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The Commons

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Abstract

Commons—resources used or governed by groups of heterogeneous users through agreed-upon institutional arrangements—are the subject of one of the more successful research programs in the social-environmental sciences. This review assesses research on the commons to accomplish three tasks. First, it surveys the theoretical, substantive, and methods-focused achievements of the field, illustrating how commons research has also influenced natural resource policy making. Second, it examines the changing trajectories of commons research, emphasizing the growing interest of commons researchers in new methods and the application of insights to new social contexts. Third, the review suggests that research on the commons can find continuing relevance by addressing contemporary and future social-environmental challenges. It highlights three directions in particular: (*a*) strengthening the focus on issues of power and equity, (*b*) applying insights about effective commons governance to collaborative attempts to craft commons in new societal spaces, and (*c*) advancing an emerging emphasis on causal analysis and taking advantage of novel streams of large-scale public datasets.

Contents

1. INTRODUCTION

Scholarship on the commons—resources used by groups of heterogeneous users through agreed-upon institutional arrangements (1)—is one of the more successful research programs in the social and ecological sciences. The scope of research on the commons is growing broader. But commons scholars attend in particular to how local institutions and communities can viably govern renewable resources such as forests, fisheries, wildlife, pastures, and small-scale irrigation waters (2–4).

By focusing on the specifics of institutional arrangements that users devise to manage their resources, scholars of the commons have made three enduring contributions. First, they have provided careful conceptual language to distinguish group management of commons from that of public goods or open-access resources and also from club or private goods (5, 6). Second, they have documented how the governance of commons through self-organized institutions can substitute for market- and state-based approaches (7, 8). Third, they have shown that the commons are ubiquitous and durable examples of decentralized resource governance, not a historical curiosity destined to disappear with time (9). In this vein, some have viewed the commons as a third way, critical venue for supporting the consolidation of civil society (10). Through these diverse contributions, scholars of the commons have provided intellectual foundations for advocates of local communities, Indigenous groups, and resource-dependent peoples (11, 12).

The intellectual and policy-relevant accomplishments of commons scholarship rest on an abiding concern with how institutions shape outcomes in social-ecological systems. Research on the commons is relevant to other social dilemmas and collective action challenges. A continuing exchange of ideas between research on small-scale resource commons and research on such diverse themes as conflict management, space rivalries, knowledge generation, climate adaptation, social movements, and institution formation attests to the broader intellectual relevance of the field (13–15). Commons research has also found traction in policy making and practice (16). After the late 1980s, many country governments, nongovernment organizations, and international donors used insights from research on the commons to support collective and decentralized renewable resource management (17, 18).

Commons: resources used or governed by groups of heterogeneous users through agreed-upon institutional arrangements

A rich history of scholarship on community-based arrangements for managing resources is the bedrock for analytical research on the commons. Economic historians, rural sociologists, anthropologists, political scientists, ecologists, and others provided antecedents for contemporary

commons research through substantial case-based, historical, and comparative writings. Classic examples of such historical commons span the globe. Writings on the English common field systems analyze the intricate social connections that enabled multiple land uses under communal organization (19). Sophisticated community-based arrangements to allocate water include the Balinese water temples and the village republics of South India (20, 21). Long-standing pastoralist tenure and allocation systems in East and West Africa, Europe, and South Asia are testimony to the human capacity for cooperation across spatial and temporal distances (22). The institutions devised by fishers in Sri Lanka, Turkey, Tanzania, and Newfoundland highlight the ubiquity and persistence of the commons (23, 24). Research from countries as different as Canada, Japan, Switzerland, and the United States demonstrates the enduring attraction of the commons across diverse social contexts, including in rich countries (25–27). More recent work on long-lived commons continues to advance this stream of commons research (12, 28, 29).

Scholarship on the commons began with rich case descriptions. But growing case-based knowledge helped the development of analytical frameworks for systematic comparisons of empirical regularities (2). Analytical frameworks directed attention toward recurring social and organizational elements shared across examples of functioning commons (21, 30). This approach found its most influential expression in Elinor Ostrom's (4) *Governing the Commons: The Evolution of Institutions for Collective Action*.

In highlighting a small set of design elements that support long-term viability of commons institutions, Ostrom drew inspiration from research on markets, bureaucracies, and voting. Scholars of market exchange had identified (*a*) numerous buyers and sellers, (*b*) entry and exit without barriers, (*c*) homogeneous goods and services, and (*d*) perfect information as leading to competitive markets (31). The Weberian bureaucratic ideal type is defined by hierarchical coordination and control, role specialization for professional management, rule-based decision-making, and expectations of permanence and continuity (32). For democratic theory, Kenneth Arrow showed in 1951 that voting rules to aggregate individual choices into collective outcomes could not simultaneously meet a small set of conditions associated with democratic decision-making (33).

In a similar vein, Ostrom (4) identified a parsimonious set of institutional design principles for the commons: clear boundaries for users and resource systems, congruence between rules and resource systems, rulemaking autonomy, accountable community monitoring, graduated sanctions, mechanisms for adjudication, recognition by higher authorities, and nested institutions. Specification of a concise set of design principles, and subsequent work that further elucidated their relevance, contributed to Ostrom winning the Sveriges Riksbank Prize in Economic Sciences in the Memory of Alfred Nobel in 2009.

Almost from the very beginning, critics highlighted factors such as politics, culture, justice, and the structuring role of context as additional factors that affect the functioning and outcomes of commons (34–36). In response, Ostrom (37) acknowledged the importance of many additional factors and developed the social-ecological systems framework. To do so, she drew upon related scholarship (38) and added scores of potentially relevant, new features that matter to the effective governance of social-ecological systems such as the commons (11, 37). The original design elements for institutions that she discussed in *Governing the Commons* continue to shape the thinking of many practitioners. But they should be viewed as the initial step toward an understanding of institutional effectiveness for the commons rather than as the final word on a parsimonious set of design elements.

