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Introducing Critical Physical Geography

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Critical Physical Geography (CPG) is an emerging body of work that brings together social and natural science in the service of eco-social transformation, combining attention to power relations and their material impacts with deep knowledge of particular biophysical systems (Lave et al. 2014). By studying material landscapes, social dynamics, and knowledge politics together, CPG answers the periodic calls for integrating geographic research (e.g. Thornes 1981; Goudie 1986; Massey 1999; Clifford 2002; Harrison et al. 2004, 2006, 2008 special issue of *Geoforum;* Bracken and Oughton's 2009a special issue of *Area*). This mission is particularly timely given the explosion of interest in 'the Anthropocene' (Fig. 1.1) and the widespread understanding that the material world is now shaped by deeply intermingled social and biophysical processes. If the biophysical world that surrounds us is now an eco-social hybrid, our research must be, too.

Yet CPG differs in significant ways from other calls for integration in light of the Anthropocene, challenging a dominant discourse that reduces eco-social relations to the unidirectional influence of humans on the environment

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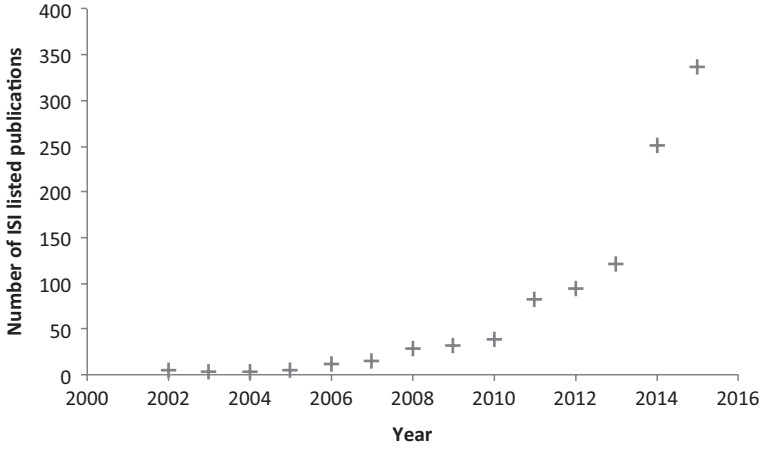

Fig. 1.1 ISI listed papers using the term 'Anthropocene'. No reference was made in the ISI to the term before 2002

and often precludes a deeper understanding of complex power relations that shape and are shaped by the biophysical world. The current conversation leaves a number of fundamental issues at the margins, including those actions that the Anthropocene is being used to legitimate, the presumptions that underpin environmental science and decision-making (e.g. a preoccupation with GDP as a goal), and the diverse suite of eco-social relations that comprise the Anthropocene. Methodologically, research on the Anthropocene has tended toward global-scale modeling and highly simplified understandings of human actions, failing to consider the material realities of day-to-day life that might give rise to very different definitions of what is important in the Anthropocene. Aspiring to a richer and more open consideration of the Anthropocene, CPG not only rethinks and breaks down the divides between conventional disciplines but also engages with fundamental questions about the conditions within which we find ourselves as a society and the role of scientific inquiry in shaping those conditions.

In this Handbook, we advocate and demonstrate careful integrative work that addresses crucial geoscientific questions while taking seriously the power relations, economic systems, and socio-cultural and philosophical presumptions upon which modern society has been built. This body of work showcases what Castree (2014, p. 244) calls 'engaged analysis', where researchers 'get their hands dirty in the places … scientists operate' while simultaneously 'questioning scientific representations of the world' and recognizing that scientific knowledge profoundly affects the systems it purports to know. We term this emerging field 'Critical Physical Geography', pointing to the integration of insights,

methods, and theories from both critical Human Geography and Physical Geography.

While CPG includes a wide range of environmental topics, research methods, and epistemological commitments, it is centered on three core intellectual tenets. First, most landscapes are now deeply shaped by human actions and structural inequalities around race, gender, and class. These power relations are not social drivers, external to nature and shaping it from the outside. Rather, structural power relations incorporate and draw on the materiality of nature, creating inextricably eco-social systems. Thus, it no longer makes sense (if it ever did) to concentrate natural science research on pristine systems or to separate research on the environment into the natural sciences and the social sciences (Urban, this volume). Second, the same power relations that shape the landscapes we study also shape who studies them and how we study them. Both natural and social science are inextricably imbricated in social, cultural, and political-economic relations that affect the questions we ask (or ignore), the way we conduct our research, and even our findings (King and Tadaki, this volume). Finally, the knowledge we produce has deep impacts on the people and landscapes we study. The myth of the ivory tower is just that: a myth. Our research has unavoidably political consequences; our choice is thus not between being political or apolitical but among different possible political commitments (Law, this volume).

