

Guiding principles for hydrologists conducting interdisciplinary research and fieldwork with participants

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To explore and address complex water-related issues, true collaborative, interdisciplinary research at the interface of hydrology and social science is necessary. Accordingly, hydrologists are increasingly working with social sciences and becoming involved in fieldwork with participants. With the overarching aim of facilitating collaboration and interdisciplinary water research, here we discuss important considerations and guiding principles for hydrologists, both those new to and those already familiar with interdisciplinary research, who are: (i) involved in fieldwork with participants; and (ii) working more collaboratively with social scientists. Drawing on first-hand experiences, this paper combines theory and experience from hydrologists and social scientists from their various interdisciplinary research projects to better understand key ethical, theoretical and practical considerations when working with participants. Complementary to this, we discuss the barriers and opportunities in collaborative interdisciplinary research. Facilitating these practices and understandings for hydrologists is essential to strengthen collaboration and to develop more holistic, successful research.

Keywords:

Interdisciplinary; Hydrology; Collaborative; Social sciences; Fieldwork;

1. Introduction

Water is at the core of many current and future global challenges, and therefore research on hydrological change is increasingly important in our dynamic world. Water is a topic with both nature and humans at its heart, evidenced by the intertwined connection between social and hydrological systems (Sivapalan et al., 2012; Montanari et al., 2013; McMillan et al., 2016; Krueger et al., 2016; Van Loon et al., 2016; Whiteford et al., 2016; Di Baldassarre et al., 2019). The global and local environmental challenges we face are fundamentally governance and behavioural challenges, and therefore there is an explicit need for interdisciplinary work. This is reflected in the agenda set by the International Association for Hydrological Sciences (IAHS) *Panta Rhei* scientific decade, which explicitly encourages interdisciplinary collaboration to research the interlinked changes in hydrology and society (Montanari et al., 2013; McMillan et al., 2016; Di Baldassarre et al., 2019). Whilst it is becoming more common for natural and social scientists to collaborate in addressing water-related issues (e.g. Blair & Buytaert, 2016; Evers et al., 2017; Wesselink et al., 2017), working in new ways and with different disciplines and their different philosophies, methodologies and vocabularies can prove challenging and time consuming (Krueger et al., 2016; Beaumont, 2020). There are claims that many “interdisciplinary” projects may not have a truly integrated approach (Martin, 2019) due to these tensions.

In this paper, we consider how collaborations and trust in each other’s knowledge are built, and in doing so, how hydrologists can engage with social science approaches and theories (Martin 2019), and social scientists themselves, to further research water-society interactions and find solutions to current and future water sustainability (Evers et al., 2017; Roobavannan et al., 2018). With more scientists becoming involved in interdisciplinary research, we aim to encourage and help guide hydrologists with our paper through two main goals. The first is for those who are new to interdisciplinary projects, to help guide hydrologists on what to expect from collaborations with social scientists when working with participants in the field (e.g. individuals, policy makers, community leaders, government representatives), and to introduce them to new terminology and methodology, necessary to help bridge the gap between the disciplines. The second is for those with more experience in interdisciplinary work, to help provide deeper insight into common social science practice to enable stronger collaborations with social scientists and to help identify when to seek further disciplinary expertise. As a result, we present in this paper important considerations for hydrologists, both those new to and those already familiar with interdisciplinary research, for: (i) fieldwork with participants (Section 2) and (ii) interdisciplinary collaborations with social scientists (Section 3). With an increasing number of hydrologists becoming involved in fieldwork with participants to study the dynamic connections between social and hydrological systems, facilitating these stronger interdisciplinary practices and understandings of the considerations for fieldwork is essential.

As a group of hydrologists and social scientists ourselves, many of us classifying ourselves as interdisciplinary scientists, working between the two disciplines, we seek to encourage more interdisciplinary work by helping hydrologists to prepare for navigating collaborative design and

application, some of which might not be routinely considered when taking a hydrology approach alone. We use our own experiences from various interdisciplinary research projects involving fieldwork with participants, combined with theory to help explain aspects such as ethical practice, power dynamics and researcher positionality, and to formulate recommendations, with the hope of guiding, encouraging and equipping hydrologists into future interdisciplinary fieldwork with participants. Overall, as a diverse group of researchers we have conducted several research projects in different countries and cultures across the globe (e.g. South Africa, India, Kenya, Tanzania, Australia, Italy, UK), using a variety of research methods with participants (e.g. questionnaires, workshops, interviews, focus groups, participant observations). We have learnt that the design of interdisciplinary research needs expert input from all sides to ensure that data collection and analysis is robust, appropriate and of high quality. For natural scientists, Martin (2019) recommends involving an experienced social scientist, or team of social scientists, from the outset to ensure the research is valuable and methodologically sound. Beaumont (2020) argues that an important component for interdisciplinary research is to improve the understanding of “the other” discipline (e.g. in this paper, improving the hydrologists’ understanding of the social sciences). Therefore, it is important for hydrologists to have access to varying ways to expand beyond their own discipline, and learn and understand the different backgrounds, methods and languages of other disciplines to maximise true interdisciplinary opportunities and interactions.