Contemporary scholars of the commons continue to assess the relevance and importance of multiple causal factors to commons outcomes such as equity, resilience, sustainable livelihoods, and carbon sequestration (39). Abandoning the search for parsimony has, on the one hand, allowed the research program on the commons to continue elaboration of contextual features, user group

characteristics, resource system attributes, and institutional arrangements that support positive outcomes (28). On the other hand, it has also become difficult to accumulate knowledge across research efforts because of differences in contexts, outcomes, definitions, measures of variables, and causal conditions (40). It is for this reason that both early and more recent reviews of the field have called for a shift in focus from identifying additional variables to improving consistency in measurements and terminology and for a focus on more careful causal attribution through alignment of theory, models, and data (41, 42).

Building on this abbreviated history, the ensuing review contributes in three ways to an assessment of the research on the commons. First, it surveys the theoretical, substantive, and methods-focused achievements of the field, illustrating how commons research has also influenced natural resource policy making (43, 44). Second, it examines the changing directions of current commons research, using both recent reviews of the literature (45–51) and substantial new empirical research. Third, and toward a conclusion, it identifies important currents in scholarship on the commons that need effective navigation for the field to continue to be relevant for addressing urgent societal and environmental challenges.

2. THE THEORETICAL, SUBSTANTIVE, AND METHODS CONTRIBUTIONS OF COMMONS RESEARCH

Research on the conceptual framework for analysis of the commons, although concerned primarily with social-ecological systems (4, 37, 52, 53), has also helped illuminate the foundations of human choices and collective action. Insights from this research deepen our understanding of the complexities of choice and decision-making, relationships between institutional arrangements and resource system outcomes, management of large-scale commons and polycentric governance, and power and equity. Commons researchers have shown how commons work in the real world, and with what effects. Finally, their use of new methods and new data contributes to methodological development more generally (4, 54–56).

2.1. Conceptual and Theoretical Contributions

A critical contribution of commons research is its attention to different characteristics of resources and goods to reduce confusion among public, common, club, and private goods. Distinctions among these types of goods are based on two features of resource systems: the extent to which it is possible to exclude users from the resource (excludability/ease of exclusion) and the extent to which resources are depleted with use (subtractability/rivalrousness). **Figure 1** provides a visual depiction. Public goods tend toward nonexclusion and nonrivalrousness: It is difficult to exclude people from using them and they do not get depleted with use. National defense is often cited as a classic example of public goods. Common goods are depleted with use (rivalrous) and it is difficult to exclude users. Wildlife is an example. Private goods (e.g., food bought and sold in markets) are depleted with use but exclusion is easy. Club goods are available to others even when used by some. Compared with commons, exclusion is easier. Toll roads are an example of club goods. Excludability and subtractability are characteristics of goods. But institutions and technologies affect whether exclusion from a good is easy and the degree to which a good is depleted with use. For example, institutions affect whether a resource system is open access or a restricted-use commons. Technological innovation can transform ease of exclusion. The invention of barbed wire, for example, effectively allowed privatization of land in the American West (57). Beyond the dimensions of subtractability and excludability, commons scholars have examined differences in goods in terms of mobility and visibility of resources and the volatility and uncertainty of benefit flows from them over time (58).

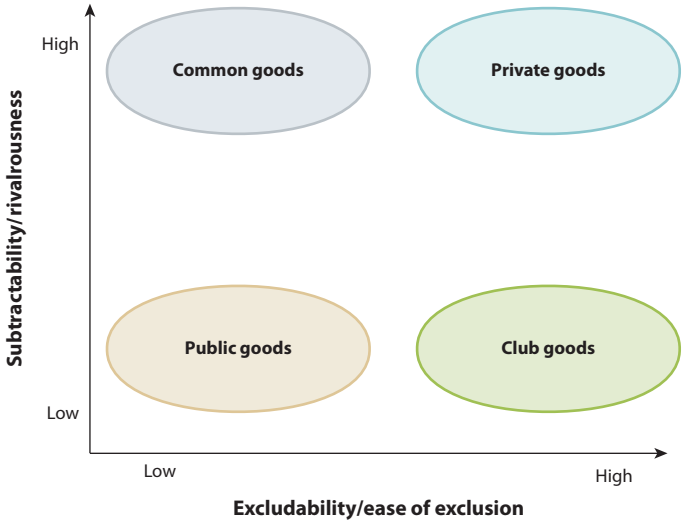

Figure 1

Types of goods. A fourfold typology of public, private, club, and common goods.

Commons scholars have made important theoretical advances relevant to relationships between institutions and resource outcomes as shaped by contextual factors. Four themes are particularly important. These concern (*a*) the individual- and community-level factors (e.g., trust, reputation, repeated interactions, and reciprocity) that affect actions and choices of individuals (58, 59); (*b*) the rules, institutional arrangements, and governance that translate individual choices into collective social and environmental outcomes (e.g., resource conditions, well-being, or equity) (60, 61); (*c*) the effects of communication on decision-making (62, 63); and (*d*) how the key concepts of equity, identity, and culture relate to resource use and governance. Variations and interactions of these important factors with features of common-pool resources (e.g., visibility, mobility, and predictability of flows of benefits) yield substantial variation in social and environmental outcomes of the commons.