Taking these three core tenets seriously requires us to ask different questions or to add layers to the questions we already ask. For example, while a soil scientist might start and end their study of lead concentrations in urban soils in Oakland, California, with measurements of soil chemistry and spatial analysis, a critical physical geographer of soils, such as Nathan McClintock (2015), would add additional layers of inquiry (Table 1.1).

Table 1.1 Questions raised by a CPG approach to soil science

• What are the concentrations of Pb in soils across Oakland, CA?
• How do political-economic factors, past and present, shape the uneven spatial distribution of Pb?
• What impacts do they have on human health and well-being?
• How are studies of urban soils shaped by particular intellectual commitments of soil scientists (e.g. soil classification systems with little capacity to engage the range of human impacts)?
• How do soil scientists' aversion to engaging issues of social and environmental justice reinforce existing inequalities in Oakland?
• How is past and current research on soil contamination being taken up in the political debate, and how does that research thus in turn shape Oakland's landscape?

Table 1.2 Questions raised by a CPG approach to desertification

• What arguments are mustered in support of the desertification hypothesis in francophone North Africa, and how have those arguments persisted or changed over time?
• What political-economic interests are at stake in these debates (e.g. colonial and state attempts to control resources and nomadic populations)?
• How do archival sources, including travellers' accounts, support or disprove desertification in North Africa?
• What physical evidence is there for or against desertification from pollen analysis, climate data, and so on?
• How have these historical and biophysical data been shaped by social, cultural, and political-economic priorities?
• What are the material impacts of anti-desertification environmental policies on the people and landscapes of francophone North Africa?

Similarly, while a sociologist might begin and end a study of desertification with analysis of the rhetoric used in environmental policy debates, a critical physical geographer, such as Diana Davis (2007), would move from discourse into a range of material concerns (Table 1.2).

Tables 1.1 and 1.2 are just two examples. We could chart a similarly expanded set of questions for any of the chapters in this Handbook and for the existing body of CPG research (e.g. Wilcock et. al. 2013; Engel-Di Mauro 2014; Lave and Lutz 2014; Barron et al. 2015; Doyle et al. 2015; Hatvany et al. 2015; Sayre 2015; Van Dyke 2015; Blue and Brierley 2016; Cullum et al. 2016; Penny et al. 2016; Simon 2016; Ashmore and Dodson 2017; Holifield and Day 2017; Lane 2017; Laris et al. 2017; Sarmiento et al. 2017; Zimmerer et al. 2017). The point is that CPG *allows us to investigate material landscapes, social dynamics, and knowledge politics together, as they co-constitute each other*. CPG is thus an intellectually and politically robust response to the implications of 'the Anthropocene'.

We hope that the examples above begin to shed light on the name 'CPG'. For physical geographers, we argue, a more Critical Physical Geography means paying attention to: (1) how knowledge is constructed in Physical Geography, through the myriad ways in which we frame what it is we wish to research and how we actually go about researching it and (2) the historical origins of the particular ways we have come to conceptualize the subject of physical geographical enquiry (see Sherman 1996). We use the word 'Critical' not to claim that physical geographers are inherently uncritical but to argue that Physical Geography might benefit from a parallel version of the transition Human Geography went through in the 1970s, highlighting both a more reflexive attention to knowledge production and a consideration of the social inequalities and power relations that are implicitly bound up with what we study and

which may be invoked inadvertently when such relations are overlooked. Similarly, our insertion of the word 'Physical' into Critical Geography is an argument that critical human geographers need to engage far more deeply with natural science. The social and environmental injustices on which critical human geographers focus are profoundly material, and we cannot understand their co-constitutive relations without studying biophysical and social processes together.