The research potentials of true partnership and collaboration are many. Successful interdisciplinary collaborative research between the social and natural sciences can bring different perspectives and methodologies to help reframe scientific problems (Phillipson et al., 2009; Lowe et al., 2013; Rusca & Di Baldassarre, 2019). Interdisciplinary collaboration is essential for better understanding of the interactions between water and society, developing further approaches to address current and future real-world environmental problems. For example, hydrologists and social scientists working together can develop more holistic datasets and results, which can facilitate more relevant and meaningful research for informing policy makers and communities (e.g. with locally relevant data and recommendations that take into account socio-cultural contexts). When working directly with other disciplines and looking collectively at the data generated by social science methods and hydrological methods, context can be set and discrepancies and conflicting data can help point to gaps in knowledge and understanding, which may lead to new research directions (Torrance, 2012). It is in fact these differences in perspective, experience and complexity that are required for understanding and addressing real-world challenges; however, these differences can also create challenges for collaborative working. Facilitating these exchanges and collaborations will ultimately improve interdisciplinary water research, resulting in a better understanding of the interactions between water and society.

2. Considerations when working with participants in the field

Drawing on the first-hand experiences of all co-authors of this paper, we have selected a number of key concepts and considerations from the social sciences that we believe hydrologists should

be aware of when planning and conducting fieldwork and research in interdisciplinary projects. These considerations include planning for research ethics (Section 2.1), power dynamics and positionality within fieldwork with participants (Section 2.2), communicating science in the field (Section 2.3) and post-fieldwork reflections (Section 2.4). These aspects might be unfamiliar to those with limited social science or interdisciplinary experience, and therefore are useful to consider when entering into interdisciplinary research. These considerations and recommendations also help to introduce hydrologists to terminology and methodology that might be new to them, helping to bridge the gap between the hydrologists and social scientists. We argue that awareness of these aspects can enable hydrologists to ask questions and fully contribute during all phases of interdisciplinary research: design, data collection, interpretation and dissemination.

2.1. Putting good ethical practice in place

2.1.1 Research ethics principles

Ethical principles should always underpin all research with participants; however, from our experiences, planning and conducting good ethical practice may be an unfamiliar process for a researcher with a natural science background and/or limited interdisciplinary research experience. Nevertheless, most funders now require an ethical review and approval must take place before any work with participants can happen. The purpose of ethical principles is to ensure the excellence and integrity of research (ALLEA, 2017), and to protect both research participants and researchers themselves. Concerning ethical research conduct, despite a diverse landscape of guidelines from governments, professional bodies, and practitioners, and differences in ethical review practices between countries, it is possible to identify some common guiding principles. These guiding principles include three foundations: (i) respect for individuals; (ii) acting in people's best interests; and (iii) being fair (Ansell & Blerk, 2005; Wellcome Trust, 2014).

In terms of "respect for individuals," researchers have a duty to ensure that people taking part in their research do this on a voluntary basis based on their informed consent. In particular, participants should be informed in plain language about the purpose of the research and how their input will be used, and they should know what to expect from the research process (European Commission, 2013). Only when they have received this information can they truly consent to taking part in the research, in writing or verbally. Written consent is generally considered best practice, where it is practical, but oral consent may be more appropriate if participants have low literacy. Questions of consent, harm and power are particularly relevant for qualitative methods that require extensive interactions between the researcher and the participants, such as in-depth interviews (Dowling, 2009). It should also be transparent to participants how they can withdraw from the research if they so wish. This information should be made clear to them during the consent process.