2.1.1. Individual actions and cooperation in commons dilemmas. Collective action dilemmas related to resources, also termed commons dilemmas, lead individuals in a group relying on a given resource to overuse it—even if collective benefits over time would be greater were individuals to restrict use (37, 64). Declines in fish harvests, degradation of rangelands, and overextraction of groundwater are well-known examples. Ostrom and her colleagues (4, 65) highlighted the structural similarities across metaphors that describe commons dilemmas, such as free riding, tragedy of the commons, and the logic of collective action. They additionally showed that overuse and degradation of commons are not foregone conclusions because of a critical feature present across a wide variety of commons dilemmas: People, as they use and manage resources, interact with each other repeatedly in the course of their daily lives. Their interactions are multistranded, since they share many goals and interact regularly across many action domains (11, 66). Repeated interactions among users and social embeddedness of their choices have high potential to shift user behavior away from free riding and toward more cooperative interactions.

Ongoing social relationships convey information about the reputations of interacting agents. In small-scale resource systems and small groups of individuals relying on these resources, a reputation for trustworthiness and reciprocity generates incentives for cooperative behavior. Recent

research continues to show how repeated interactions create strong individual interest in positive reputations, incentives for building trust, and reciprocity in social interactions (67–69).

Trust, reciprocity, and reputation are thus to be expected in local resource governance settings, but in variable quantities. Their presence is important to prospects for cooperation needed to sustain resource systems (70–72). Focusing on these elements has helped commons scholars advance the argument that socially embedded human interactions do not conform to predictions of free riding or short-term utility maximization as is common in metaphors of the tragedy of the commons. Rather, users can work together to govern resources and address commons dilemmas instead of needing privatized property rights or government control.

2.1.2. From individual actions to collective outcomes: institutions, governance, and scaling. Perhaps the most familiar aspect of commons research and its most enduring contributions concern how institutions translate individual actions into collective outcomes, including across scales and through different forms of governance (73, 74). Variations in institutional arrangements lead to systematic differences in use, management, and protection of the commons. They affect the persistence of institutions, longevity of resource systems, conservation of biodiversity, and well-being and equity among user group members. Improvements in one type of outcome do not necessarily correlate with those in other types; for example, declines in resource conditions may co-occur with improvements in well-being (75).

Several factors at the local level repeatedly emerge as important influences that shape different resource commons outcomes. These include user group characteristics, participation, autonomy of local decision-making, monitoring and sanctioning arrangements, formalization of management and control, market access, and biophysical conditions (47, 76).

Of the local-level factors identified in the literature, participation in institutional processes and monitoring and sanctioning are particularly important elements in the effective governance of commons. Both case-based and quantitative studies highlight user participation (77, 78), even as some question the mechanical ways in which higher-level decision makers interpret participation. Participation is important for institutional functioning; at the same time, institutions align user expectations regarding permitted and proscribed actions. Locally devised and accepted monitoring arrangements communicate to users behavioral expectations and the sanctions associated with rule breaking. Effective monitoring can occur in a variety of forms, including mutual monitoring by users and delegated monitoring by nonusers. Recent research shows that externally introduced monitoring arrangements that find acceptance among users are also effective for improved resource outcomes (9).

Beyond its attention to features of user groups, resource systems, and local-level institutions, research on the commons highlights cross-scale linkages for a deeper understanding of institutional effectiveness when resource systems span jurisdictions. Ostrom's (37) and Keohane & Ostrom's (73) work on cooperation in large-scale commons dilemmas prefigured subsequent research on cross-scale relationships and dynamics.

Broadly, analyses of commons beyond the local scale have contributed to two important areas of work: comanagement and global commons. In both, cross-scale linkages, interactions between decision makers and users at different levels, and the relationship between institutions and context assume importance (79). Consider comanagement. Across resource types, governments may own resource commons, but local communities often access, use, manage, and govern them, even if informally (80). Comanagement focuses on the relationships between government agencies and local resource management institutions (81). It applies to the governance of resource systems the essential justification for coproduction: Collaborating stakeholders bring distinctive (and complementary) skills and capacities to advance solutions in service of a common purpose (82, 83).

Scholarship on comanagement highlights the importance of polycentric governance (i.e., rule-based coordination of actions by multiple decision makers across jurisdictions and scales). It also highlights some of the features of polycentric governance relevant to success: recognition of differences in powers, capacities, and interests; an emphasis on flexibility and adaptive capacity; delegation of decision-making in accordance with principles of subsidiarity; and complementary capacities and common goals (84–86). Local institutions and their functioning increasingly respond to external influences with globalization (35), and boundary organizations become critical to addressing commons dilemmas across scales (87).

Global commons constitute a particularly thorny example of resource systems that span jurisdictions because relevant spatial and jurisdictional scales span national boundaries and governance may be in tension with national sovereignty claims (88). Global commons challenges include those associated with the sustainable use and governance of atmosphere, freshwater, and fisheries, where increasing use and new technologies have converted erstwhile public goods into commons, but at a substantially larger scale than the familiar case of local resource commons (89).

Rather than issuing calls for global governance mechanisms in this context, commons scholars highlight the importance of polycentric governance. Such calls stem from two important insights about global commons dilemmas. The first is that seemingly intractable challenges of global commons degradation often result from the aggregation of choices in smaller-scale commons dilemmas (90). The other insight follows: Even without global governance, it may be possible to address the overuse of large-scale commons through the efforts of many distributed decision-making units that span jurisdictions and scales (36, 91, 92). These insights provide creative avenues for managing global commons in addition to the possibilities and challenges of hierarchical global governance.

2.1.3. Information sharing, communication, and decision-making. Information sharing and communication affect trust and reciprocity, participation, decision-making, and collective action (93, 94). Different layers of information are critical to understanding how and why individuals cooperate to manage resources. At one level, individuals draw on available information about the resource system, other users, and rules. At another level, users bring a wealth of information from past experiences that they evaluate and incorporate into their decision-making (63).

The context of communication, including who shares information, how, and for what reasons, is relevant to how shared information affects choices and behavior (95). For example, face-to-face communications carry greater weight than impersonal communication does (96, 97). Communication aimed to enhance group solidarity (rather than facts about the context) finds more positive reception among participants (98). Communication in repeated commons dilemma games, tested through structured games both in laboratory and in field settings, facilitates collective action (62, 99–101).