Barriers to Interdisciplinary[1] Research

Is interdisciplinary research actually a good idea in practice? Why would we go through the extra effort needed to conduct integrative research rather than staying within the comforting confines of a particular field? 'Interdisciplinarity' now seems to be considered an obvious good in much of the academic world. There have been dozens of articles and books advocating integrative research (e.g. Wear 1999; Ramadier 2004; Bracken and Oughton 2009b; Hall et al. 2012; Barry and Born 2013), but the continued advocacy of the need to be interdisciplinary suggests that response remains slow.

It is easy to hypothesize why calls for integrated geographical research might go unheeded, as there are formidable barriers to such work. Sometimes the barriers are physical: in many European universities, physical and human geographers are increasingly based in different administrative units and sometimes even housed in separate buildings, preventing the casual interactions and intellectual familiarity on which collaborations are often built. For other disciplines this physical separation is even more pronounced: Anthropology and Chemistry rarely share a building, much less a department.

There are also logistical barriers. It has until recently been quite difficult to get funding for integrative research, with a tendency for such projects to be supported through programs directed to applied, pre-defined questions rather than more open-ended research. In many countries, there are separate grant agencies for natural science and social science, making it impossible to fund integrated research. Even when the same agency funds a wide range of research, finding reviewers qualified to review interdisciplinary proposals can be challenging. Similarly, the vast majority of journals publish either natural or social science but not both; journals that publish across the divide struggle, like funding agencies, to find qualified reviewers. There is some hope for substantive change on this front, however, as the rise of the Anthropocene concept and the increasing insistence that research demonstrate practical impact have catalyzed integrative funding calls and journals.

Another barrier is a lack of cross-training that renders even basic research methods unfamiliar across the physical-social divide. Most natural science programs do not require cross-training in the social sciences and vice versa. While both Physical and Human Geography courses used to be a staple of graduate programs in Geography, many departments have reduced or even eliminated these requirements, diminishing our ability to understand the importance of our colleagues' research questions and the strengths and weaknesses of their methods. This mutual ignorance inhibits collaboration, as it prevents us from evaluating the rigor and understanding the intellectual value of our colleagues' research, surely both prerequisites for working together.

Mutual disrespect is also a formidable barrier to integrated research. Spurred in part by the lack of cross-training mentioned above, natural scientists and social scientists are sometimes quietly dismissive of each others' approaches, in other cases openly hostile. For example, one of us received an accidentally forwarded mass email to river scientists praising her work that began, 'I know social scientists are navel-gazing idiots, but this woman has something to say that you actually want to hear!' Similar disrespect flows from those social scientists who view natural scientists as 'naïve positivists'. This mutual disregard is a very serious obstacle in the way of interdisciplinary collaboration. It is perhaps most commonly seen when the word 'jargon' is assigned to a particular person or approach. Labeling someone's work 'jargon' is as much an opportunity missed to learn something new as it is a failure to agree to a common terminology.

A final barrier is the potential career risk from pursuing an unconventional research program (Lane 2017). In many academic fields, the boundaries of acceptable inquiry are far more narrowly drawn than in Geography. Entrenched power structures protect disciplinary norms as to what constitutes appropriate publication outlets, research questions, and even course topics. Within such fields, taking up an integrative research program is highly risky, particularly for graduate students and those without stable, tenured employment. Even within Geography, CPG approaches pose some risk. Physical geographers have put considerable effort into establishing their field as a serious natural science (Thrift 2002); embracing social science, a less authoritative form of knowledge, risks loss of perceived status. Critical human geographers who embrace natural science risk ejection from their field, which defines itself in opposition to realist research approaches. One impetus for the development of CPG as a field is to provide institutional shelter from at least some of these risks. Ironically, doing so will need to invoke some of the same processes of boundary creation and maintenance that make CPG research risky in the first place.

Doing CPG Research: Structure and Methods

The barriers we have just outlined are substantial, but they are not impassable. The growing body of CPG research demonstrates the feasibility and intellectual strength of integrative research on the environment. What enables CPG to transcend the obstacles just described?

