid substantial harm to biodiversity; and improve accountability through regular reporting. The agreement can thus create rules, monitoring systems, and sanctioning powers to enhance compliance while ensuring more sustainable outcomes at the global, regional, and sectoral levels.

Science also has a major role to play as a catalyst for unifying stakeholders behind common concerns (*30*). The agreement can boost capacity and understanding by fostering collaboration in marine science, knowledge exchange, and technology transfer, including on marine genetic resources (*30*). The UN Decade of Ocean Science 2021–2030 could further facilitate knowledge advancement and collective capacity to enable informed, equitable, and sustainable management of our global ocean commons. The question is, will states adopt the mutual restraints and allocate the required resources to evade tragedy and renew ocean health? There is hope, but little time. An ambitious agreement is needed by 2020 to protect our common interest in a healthy, productive, and resilient ocean in the challenging decades to come.

Common knowledge

By **Brett M. Frischmann[10], Michael J. Madison[11], Katherine J. Strandburg[12]**

Intellectual resources have their own tragedy-of-the-commons allegory. Replace Hardin's pasture with an idea, and consider what happens when the resource, the idea, is openly accessible to all. Everyone who can profitably make use of the idea will do so, as much and as often and in whatever manner suits them. But ideas are public goods, not common pool resources; ideas are not congested or depleted by overuse. Unlike the pasture, unconstrained consumption of ideas seems good, and often it is.

But there's a catch. Ideas are products of human intellect, often requiring investment of time, effort, and capital. Unconstrained consumption by free riders, who invest little or nothing in creating the ideas, presents a risk for those who might make such investments in creating knowledge because they may struggle to recover a sufficient return on their investment. Anticipating this, they may underinvest, contributing to tragic underproduction of intellectual resources.

Avoiding cultural, technological, and scientific stagnation thus seems to require collective action to ensure adequate investment in knowledge creation. To facilitate this, many analysts assume two options: government subsidies or intellectual property-enabled markets. Though both are indeed important drivers of knowledge production, so are "knowledge commons," which we should not take for granted.

Knowledge commons refers to institutionalized community governance of the sharing and, in many cases, creation and curation of intellectual and cultural resources (*31*). Examples range from scientific research commons, including data, literature, and research materials (*32*), to intellectual property pools, entrepreneurial/user innovation commons, rare-disease clinical research consortia, open-source software projects, and Wikipedia (*31*). Understanding how such communities share and develop knowledge is crucial in today's "information society."

Following Ostrom (*2*, *33*) and Hess and Ostrom (*34*), we have worked to systematize the study of knowledge commons and build a new field of interdisciplinary research in which law, economics, sociology, political science, network science, and other fields converge. Dozens of case studies have begun to reveal an empirical picture of knowledge commons. A representative theme is that knowledge commons confront diverse social dilemmas not reducible to the simple free rider or tragic commons. Rare-disease research consortia, for example, address numerous governance challenges, including allocating research funding, authorship credit, and other rivalrous resources; overcoming potential anticommons dilemmas arising from researchers' incentives to hoard access to patients and their data; maintaining privacy, security, and the trust of patients and their families; reducing transaction costs of cooperation between widely dispersed researchers; and managing interactions with outsiders, such as pharmaceutical companies. The diversity of dilemmas is matched by the surprising diversity of participants critical to successful collaboration. Hardin's sheep-herder must be replaced with researchers, clinicians, patients, site coordinators, funders, third-party data custodians, and even government officials.

Despite growing evidence, we're still far from design principles, much less strong prescriptions. Yet social demand for trusted governance of shared knowledge resources, ranging from medical data (*35*) to algorithmically generated intelligence, is growing, even as public trust in governments and markets as sources of governance seems tenuous. Many researchers and policymakers understood the scope of Ostrom's commons-based framework as limited, for example, to small communities managing local resources. Now, more than ever, we need to explore if, when, and how commons governance can scale.

The antimicrobial commons

By Angela R McLean[13,14] and Christopher Dye[13]

It has become commonplace (*36*–*38*) to refer to the rise of antimicrobial resistance (AMR) as a tragedy of the commons. Each individual wishes to use the common-pool resource of functioning antimicrobials whenever they might have a beneficial effect

Antimicrobial use could be decreased if overuse led to loss of good reputation, and rules for prescribing established boundaries of "reputable" behaviors.

PHOTO: RICHARD PASLEY - DOCTOR STOCK/GETTY IMAGES

(whether in treating human illness or in raising livestock), but overuse accelerates the spread of drug-resistant pathogens, so the drugs become useless to all—and therein lies the tragedy. One way or another, some individual freedoms must be sacrificed in order to maintain a valuable resource for the common good. Whereas Hardin emphasized private or state ownership to achieve this, Ostrom argued that those who share in exploiting a common-pool resource can develop their own rules to prevent its overuse. She identified factors that are conducive to the establishment of effective institutions to regulate the exploitation of a resource: Users have common interests; they place a high value on the resource far into the future; users support effective monitoring; accurate information is valued and easily communicated; and it is feasible to establish binding and enforceable regulations. Ostrom warned that large groups often struggle to govern common pool resources and that boundary rules are needed to determine rights and responsibilities.

Many of Ostrom's observations are starting to be fulfilled in the search for solutions to the problems of AMR, even if few people in this area explicitly set out to apply her work. The growing threat of AMR is increasingly understood by medical professionals, policy professionals, and the public alike. The associated discourse reflects the common, long-term interests of these diverse users (*39*). The widely accepted need for better surveillance of AMR signals rising support for effective monitoring and accurate, shared information. In a growing search for effective rules, physicians are adhering more strictly to evidence-based guidance for diagnosing infections; for infection control in hospitals; for procuring, prescribing and dispensing antimicrobials; and for ensuring that patients complete treatments. Beyond codes of practice, governments have in some settings introduced methods of enforcement, such as restricting the use of essential drugs to certified treatment centres. And public health specialists have called for AMR to be included among the International Health Regulations, a legally binding agreement to prevent the international spread of disease. Last, the global nature of the challenge is acknowledged in the World Health Organization's leadership in developing new norms for using existing antimicrobials and investing in new ones (*40*).

Some other useful ideas arise when AMR is viewed as a tragedy of the commons. For example, a desire not to be seen as selfish offers a potential solution: antimicrobial use could be decreased if overuse led to loss of good reputation, and rules for appropriate prescribing helped establish boundaries of "reputable" behaviors (*41*). Further, the "large groups" problem may be less acute if local effects are strong enough that a region or nation can benefit from reducing their own usage, even if their neighbors do not (*42*).

In 1968, Hardin remarked that the tragedy of the commons was understood mostly as a set of special cases rather than as a general problem of resource management. The AMR tragedy will benefit from the application of the broad principles of governing a wide range of common pool resources. That will bring focus, for example, to the question of "boundary rules". Can one country ever manage AMR alone, and can AMR for human infections be controlled without also controlling agricultural use? Also uncertain is the best mechanism of control: When are binding and enforceable regulations preferred over guidelines and codes of practice? How can the principles laid out by Hardin and Ostrom guide the creation of new resources (discovery of antimicrobials), besides conserving the ones we already have? In the face of these pressing questions, taking a broader view of the AMR tragedy, and of its resolution, will show how best to govern the antimicrobial commons.

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Tragedy revisited

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