Complementary to (but not substituting for) individual informed consent, researchers need to consider gaining community-leader consent, which might be necessary in many research settings such as in indigenous communities. This may involve obtaining permission to conduct the research within the community, and maintaining good communications with the community

leader/group throughout, and aiming to deliver meaningful results back. For many of the co-authors, this community-leader consent was necessary for many of our various interdisciplinary research projects. For example, in an interdisciplinary research project investigating drought in a rural South African community (Rangecroft et al., 2018), researchers first obtained consent to research in the community from the Chief and his royal council, and then gained consent from all participating individuals involved in the group interviews and workshops during fieldwork. Furthermore, the process of gaining consent through engagement with community leaders also helped to address negotiations of power relations between the researchers and community (see Section 2.2.1).

“Acting in people’s best interests” refers to the principle that the research being undertaken will do no harm to either the participants or the researchers. Researchers should consider the impacts of their research on participants, their communities and their environment. One important aspect of this is the question of privacy of participants. Researchers need to carefully consider issues of confidentiality and anonymity before carrying out their research and discuss those with participants as part of their informed consent. Finally, “being fair” means that research should be fair in giving people an opportunity to take part, making sure that there is no systematic exclusion, such as of generally marginalised groups, and that the immediate benefits of participation should be distributed fairly. If there is any compensation to participants, for example in recognition of their time or expenses, this should be in an appropriate form and not to a level that could be considered coercive. However, we also note that there are reasons why compensation and incentive may not be appropriate, such as setting up expectations for any future research, or they are disallowed by some funders, so this is an issue that also needs careful consideration.

Whilst ethical concerns can often only appear to be at the top of the agenda during the process of applying for ethical approval, the practice of ethical principles should be ongoing in research projects, from the early design of the research through to its implementation and dissemination (Guillemin & Gillam, 2004; Wiles, 2012). This reflexivity brought about through the ethical review process can significantly enhance the research process, especially with regards to considering power dynamics and positionality during fieldwork (see Section 2.2).

2.1.2. Ethics in practice

More and more research is being conducted internationally and in partnership with low- and middle-income countries, which raises its own set of ethical issues. Recently, a new Global Code of Conduct for Research in Resource-Poor settings has been developed (TRUST, 2018), which takes forward the principles discussed above and expands on them to prepare researchers for the additional challenges that arise from international research. Furthermore, research ethics review procedures can be different in different countries and universities. For example, in the UK, research projects involving participants (e.g. workshops, interviews, surveys, etc.) need ethical approval. This means that a clear understanding of the intended approaches, interactions and outputs from the different disciplines and partners involved in the project is necessary, in order to

consider all potential ethical issues that might arise and how those can best be dealt with. Early collaboration with stakeholders can help to establish clear understandings of the intended approaches and interactions, necessary for ethical planning of the research.

Despite the importance of following good research ethical practice, in some countries or organizations, formal procedures for natural science fieldwork with participants are still under development (e.g. some Dutch and German institutes, at the time of writing). In most countries, research ethical procedures and committees are in place for medical and social science, but may not be for physical, environmental and earth sciences as these fields historically had limited interaction with people, and therefore less need to develop procedures for ethical approval. Without guidelines and procedures, and without knowledge of or direction to research ethical committees, more will be left to the ethical considerations and expertise of the researcher. If ethical procedures and committees do not exist, we would recommend following the procedures of the social science department project partner (who is likely to require it in any case, if no other review will take place) or to seek out another institution to conduct the ethical review.

Nevertheless, whilst there is the need for clear procedures, ‘ethical literacy’ requires more than ethical approval and compliance with procedures (Wiles, 2012). It is about having an understanding of the concepts - why and how they are used - to enable flexibility and applying common sense in situations that are not covered by generic rules. To illustrate, regarding consent procedures, during a research project in rural South Africa, we found that literacy in the researched community was low. As a result, at the start of every interview, information on the project and use of participant data was verbally given to participants in their native language before oral consent was sought from all participants and recorded on a voice recorder, as an alternative to written consent.

2.2 Power dynamics and positionality

Natural scientists, in contrast to anthropologists and social scientists, might not be trained to see embedded power asymmetries and cultural differences. Power dynamics refer to various power inequalities in the research process, between researcher and participant, and between participants. Power dynamics exist between the research participants themselves, such as gender, age or class, and should be considered and planned for in the research design (Section 2.2.1). Power relations between the researcher and research participants are inevitable, and efforts should be made to minimise these as much as possible. The “positionality” of the researcher refers to their own identity and background, including personal values and beliefs, gender, race and socio-economic background (positionality, see Section 2.2.2). This affects how they are perceived by participants, and hence the interpersonal dynamics in the research process, but also how the researcher approaches interpretation of the research context and data. Different researchers may be trained to see different power dynamics and differences, and thus working with multiple researchers, with different positionalities, is advantageous for addressing power dynamics and positionality.