One aspect is simply the flipside of barriers described above: mutual respect (for interdisciplinary teams) and sufficient cross-training either to carry out a project solo or to function smoothly as a team. Equally important is a set of research questions that *requires* both biophysical and social analysis to answer. Without integrated questions, it is very easy to slip into a multi-disciplinary framework in which results from different parts of a study are simply juxtaposed at the end or in which ties between the different parts disintegrate altogether rather than informing each other in any way. This points to another central characteristic of CPG work: iterative analysis, in which researchers work back and forth between their biophysical and social findings, modifying their research plans in one area in response to new data or questions in another. In this sense, CPG reflects a call for science to return to being more scientific, through the ways in which the empirical (in the broadest sense) can be allowed to 'speak back', to sow seeds of doubt about what it is we think we know and slowly engender new questions about the world around us (Stengers 2013). Finally, collaborative writing up and presentation of results deepen integration as researchers hone their findings. The chapters in this Handbook present many variations on these key qualities of successful CPG research.

While there is clearly a shared structure, integrated and iterative, to research that sails under the CPG flag, there is no standard suite of research methods. Because CPG researchers address contingent problems across a broad range of environmental topics, they have to be able to choose methods best suited to the problem at hand. But while CPG cannot be delimited by a pre-defined methodological toolkit, it can be characterized by an emphatically mixed-methods approach. Figure 1.2 presents a heuristic for thinking about CPG research methodology. There are two distinctions at work in this figure: natural versus social science and quantitative versus qualitative research; it is important not to conflate them. While it is easy to assume that there is a one-to-one match between natural science and quantitative methods and social science and qualitative methods, actual research practices are far more varied. There is a long and distinguished tradition of descriptive, qualitative natural science research, such as Charles Darwin's *The Origin of Species*, which continues today as an important complement to quantitative research in practices of classification, analysis of aerial photographs, and so on. Similarly, there is a

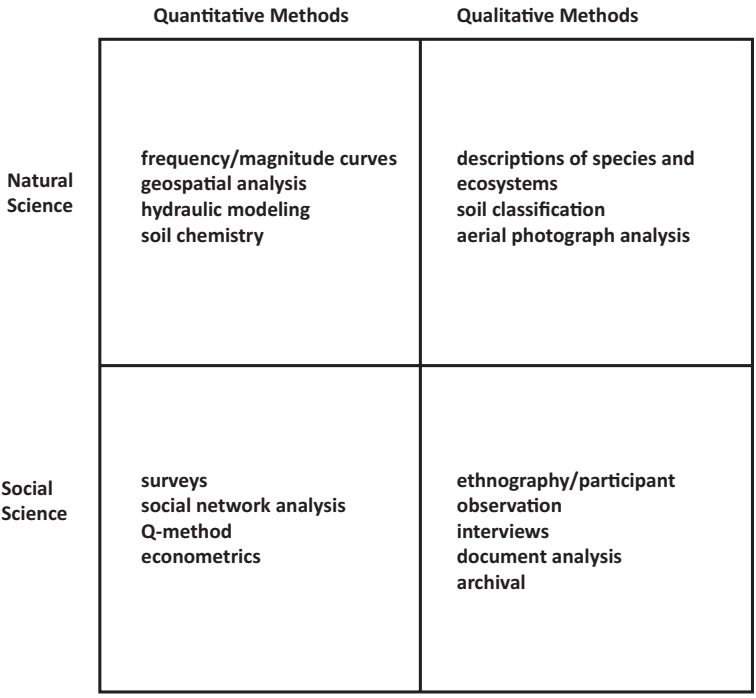

Fig. 1.2 Methods four-square

long and distinguished tradition of quantitative research across the social sciences in surveys and econometric approaches, among many others. What distinguishes CPG research methodologically is thus not use of a particular suite of methods but a reach across traditional ideas of what are admissible methods, whether in the natural or social sciences, and often a reach across at least three of the four squares in Fig. 1.2 (e.g. see Fig. 1.3). This vastly increases the explanatory power of CPG research by allowing triangulation among many different data sources and forms of analysis. It is worth noting that while triangulation may increase explanatory power, a mixed-methods approach can also yield contradictory data; such contradictions are important results themselves, particularly given CPG's explicit recognition that research findings are inextricably imbricated in social, cultural, and political-economic relations.