Commons research on the relationship between information sharing, decision-making, and collective outcomes also highlights the importance of deliberative arenas for discussion and debate to facilitate pluralistic values in the use of resources (102–104). The importance of deliberation and citizen participation is evident in the context of the global commons dilemmas related to climate change (105). For example, in 2019, the French Citizens' Convention for Climate presented 150 randomly selected citizens with different policy proposals. While expert information framed subsequent deliberations, citizens felt empowered to adjust the Convention agenda and select proposals that addressed climate challenges on the basis of their interests and values (106).

2.1.4. Equity, politics, identity, and culture. Themes related to power and equity have become an important focus in research by commons scholars. In addition to influencing commons

governance and distributive justice, variations in power and equity structure how identity and culture affect commons outcomes (107, 108). Differences in power often manifest as inter- and intragroup inequality, and commons research shows that such inequalities negatively affect commons outcomes (109, 110). Economic inequalities interact with and consolidate other axes of social differentiation, such as caste, ethnicity, indigeneity, and gender (111).

A focus on gender and common-pool resource management originated early in research on the commons (112, 113). This focus has developed into an important subfield. Multiple studies emphasize how gender inequities affect both the governance of commons and the allocation of benefit streams. Men are often in control, whereas women face restricted resource access and harsher penalties (114–117). Other studies find that resource rights vary by gender: Men hold formal rights to resources such as pasture and livestock, but women are tasked with the work of management and maintenance (118, 119). There is a positive relationship between women's participation and sustainable resource management (120–122). At the same time, proenvironmental behavior by women is not guaranteed. A framed field experiment in Kenya found that mixed-gender groups reached more socially optimal outcomes (123). Recent reviews of gender in environmental research highlight the need for a nuanced approach, emphasizing gender roles, socialization, and practices in relation to commons management (124–126). Indeed, practices of management and governance can shape gender identity (127).

Much research points to the major contributions of Indigenous groups to the sustainable management of common-pool resources. Examples of successful Indigenous management of fisheries (128, 129), grazing lands (130, 131), water (132, 133), wildlife (134), and forests (135, 136) abound. They have helped reinforce the global importance of Indigenous groups for resource management (137, 138). Other scholarship seeks to understand drivers for different outcomes, and potential futures, of Indigenous management. Although it is now commonplace to associate Indigenous management with sustainable resource outcomes, recent scholarship invites nuance into understanding this trend and its implications. For example, local rulemaking that is transparent and inclusive should reflect user desires, which may not align with common understandings of sustainable resource use (139). Formalizing local decision-making may come at the cost of beneficial social and environmental outcomes (140). If different features of local decision-making emerge together, it raises questions about whether community-based resource management can be merely found rather than made (141, 142). In turn, questions about whether individual features of local governance can be isolated pose doubts related to the ability of nongovernmental organizations, governments, or the private sector to instill cultural attachment and other forms of intrinsic motivation for sustainable resource management in groups where it does not already exist.

Beyond the examination of how gender and other specific identities affect participation and inequalities, new research also highlights the intersectional nature of identity (143–145). Evidence is mixed on the role of culture (defined as historically transmitted patterns of meanings embodied in symbols through which people communicate, perpetuate, and develop their knowledge about and attitudes toward life) (146, 147). Early scholarship on the commons established that cultural heterogeneity among communities renders commons management more difficult, the implication being that culturally homogeneous groups are more likely to manage common-pool resources successfully (148). Some studies similarly find that cultural heterogeneity, proxied by ethnicity, reduces the effective management of common-pool resources (149, 150).

The above findings point to an interaction between in-group norms and preferences among different ethnicities. Such an interaction is likely to deter collective action between individuals of different ethnicities (151) and may facilitate elite capture, eroding common-pool resource governance (152–154). Mini-publics—defined as representative institutions supporting debate and

deliberation on issues of common concern to citizens—provide platforms for diverse groups of citizens to receive information, deliberate on policy-relevant decisions, and inform or direct decision makers. They can combine the benefits of multicultural collective action while avoiding the pitfalls of within-group competition (106). There is empirical evidence for the challenge that multiculturalism poses to resource management. Exchanges between commons scholarship and fields of study such as deliberative democracy hold promise for addressing challenges of multiculturalism (103).

2.2. Domain-Specific Substantive Contributions

Substantively, research on the commons has focused on social-ecological systems such as pastures, forests, fisheries, and water used by communities (19, 155–158). More recent writings continue this focus, providing a wealth of evidence to demonstrate that across diverse social and ecological circumstances, commons can be used and managed sustainably, efficiently, and equitably (159–162).

2.2.1. Conventional foci of commons research: forests, fisheries, pastures, water, and wildlife. Diverse resource commons are similar in their rivalrous and nonexcludable nature but differ in terms of mobility, visibility, and predictability of their resource flows. Forests and pastoral commons are characterized by stationarity and relatively clearly defined boundaries (163). In contrast, water, fisheries, and wildlife commons are mobile across jurisdictions and resource units can be difficult to detect. These features necessitate collaboration across user groups and authorities, often in the form of polycentric governance (164, 165).

Early scholarship on the commons provided compelling evidence for the effectiveness of local governance arrangements for system longevity, resilience, and equitable cost/benefit allocation (4, 166). This strain of commons scholarship remains of importance. In addition, empirical work has begun to examine the outcomes of livelihoods, biodiversity, carbon sequestration, and resilience in multifunctional commons (47, 75, 156, 160, 167).