2.2.1 Power dynamics

Where possible, power dynamics among research participants should be identified beforehand, such as through discussions with local partners. Power dynamics, if not attended to, can drastically affect the efficacy of data collection techniques, especially where they involve participatory techniques or group discussions. For example, in group discussions within communities, between communities and other stakeholders, or between different sets of stakeholders, power dynamics will vary and may affect the discussions (Cooke, 2001). Typically, those of lower status or less social power will feel inhibited from talking freely in front of those with higher social status or more power (Nelson & Wright, 1995). Power and status may relate to wealth, to gender or generation, and/or to other social groupings such as ethnicity, kinship, caste or occupation (e.g. Ge et al., 2011; Cairns et al., 2017). Generally, it is good practice to keep discussion with those of different status separate so that participants are not inhibited. For example, in Tanzania (Höllermann et al., 2020), focus groups were held with only female farmers to address power dynamics related to gender in this study region. However, whilst research design might involve female-only discussion groups to address gender issues and power relations, in practice this might not be possible in the field. Consideration of the location of discussions with participants is also essential as it can affect the dynamics between participants. Meetings should ideally be hosted in a neutral space for groups (e.g. a community hall), rather than a space affiliated with any specific person or group. For individual interviews, the place may be of the participants' choosing, e.g. their home, to help create a trustful atmosphere, although within the bounds of consideration of the researchers' comfort and safety also.

When designing data collection in communities, researchers should make an effort to establish who the marginalised or generally excluded people in that community are likely to be, and to seek out their perspective through appropriate means, such as separate participation (e.g. one-to-one interviews instead of focus groups) to ensure their voice is heard by the researcher (Cairns et al., 2017). However, it should also be noted that potentially empowering the marginalised may cause problems with existing power structures (Kothari, 2001). As a result, it is important to understand that this type of research comes with responsibilities towards the local communities, and might have unintended consequences. Without attention and sensitivity to power dynamics, data can become inadvertently skewed to represent and perpetuate the views and interests of the most powerful (e.g. Resurreccion et al., 2004), in ways that might not be readily obvious to researchers.

Regarding power relations between participants and researchers, research participants are often classified into elite participants, who are mostly described as policy makers, government employees or members of international organizations and funding agencies, and non-elite participants, associated with both "ordinary" citizens and vulnerable groups (Rose, 1997; Smith, 2006). Elite participants are often assumed to have more power than the researchers, in general terms and in the area addressed by the research, which can affect the research process as they may attempt to steer or influence it by limiting access to information, influencing the questions that are addressed or attempting to control the research outcomes (e.g. requesting veto powers on the draft

research work). They can also expect a more deferential dynamic in interviews. To reduce this power differential, researchers must carefully prepare for the interview. On the other hand, elite participants can also be important gatekeepers and facilitators of the research by enabling access to data and networks.

At the other extreme, more marginalised or vulnerable non-elite participants may feel at a power disadvantage during the research process. Here, it is important to elicit information in ways that interviewees feel free to express themselves and are free from “social desirability bias” (Williams & Heikes, 1993), i.e. a tendency of interviewees to filter information to impress or please the interviewer. Strategies to try to lessen the differential and encourage their open input might include matching them with an interviewer or facilitator who is more similar to them, finding a meeting place that is familiar and comfortable for them, paying attention to cultural norms (e.g. avoiding taboo topics and conforming to local customs on greetings and dress code) and language, and being attentive to the context and the dynamics at play during the interview.

Participatory research methods are a specific approach that can help address researcher-participant power asymmetries (Coombes et al., 2014; DeLyser & Sui, 2014). Participatory data collection is where the participants and researchers have “equal expertise.” For example, participants and researchers might work together to define questions and possible answers themselves. Participatory research approaches are based on the idea that research should actively involve participants in the research process, including the design of projects and activities relating to data collection (Durham Community Research Team, 2011). Ideally, participatory research involves participants as co-researchers in the design of the research, which gives the process more credibility and makes it as relevant as possible for the people concerned. Norström *et al.* (2020) highlight the importance of co-producing research among researchers, participants and practitioners when addressing sustainability challenges. However, this comes with challenges too as it can be a time-intensive process for both the researchers and participants, and there may be many complex relationships to manage (see e.g. Banks et al., 2013).