Epistemology

As with topics and methodological toolkits, there is no single epistemological position that defines CPG research. Figure 1.4 lays out the range of epistemological positions and the ways in which scholars along that spectrum adjudicate

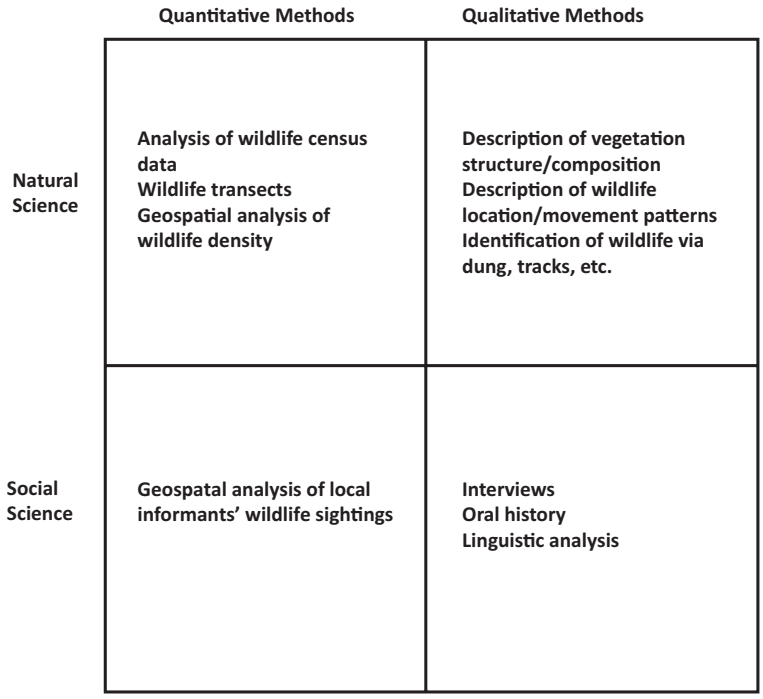

Fig. 1.3 Example of CPG methods: circulating wildlife (see Goldman, this volume)

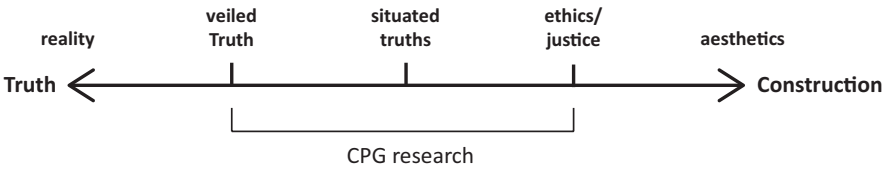

Fig. 1.4 The epistemological spectrum

among rival knowledge claims. At the far left end is capital 'T' Truth: science as the mirror of nature. At this end of the spectrum, the core epistemological assumption is that scientists have unmediated, entirely objective, and neutral access to the world. A knowledge claim is either correct or incorrect, and the test of that is entirely empirical. Moving right, we come to scholars who still argue for capital 'T' Truth but who argue that that Truth is veiled or obscured by social relations which shape the questions we ask and our understanding of the world around us. This is the classical critical realist position (e.g. Bhaskar 1975, 1979). Knowledge claims are still adjudicated with reference to material reality but with the assumption that obvious commonsense explanations are themselves objects of study, not arbiters of correctness.

The next position to the right claims no single reality. Instead of capital 'T' Truth, what we have are myriad little 't' truths that are situated in the lived experience of those who claim them. In this thinking, the lived reality of a heterosexual, white, homeless male is importantly different than the lived reality of a homosexual, dark-skinned, upper-class female. Neither of their truths is more correct; what is important is to ground truth claims in the power relations that shape them. Moving further to the right end of the spectrum, we reach strong constructivist positions in which there is still an external world, but it does not pre-exist humans: it is entirely co-produced and deeply shaped by our actions and intentions. Here a knowledge claim is not true or false but better or worse depending on its ethical implications; there are no longer correct or incorrect truth claims, even if they are only true for particular situated bodies, as in the center of the epistemological spectrum. Finally, at the far right end is capital 'C' Constructivism, which argues that there is no material reality at all, only a collectively or solipsistically constructed world to which we have no verifiable access. Here, a knowledge claim is superior to another only on aesthetic grounds.

Given CPG's core tenets, it is unsurprising that no CPG scholarship occupies either end of the spectrum. Instead, as the chapters in the body of this volume demonstrate, the field's core commitments to reflexively examining the production of knowledge, to careful analysis of the biophysical landscape, and to social and environmental justice direct scholars into the middle of the spectrum.