Research on forest commons has contributed to a better understanding of when, how, and with what consequences monitoring and sanctioning improve sustainable resource use (168). Studies that assess the role of monitoring and sanctioning of forest commons find that clear boundaries, regular monitoring, and local participation or rulemaking lead to improved resource management, measured as sustainable resource use (9, 86, 169) or as transparency and responsiveness to local interests (139). Factors such as group size, location relative to markets, education, and identity are associated with monitoring compliance but often have contextual and nonlinear relationships to resource outcomes (160, 170). Research on forest commons has also provided strong evidence for the occurrence of leakage or displacement, which refers to forest cover change that occurs not within a forest subject to monitoring and sanctioning but in surrounding forest area that is not (171).

Although grazing commons resemble forest commons in their stationarity, they are often used by mobile user groups. For this reason, scholarship on grazing commons has focused on how mobility, spatial overlap in resource boundaries, and stacked or overlapping tenure regimes affect resource outcomes (172–174). Many scholars of grazing commons use Ostrom's social-ecological systems framework to advance a deeper understanding of the heterogeneity of pastoral practices (172). This research is particularly important in highlighting how mobility of pastoralist herds addresses spatiotemporal uncertainties in resource growth, patchiness in the distribution of rainfall and productivity, and the role of institutions in addressing uncertainties.

Irrigation systems are complex owing to the mobile nature of the resource, asymmetries between head-end and tail-end users, and the need to create and enforce rules related to

infrastructure maintenance and resource extraction. Commons researchers have paid special attention to trust and reciprocity as means to overcome challenges of asymmetry and heterogeneity in user groups and differences in the distribution of benefits from resource systems (175). Moreover, scholarship on irrigation commons has helped identify the range of conditions under which water-dependent groups create rules for equitable water distribution based on different concepts of fairness and equity (176).

In contrast to forests, pastoral commons, and irrigation systems, fisheries and wildlife are highly mobile and often governed by a combination of state and community regimes (177). A recent study found that sustainable sea farming depends on cooperation between local communities, local governments, and fisheries associations through formal governance structures of comanagement (167). The traditional fisheries management techniques used by the local communities include restrictions on modern gear, season, species, size, and ownership (178, 179). There is debate over whether traditional conservation practices by the local communities help conserve marine resources. Some commons research has focused on interactions between community fisheries and marine protected areas (MPAs) established to address marine biodiversity loss (180). The objective of MPAs is to achieve multiple outcomes: sustainable development, biodiversity conservation, species management, and cultural preservation (181). However, human dimensions have often not received priority in the development of large MPAs, undermining prospects of user group acceptance (182, 183).

Similar to fisheries, wildlife commons are mobile resources essential to biodiversity and people. Evaluating the relationship between community wildlife management and private landowners as well as public lands has been a central focus of this subfield, with an emphasis on comanagement by governments and communities (184). In particular, recent scholarship has focused on the need for social control and regulations rather than only on state-based enforcement arrangements to manage wildlife (185, 186).

2.2.2. Overlapping themes in analyses of resource commons. Three tendencies are evident in recent empirical scholarship on resource commons. First, much of the research on forests, water, grazing lands, fisheries, and wildlife focuses on examples of a particular resource type rather than on an analysis of different types of resource commons. This insularity is regrettable. Across these domains, similar concerns about institutional arrangements, participation, power, and resource access motivate researchers (187, 188). Research interests in outcomes also overlap, with persistent attention to variations in institutional longevity, resource sustainability, well-being, and equity (162, 176, 189). But broadly comparative research across resource commons has been limited since Ostrom's *Governing the Commons*.

Commons scholarship tends also to focus on the stability (of institutions and resource systems) rather than attending to change and dynamics (40, 190, 191). One reason for the focus on stability and persistence lies in the objective of many commons researchers, since Ostrom's seminal contributions, to show that common property arrangements can effectively protect and sustain resource systems (40). But in trying to achieve this research goal, they have been less attentive to how institutional arrangements can also facilitate transformations toward sustainability. Such transformations are particularly important when prevailing arrangements to sustain resource systems support unfair allocation of benefits or limit improvements in well-being (192).

Finally, commons research has been more attentive to the material relationships of institutions and rules with resources and user behaviors than to how institutions also shape and reconfigure user preferences, identities, and subjectivities (193–195). There is an intimate relationship between behaviors and subjectivities, however. Exploring the dimensions of this relationship can help improve institutional outcomes as well.

2.3. Methods Contributions

Drawing on advances in both the natural and the social sciences, commons scholarship has applied novel methods for understanding social and ecological relationships associated with collective action. The multidisciplinary training of commons scholars makes them adept in the use of methods from diverse disciplines. Here, we review methodological tools used by commons scholars that fall under four general approaches: observational, simulation and agent based, game based, and experimental.

2.3.1. Observational studies. Canonical scholarship on the commons has focused on the systematic description and comparison of examples of existing commons governance (4, 30). This research yielded some of the most important insights about how self-organized users can sustainably manage commons over decades and centuries without privatization or government control (196, 197). Focusing on a small number of observations allowed for deep description and analysis (166, 198).

A literature review of commons scholarship from 1990 to 2004 found 172 observational studies, of which only 36 contained more than 30 observations (56). More recent work has built on these early contributions with analyses that use quantitative datasets to improve the statistical generalizability of results (199). This research has compiled case study information from across examples to increase sample size and has also used original fieldwork-based data collection (56, 179). Multiple partnerships and multilateral efforts to harmonize the collection of observational data have created a rich foundation of observational information on commons governance (200). Statistical analyses have modeled social and ecological relationships on the commons, with the expectation that more transparent methods that document case selection, coding, and analysis are key to advancing replicability and reliability (75, 136, 137, 201–203).