This may strike casual observers of natural science as strange. Would not, perhaps should not, natural science fall on the far left end of the epistemological spectrum? Put differently, can any work to the right of the arrowhead in Fig. 1.4 still be considered natural science? It is important to realize that the environmental sciences are a long way from the certainties of Newtonian physics. Most natural scientists acknowledge that what they study and how they study it have unavoidably social and political constraints in terms of priorities for research funding, institutional politics, intellectual property concerns, and a laundry list of other factors that shape scientists' day-to-day research practices. This messiness extends outward from academia into the field. Environmental scientists (natural and social) study complex, particular, deeply interconnected systems and their knowledge claims are correspondingly specific and partial. Fluvial geomorphologists, for example, are far better at explaining why particular systems behave the way they do than at generalizing their findings into rules that predict how other systems will behave (Phillips 2007). In many cases, even arriving at broadly accepted explanations can be difficult because the best available techniques are imprecise (as in

sediment measurement) or because scientists do not agree about which methods are best. One notorious example among river scientists is the Water Division I court case, in which opposing teams of researchers led by two of the most respected figures in twentieth-century geomorphology (Luna Leopold and Stan Schumm) were sent out by the judge to gather basic data on the same stretch of river and came back with different numbers (Gordon 1995). There is tremendous uncertainty in environmental science and broad acknowledgment that scientists have not reached the standard of replicability or falsification expected of lab-based sciences. Thus there is far more compatibility between the epistemological positions of critical environmental social and natural scientists than is immediately apparent, and environmental science can indeed be found to the right of capital 'T' Truth on the epistemological spectrum.

Relations to Cognate Fields

Lane et al. (this volume) trace in detail the genealogy of CPG, including its relationship to the history of and debates regarding integration in Geography. Here we briefly address the cognate fields to which CPG relates, including political ecology, science and technology studies (STS), and land use/land cover (LU/LC) change research. First, CPG has deep roots in political ecology, particularly the initial formulation of the field in the 1980s. In this early work, scholars such as Piers Blaikie, Susanna Hecht, and Michael Watts brought together agrarian political economy and climate science, ecology, and pedology in a powerful and intellectually robust critique of the core claims of development practice, such as Malthusian and Tragedy of the Commons arguments (Blaikie 1985; Blaikie and Brookfield 1987; Hecht 1985; Watts 1985). Political ecology has for the most part moved away from this integrative approach, however, and even in its early days few political ecologists conducted their own natural science research. Political ecologists today typically give little attention to natural science; the landscape has become a backdrop to political research rather than an important object of analysis (Walker 2005; but see Turner 2015). By contrast, CPG's first core tenet is the importance of employing natural and social science approaches together to better understand the co-produced landscapes we inhabit today (see Urban, this volume).

Second, STS research findings have deeply influenced CPG, grounding its focus in the inextricably social character of scientific knowledge production. CPG also draws on the STS emphasis on following the sites of knowledge

production as they are revealed rather than reducing research to the orchestration of pre-defined research plans. CPG's second core tenet (King and Tadaki, this volume) is a direct response to decades of STS research. Yet, the two fields differ importantly in their object of study. STS is a social science: natural science is a primary analytical object, not a central aspect of STS scholars' intellectual practice. CPG thus differs markedly from STS in its methodological emphasis on combining social and natural science research.

Third, LU/LC research has also been deeply influential on CPG research, in part by demonstrating the practical and intellectual value of integrative environmental research. However, the two fields have quite different methodological approaches. CPG embraces any research method appropriate for the topic at hand, while LU/LC's emphasis not just on explanation, but on prediction, leads to a strong preference for quantitative and spatial analysis and modeling. CPG's emphasis on the inextricably social character of scientific knowledge production is also quite different from the positivist commitments of most LU/LC research (but see Munroe et al. 2014, the authors of which have contributed to the development of CPG and are encouraging the LU/LC community to move in similar directions). LU/LC and CPG are thus distinct but complementary endeavors.

In summary, we wish to emphasize that while CPG is different from political ecology, STS, and LU/LC research, CPG research is both enriched by and very much in conversation with these fields. Our intention is to build a complementary body of research, not to replace them.