Research on the commons also uses a variety of synthesis approaches to address specific research questions (45–48, 50, 51, 179, 204). Such syntheses often rely on quantitative methods but include additional techniques as supplement. The normalization of mixed-methods approaches in observational analysis is perhaps an enduring contribution of commons scholars, as they draw upon methods from the disciplines of ecology, geography, economics, political science, sociology, and psychology.

2.3.2. Simulations and agent-based models. Simulations help commons researchers test and evaluate theories about collective action and commons management. Simulation-based models of agent behavior under specified conditions generate data on agents' behaviors and system outcomes. In agent-based modeling, agents refer to rule-based algorithms that make autonomous decisions to achieve specified goals and that react to traits and decisions of other agents (56).

Agent-based models, with agent-based decision-making at the microlevel, have provided descriptive and predictive insights into commons management. Descriptive insights include elaboration of, for example, specific strategies such as tit for tat. Tit for tat is a strategy in which agents cooperate in initial interactions with other agents and in subsequent interactions copy the decision taken by their coplayer(s) (205). Tit for tat demonstrated how cooperation can begin among many agents with social behaviors to become a dominant strategy with the ability to resist invasion (206). However, agent-based modeling is limited in illuminating when and how norms become formalized and how different scales of rules interact to influence commons outcomes (56).

2.3.3. Games: from laboratory to field. In scholarship on the commons, researchers enlist one or more people to play games in the laboratory or in field settings for the use of common resources (207). Such commons games simulate and test how changes in rules affect user behavior,

how participants use a resource, the incentives for resource use, and participants' interactions to advance insights into relationships among institutions, resources, and behaviors (207, 208). Focusing on two broad categories of games, public goods and common-pool resources, commons scholarship has made crucial contributions to methods and findings related to the experimental manipulation of rules for communication, player heterogeneity, and sanctioning, among others (56).

Although games and game theory provide a useful approach to evaluate the relationship between players, rules, and outcomes of interest, questions remain concerning the external validity of their findings. Because players are in a game, the behavior they demonstrate may not replicate their behavior outside the game. Framed field experiments seek to reduce the distance between experimental games and reality by mirroring the rules and context in which participants use common-pool resources. In contrast to a laboratory setting, where users are in a highly controlled environment and may be faced with a game they have little experience playing, framed field experiments seek to match context, resources, and players to analyze outcomes (209). Commons scholars typically employ framed field experiments by developing a game that reflects field-based research on a specific resource context (e.g., forests, fisheries, rangelands, or irrigation waters) and observing how participants use and manage those resources (62, 100, 210, 211). Advancing the use of games beyond the laboratory has contributed substantially to an understanding of the maintenance and use of resources.

2.3.4. Experiments: natural and coordinated. To understand causality in the commons, researchers have leveraged natural experiments or quasi-experiments and randomized control trials (RCTs) (171, 212). Experimental research on the commons seeks to pinpoint causal relationships more precisely. Interventions in studies designed as randomized field trials include a variety of possibilities, among them incentives (positive or negative), information, and institutional or rule variations (213).

Recent advances in causal inference methods have improved the precision and accuracy in the estimation of causal impacts, both within and outside research on the commons. Panel and time-series data help researchers understand how impacts of commons management change over time, and methods such as statistical matching and synthetic controls seek to include (or generate) units that are most similar to those that have undergone a treatment of interest, such as decentralized forest management (86, 214, 215). Combining panel or time-series methods with statistical approaches designed for rigorous causal estimation (e.g., difference-in-difference, fixed effects, and regression discontinuity models and the use of instrumental variables) assists researchers in measuring the direction and magnitude of causal effects. Leveraging these natural experiments or quasi-experiments has provided insights into how local rules for cooperation and conflict resolution promote sustainable resource use (86) and the short- versus long-term trade-offs of monetary incentives for conservation (214, 215). Such causal inference methods present new opportunities to evaluate outcomes of commons management.

Whereas natural and quasi-experiments leverage observational data, RCTs manipulate information, incentives, or rules to draw inferences about their effect on resource and human well-being outcomes. For example, the random assignment of payments to forest-owning households in Uganda reduced forest cover loss over a short-term (2-year) period (216). Random assignment of a treatment addresses many issues with identifying causal impacts of governance treatments.

Individual RCTs are often unable to address vast differences in geography, culture, and institutions that can alter the effect of an intervention on resource or human well-being (217, 218). To address this concern with external validity, coordinated experiments randomly assign interventions across several different contexts (42). For example, research that examines the impact of

community monitoring on resource outcomes generated experimental data on forests in Liberia (139), Peru (9), and Uganda (171), as well as water resources in Brazil (219), Costa Rica (220), and China (221). This effort provides useful cross-context evidence that externally initiated community monitoring improved sustainable use of forests and water resources while also increasing reported satisfaction of resource users (9). This methodological advance builds on the communities of practice that generate similar case study data across contexts, and it extends such scientific partnerships to enhance experimental findings.

3. CHANGING THEORETICAL, SUBSTANTIVE, AND METHODS TRAJECTORIES

Important shifts in theoretical, substantive, and methods orientation are identifiable across three periods of scholarly work on the commons: before 2000, during 2000–2010, and after 2010. A review of these shifts prepares the grounds for a discussion of some of the critical areas of future research for commons scholarship as the field seeks to retain its relevance during rapidly changing contemporary societal, environmental, and research contexts.

3.1. Three Periods of Commons Research Between 1980 and 2020

In its early phase, scholarship on the commons sought to define and address key questions related to collective action dilemmas (52). This period (prior to 2000) emphasized theoretical elaboration and the accumulation of empirical evidence through description and analysis of many cases of commons governance. Commons research focused primarily on resource commons but also used mathematical modeling to derive predictions for individual behaviors in commons dilemmas and tested these predictions in laboratory experiments (207, 222).

During the first decade of the twenty-first century, the emphasis shifted to theoretical refinement of established insights and the development of larger-scale datasets for empirical tests of theoretical generalizations (28, 170, 223). While some of the analysis relied on quantitative datasets collected de novo, other quantitative work, such as through meta-analyses and qualitative comparative analysis, relied on information derived from large numbers of prior case studies. Commons scholars also began to examine how controlled experiments in field settings might lead to different outcomes compared with similar experiments conducted in the laboratory (175, 224). Their work led to a focus on how different sets of institutions, different types of agents (users and decision makers), and interactions among agents and institutional rules generate unexpected outcomes across social-ecological contexts (208).

During this second period, commons scholars, following a coupled human and natural systems framework, also began to emphasize the need for new analytic methods to identify and quantify spillovers and feedback in coupled systems (225). As a result, commons researchers pioneered the use of agent-based modeling in researching complexity and emergent outcomes in complex systems (226, 227). This work allowed explicit incorporation of models of learning, agent heterogeneity, feedback, network relationships, and nonlinearity to assess how distributed interactions among rule-following agents produced macrolevel phenomena that were difficult to pinpoint using the rational-agent models of game theory and mathematical economics (228). At the same time, the explosion of remote-sensing-based data products opened new possibilities of situating resource commons such as forests and grazing areas in the context of larger-scale landscape dynamics.

In the most recent period (after 2010), commons researchers have added new methods to their analytical toolkit. In particular, research has focused on refining empirical methods for examining causal relationships and testing and validating causal predictions (75, 229–233). These approaches have generated reliable empirical evidence for theoretical arguments advanced in earlier commons

research. The field has also seen a significant growth in new substantive areas of analysis and focus, for example, on commoning (see below).

Commoning: shared, collaborative, situated social practices through which groups of people with joint goals create the commons

3.2. New Societal Contexts and Future Directions

Research on the commons has matured to advance knowledge about collective action, sustainability, and human–environment interactions and provides fundamental lessons for social-institutional and social-technological systems research (234). One measure of the accomplishments of the field is that it is no longer an anomaly to expect that small, dispersed communities manage natural resource systems sustainably and equitably. Instead of being instruments of resource degradation, Indigenous peoples and local communities have emerged as agents and partners for sustainability.

A continued emphasis on empirical elaboration is important for the field of the commons as a means to influence ongoing policy interest in common-pool resources. At the same time, commons scholarship can respond to novel, emerging challenges through innovations in three areas of research that engage urgent theoretical, substantive, and methodological challenges. Theoretically, insistent attention to issues of power and equity continues to be of enormous importance. Substantively, exciting work on the novel concept of commoning, which refers to shared, collaborative, and situated social practices through which groups of people with joint goals create the commons (235), possesses the potential to bring together different streams of commons scholarship. Finally, methodologically, the availability of novel data and techniques for analyzing large datasets presents new opportunities for commons research and more effective commons governance.

3.2.1. Power, equity, and justice in the commons. Commons scholarship has identified polycentric governance, collective action, and commons governance as arenas where deeper insights would improve social-ecological outcomes (46, 236). Scholarship on the commons has begun to engage with the critical role of power in shaping institutional structures and outcomes (237). Analyzing how communities become responsible for managing forest resources, for example, reveals power asymmetries between the state and local groups and can create tensions related to community well-being and well-doing activities that promote societal benefits (238, 239). Similarly, the structuring role of values in rules and governance arrangements has begun to receive more emphasis than it did in the past (240, 241). Power, values, equity, and justice are also receiving deservedly greater attention from scholars of sustainability and commons. But much remains to be done.

In particular, understanding how different outcomes such as carbon sequestration, biodiversity conservation, and livelihoods are related to equity and justice, and the factors that account for patterns of relationships among these outcomes, is critical for future work (242–244). Global commodification of natural resources has meant that analyses of individual commons arrangements must be situated in the larger social and environmental contexts (245). The themes of power, equity, and justice make future analyses of the commons both more complex and more exciting, with new work needed to bring the drivers of these outcomes into sharper focus.

3.2.2. Commoning: application of insights from commons research to critical societal challenges. The idea of the commons signifies a set of social and institutional approaches to resource management that stands in contrast to both markets and states. A new body of research on commoning and the practices through which commons emerge has begun to extend our understanding of commons as an alternative to markets and states to previously unsuspected contexts such as urbanization, renewable energy, climate adaptation, waste management, and the workplace, among others. This work examines how groups of citizens and members of communities are redefining

social interactions and political relationships toward solidary living for realizing jointly defined purposes (246).

The rapidly growing literature on commoning charts a different path from the literature that aims to identify conditions that facilitate collective action and positive social-ecological outcomes. Rather, it treats commoning as a means to redefine social and political relationships and social-environmental engagements. With a focus on practice, contingency, and community, those involved in commoning see themselves engaged in the creation of collective ways of surviving to counter different forms of capitalism. They view their challenge as the need to "build a radically different system while living within the constraints of an incumbent system that aggressively resists transformational change. . . [and] not just articulating attractive alternatives but identifying credible strategies for actualizing them" (247, p. 1). Processes related to commoning are visible across diverse contexts: buying clubs, stakeholder trusts sponsored by governments, open-source programming, peer production and design networks, artisan guilds, and labor-sharing arrangements (248, 249). Commoning is a novel underpinning for the extension of commons ideals and principles to new social institutional domains (247, 248, 250). It is a reaction to the volatility and unpredictability of contemporary social-institutional and social-ecological processes, to the polarization and concentration of wealth and power, and most directly to the diverse forms of enclosure and commodification that capitalism and globalization have come to embody (249, 251).