Structure of this Handbook

This Handbook is organized into three sections. The first section introduces CPG as a field. This introduction and a chapter on CPG's genealogy by the editors define the scope of CPG and explore its intellectual roots, situating it in relation to the history of integrative science in Geography. Three additional chapters then provide detailed treatments of each of the three core tenets of the field. Michael Urban explains the focus on 'crappy' rather than pristine landscapes. Leonora King and Marc Tadaki lay out the knowledge politics that shape not only the practice of science but also its findings. Section One ends with a chapter by Justine Law that explores the physical, social, and environmental justice impacts of scientific research and knowledge claims.

The second section of the Handbook makes the case for CPG research empirically by demonstrating the intellectual and political utility of CPG approaches for a range of environmental topics. This section is subdivided into five parts by

topic (in the print version only): landscapes, plants, animals, soil, and water. In the first of these sections, Chris Duvall, Bilal Butt, and Abigail Neely reveal the ambiguous and sometimes troubling history of 'savanna' landscapes, and of environmental classifications more broadly, particularly in the colonial context of Africa. This is followed by Diana Davis' critique of centuries of Eurocentric views of the semi-arid and arid landscapes of the Mediterranean region as ruined, deforested, and desertified. Gregory Simon then demonstrates how the actual causes of fire in the American West, including the political economy of US housing markets, are down-played and de-politicized. And finally, Daniel Knitter, Wiebke Bebermeier, Jan Krause, and Brigitta Schütt examine the challenges of conducting integrative research in landscape archaeology.

The next set of chapters showcases CPG research on plant species. Christine Biermann and Henri Grissino-Mayer explore the potential for integrative, reflexive, and engaged scholarship in dendroclimatology. David Robertson, Chris Larsen, and Steven Tulowiecki present the results of a meta-analysis of the scientific literature on forest land-use legacies, showing that while this cognate field shares some CPG characteristics, it could benefit from stronger engagement with CPG's core tenets. Christian Kull then calls for integrating CPG into the study of invasive species to create a critical invasion science that questions the terminology, spatial and biological scale, social implications, and privileging of scientific authority characteristic of invasion science today. Simon Dufour, Xavier Arnauld de Sartre, Monica Castro, Michel Grimaldi, Solen Le Clec'h, and Johan Oszwald close this sub-section by demonstrating the perils of overly simplified mapping of ecosystem services in the Brazilian Amazon.

Animals are the focus of the subsequent set of chapters which present a range of CPG approaches to mosquitos, wildlife, and livestock. Dawn Biehler, Joel Baker, John-Henry Pitas, Yinka Bode-George, Rebecca Jordan, Amanda E. Sorensen, Sacoby Wilson, Heather Goodman, Megan Saunders, Danielle Bodner, Paul T. Leisnham, and Shannon LaDeau analyze the intellectual and political transformation of their urban ecological study of mosquitos in a mostly black neighborhood in Baltimore, Maryland. Switching continents, but paying similar attention to the tensions between local and academic knowledge claims, Mara J. Goldman analyzes wildlife conservation in Tanzania. Nathan Sayre concludes this section by revealing the capitalist and racist assumptions that underpinned the foundational principles of range science in the US West.

The next set of chapters illustrate CPG approaches to soil, from erosion and acidification to nutrient cycling and fungi. Greta Marchesi examines populist programs in Columbia in the 1920s–1940s that worked to prevent soil

erosion and degradation in small-scale coffee farming through holistic attention to soil health. Elizabeth Barron then demonstrates how fungal conservation's poor fit with traditional conservation efforts opens up space for reconsidering how we value biodiversity more broadly. Salvatore Engel-DiMauro reveals the linked biophysical and social relations that lead to soil acidification in the Northern Drava basin in Hungary. Finally, Matthew Turner analyzes the ideological roots and political implications of nutrient budgets, a common tool for evaluating the sustainability of African agriculture.

The final group of chapters in Section Two focuses on water. Rebecca Lave, Martin Doyle, Morgan Robertson, and Jai Singh explore the biophysical impacts of market-based environmental management of streams in North Carolina. Javier Arce Nazario combines water chemistry and political ecology to argue that water-quality regulations intended to promote environmental justice can in fact undermine it, based on a case study of community water systems in Puerto Rico. Peter Ashmore concludes Section Two by demonstrating that it is only possible to understand the evolution of fluvial systems through a socio-geomorphological approach that attends both to the biophysical dynamics of rivers and to changing social priorities around flooding and conservation.

Section Three steps back from the case studies that make up the bulk of this volume to address the importance of pedagogy in enabling CPG research in two chapters with graduate students as lead authors. First Nicole Gillett, Eve Vogel, Noah Slovin, and Christine Hatch address the challenges and opportunities of CPG pedagogy during the course of a single research project: the RiverSmart Communities project. Then Lisa Kelley, Katherine Clifford, Emily Reisman, Devin Lea, Marissa Mattsler, Alex Liebman and Melanie Malone explain how to successfully navigate the challenges of conducting CPG research at different stages of graduate school, drawing on their diverse experiences in a wide range of graduate programs. The volume closes with the editors' critical reflections on the distinctiveness, risks, and benefits of CPG research.

Conclusion

As we argue explicitly in Chap. 2, and implicitly throughout this Handbook, a CPG approach enables researchers to take up the gauntlet thrown down by the Anthropocene concept: if the world we inhabit is widely understood to be shaped by social and biophysical processes, it is unreasonable to assume that

we as scholars can investigate either in isolation. Yet arguments for CPG both pre-date and stretch beyond debates over the Anthropocene and are inspired both philosophically by calls to undermine nature-culture dualisms and practically by the deeply co-constituted world we see at our field sites. Accepting that our biophysical systems are profoundly social (and vice versa) is not the ultimate objective of CPG but rather the starting point.

Why is Geography the field in which this critical, deeply integrated natural and social science research has emerged? One factor is clearly Geography's intellectual diversity. It is the original interdiscipline: many Geography departments span the full breadth of the university from natural science to social science to the humanities. Physical geographers regularly hear about social science research in colloquia and more casual conversation with colleagues and visitors, just as human geographers are routinely exposed to natural science research. Within many Geography departments, there is a broad methodological toolbox in use and a wide range of respected publication outlets, topical foci, and pedagogical approaches. This produces tremendous intellectual freedom: geographers can pursue a strikingly broad range of research questions while still remaining comfortably within disciplinary bounds. Another important factor is Geography's origin in place-based research. The long-standing tradition of 'muddy boots' in Geography has meant that generations of researchers delved deeply into the specificities of particular locations. This focused attention to a particular place makes eco-social relations more visible than they would be from the vantage point of the laboratory or the library, building on a tradition of research on human-environment relations that extends back to the early nineteenth century (Turner 2015). We also see within Geography a more normative take on the eco-social worlds we inhabit than in the other geosciences, a perspective which challenges the often technocratic nature of the integration imperative that has come to dominate calls for interdisciplinary problem-led science.

That said, even within Geography, CPG's deeply integrative approach can be challenging and even a serious risk, as it requires scholars to move beyond familiar intellectual comfort zones, to work across long-established disciplinary boundaries, and to seek relevance and legibility among academic communities with differing norms, expectations, and disciplinary practices (Lane 2017). It is certainly worth asking whether such research is indeed worth the effort. How does CPG advance our intellectual and political agendas?

Our advocacy of CPG is part of a broader agenda to attend more directly to the practical and political consequences of our research. A CPG approach recognizes that scholarship is unavoidably political and that the knowledge we produce has deep impacts on the people and landscapes we study. As such, we

are motivated by Feyerabend's (1978) observation that there is a need to challenge the socialization and enculturation that produce natural scientists who are unable (or at least only partly able) to think freely despite being exceptionally able, through their claims to knowledge authority, to place limits on what others can think. Put differently, we cannot escape David Harvey's (1972, p. 114) question: 'who is going to control whom, in whose interest is the controlling going to be, and if control is exercised in the interest of all, who is going to take it upon themselves to define the public interest?' These questions apply not only to how we do our work but also to the eco-social relations we study. Explanation that does not combine attention to power relations and their material impacts with deep knowledge of particular biophysical systems (Lave et al. 2014) will produce knowledge that is incomplete at best, and incorrect and unjust at worst.

Notes

1. Perhaps symptomatic of the increasing number of calls for interdisciplinary research, there are a number of different terms for such work, including interdisciplinary, transdisciplinary, post-normal, triple helix, and Mode II research (Gibbons et al. 1994). Here, our starting point is interdisciplinary research, but we argue for a particular kind of interdisciplinarity, one that provides a much stronger attention to the nature of the things we study and their capacity to make us redefine how we study them. Our use of the term integrative is designed to capture the disciplinarily interwoven character of CPG inquiry.

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