3.2.3. Big data, new methods. Technological transformations are generating novel datasets and methods with which to study the commons. Advances in the amount and precision of imagery from remote sensors provide new information on social-ecological systems, such as changes in common-pool resources, infrastructure, and economic livelihoods, as well as inequality (252, 253). In addition, digital records of human behavior, such as how and when individuals contribute to knowledge commons like iNaturalist (254), provide greater information about what individuals and groups do. Most human behaviors, as well as data on institutions, practices, rights, and responsibilities, remain largely illegible, despite data advances. Careful fieldwork, in the form of observation, interviews, or survey research, remains necessary to assess when and where certain institutions occur. However, new advances in tools and technologies for fieldwork promise to expand the scale of commons research, including continued refinement of voice-to-text software, the combination of machine learning and artificial intelligence, and new survey research methods to improve questionnaires and data quality (255, 256).

Combining novel or previously acquired data with advances in causal inference (257–260), machine learning (261), natural language processing (262), and other forms of computational analysis will expand the scope of commons scholarship. While these advances will enable greater capacity for pattern recognition in the commons, it is through the combination of theory and analysis that commons scholars will generate novel insights about the relationship between communities and environmental resources (263). Thus, testing, iterating, and refining propositions that guide scholarship on the commons will be subject to new data and methods, but so too will the opportunities to reflect on the role of the commons in an era of big data and artificial intelligence.

Large datasets, their infrastructure, and machine learning approaches represent an emerging domain for commons scholarship. Such large datasets, sometimes termed big data (264, 265), provide often automated digital information on changing social and economic relationships, land cover, communication habits, and numerous other activities. Representation of such minute social exchanges via data has been termed datafication (266). A variety of statistical and machine learning algorithms extract useable information from datafied actions (267). Careful scholarship that addresses the common creation, storage, ownership, and analysis of data presents unique opportunities for new commons scholarship (268).

4. CONCLUSION

Research on the commons has highlighted how different institutional rules and arrangements can support successful collective action to sustain renewable resource systems. Future progress for the field hinges on its members responding to challenges and opportunities characteristic of the Anthropocene to address persistent gaps in current and past research in the field.

Unprecedented threats to human societies and natural systems are evident both globally and locally in the form of climate change, ecosystem erosion, social polarization, and striking injustices and inequalities. These threats emerge against a background of accelerating global change. Such global change is evident in the organization and dynamics of social relationships, in institutional evolution, in technological innovations, in ecological systems, and in the continuing commodification of natural and human lifeworlds. One consequence of these shifts is greater unpredictability of social interactions. Another evident result is the extraordinary growth in inequality, in the polarization of politics, and in the concentration of wealth and power.

Integrating different streams of commons scholarship, particularly of work that focuses on the conditions that lead to improved governance of resource commons with research on commoning, has the potential to highlight the dynamic practices through which societal transitions toward sustainability may bear fruit. Indeed, the promise of the commons has always been to highlight different social relations and models of existence. Predating commons scholarship, communities grounded in solidary relationships among members were a source of inspiration to foundational thinkers in the social sciences as the nineteenth century gave way to the twentieth (269). In the first quarter of the twenty-first century, commons and community are no less a source of hope and possibility. The commons provide a meaningful alternative for social existence and draw attention away from polarized narratives around the accelerating biophysical threats that characterize contemporary politics. This hope is a central element of research on commoning. It is anchored in findings that self-organized communities and their members can cooperate to provide an alternative to coercive, centralized, and hierarchical state-based social organization and profit-driven, individualized, exchange-based organization offered by markets (270–274).

Potent as the contributions of commons scholars have been, the field came into being, despite its enormous potential, with little fanfare. So it continued for decades. The arrival of fanfare came most notably as a celebration of Ostrom's work on the commons through the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel. Ostrom's Prize is a matter of celebration for all commons researchers. We suggest that the most appealing celebration of this success would be for commons scholars to grasp and elaborate the possibilities of the commons and commoning for the current moment and for the future. Doing so requires more focused, more inclusive, and more integrative scholarship that grapples with threats from both markets and states to democratic participation, reciprocity-based exchanges, and the fundamental dignity and equality of human relationships. It requires imagining and elaborating relationships for a social order in which a select few do not monopolize the vast majority of global resources. Most of all, it requires engagement and partnerships that focus on how to achieve and secure such engagement, reciprocity, and equity—the overriding concern of scholarship on commoning. Such an outcome will truly be uncommon. It will also be the most rewarding of all for researchers and stakeholders interested in the commons.

SUMMARY POINTS

1. Research on the commons, focusing on small-scale resource systems, is one of the most successful research programs in the social and environmental sciences.

2. This research has substantially advanced our understanding of the conditions under which commons are successful in improving livelihoods, equitable benefit allocation, carbon sequestration, and biodiversity conservation.
3. The success of research on the commons is visible in the multiple ways it has influenced resource governance and policies.
4. Commons research continues to grow, with incorporation of novel analytical methods and new data, an emphasis on causal inference, and application of insights to new social domains.
5. An exciting development for commons research is attention to commoning, the shared practices that groups of individuals pursue with the goal of advancing and enhancing solidaristic interactions and existence.
6. Collaborative actions to achieve shared goals are important as a means to invigorate research on the commons and as a source of hope across diverse social contexts.

FUTURE ISSUES

1. It is important to identify how different social, institutional, and contextual factors are differentially associated with the distinctive outcomes of livelihoods, equity, ecosystem services, carbon, and biodiversity.
2. Patterns of outcomes in multifunctional resource commons such as forests, pastures, fisheries, and wildlife and drivers of observed patterns are critical to understand and explain.
3. Novel areas of application for insights from research on the commons continue to be important and are of urgent relevance to address persistent societal challenges of polarization, resource degradation, and commodification of social relations.
4. Developing strategies to integrate research on factors that explain successful governance of commons with research on collaborative practices of producing new commons in urban, organizational, digital, climate change, and other contexts has substantial potential to invigorate the study of commons.

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