2.2.2 Positionality

Positionality is the lens through which a researcher (or anyone) sees, understands and interprets the world, based on their background and experiences (Rose, 1997; Dowling, 2005; Hesse-Biber, 2007; Palaganas et al., 2017). When hydrologists - or any researchers - conduct fieldwork involving participants, they interact with research participants who may differ from them on several axes, such as education, class, age or gender. Researchers need to understand these differences so that they can work to build trust with research participants (Sultana, 2007). Strategies can include for example paying attention to dress, informality of language, using locally appropriate greetings, and being aware of body language meanings. From our experience, we would recommend to take as much time as is practically possible to orient to local culture and to build rapport with participants, for example by sharing food, before collecting research data.

Researchers should also consider their own position within existing power relations (Section 2.2.1) and value systems, and how this may influence their research questions, methods and interpretation of data. This is integral to conducting ethical and non-exploitative research (Sultana, 2007). Relatedly, it is also important to be aware that the knowledge produced in the field by the researcher may not be objective, but rather may be partial and subject to their own positionality. Working with multiple researchers, with different positionalities, is advantageous for addressing these issues and arriving at more robust interpretations (Norström et al., 2020).

2.2.3 Importance of partnerships with local partners

Our collective experiences working in various locations worldwide have highlighted how essential our local partners and partner organizations have been through their insights into local issues, culture and language, and their knowledge of community gatekeepers (people who can facilitate access to research participants) and how best to approach them. For example, during a UK-based research project on flooding in England, the fieldwork was supported by Environment Agency colleagues who had worked with at-risk communities for a long time. They were able to share their useful insights to help shape fieldwork decisions, such as choosing the communities to work with and recommending the best way to get in touch with the participants. Before discussions with participants can be fully planned and facilitated by the researcher, the researcher must ensure that they know the participants' environment well enough to create questions which fit the participants' knowledge and setting. Researchers should consider the importance of pre-fieldwork training and debrief meetings in the field for two-way communication with local partners and fieldwork researchers, to learn more about the participants' environment, and to minimise misunderstandings (see Sections 2.2.2 and 2.3.1). This can be especially useful when working in the field where the researcher is having information translated into the language of the participants.

Recent research in South Africa (Rangecroft et al., 2018) would not have been possible without the working relationship and support of an academic from the local university as an on-the-ground local project partner. They were able to visit the study region village (before, during and after the project fieldwork), communicate with the chief and the village elders in the local language, and introduce researchers to local customs. The local partners were also able to identify what would be the most appropriate compensation for the community for their time and involvement in the research ("being fair" in ethical research, Section 2.1.1). Furthermore, a selection of postgraduate students from this local university were employed on the project as translators, workshop leaders and general local support, which was invaluable.

In another example in Australia, in addition to the discrete knowledge traditionally practiced by local partners, one of the Indigenous communities in the Northern Territory provided a great insight into how water resources govern the landscape of places and people and constitute their world (Christie, 2010; Bowaynu et al., 2018). Prior to the fieldwork, in an induction training delivered by a local Indigenous knowledge representative, both hydrologists and social scientists were introduced to cultural protocols ancestrally required in engaging with Indigenous water.

Researchers, local partners and non-Indigenous project participants were guided by traditional owners of the community and local Indigenous rangers to visit the Indigenous water sites in order to be known and welcomed by the community for fieldwork activities over a 3-year period.

However, as invaluable as these local partnerships are, not being geographically close for most of the research project can reduce communication mainly to emails, phone calls and video conferencing, which can lead to numerous misunderstandings, and dependence on good connections and infrastructure (e.g. a good signal for successful teleconferencing meetings). For hydrologists aiming to become involved in fieldwork with research participants, we recommend spending a generous amount of time to build good relationships with local partners. These might be local hydrological researchers, social scientists and/or institutes, who potentially have a good grasp of aspects of the positionalities and power dynamics at play as well as the local geographical setting. Allowing time for pre-fieldwork meetings with local partners can be extremely beneficial, and a successful way to build trust and a shared understanding of the research. We have found that it can also be important to engage local field assistants where possible to increase trust in the partnership, co-ownership and responsibility for how decisions and directions of the research are made.

2.3 Communication and interactions in the field

2.3.1 Communication barriers with participants

When interacting with participants, several communication barriers may exist, on various levels. These challenges may need to be considered throughout the research, and potential strategies drawn upon to overcome the barriers. Our experiences have shown that it is important to be aware of potential miscommunications and have a strategy in place to deal with these, even if they cannot be completely prevented. For example, when working in rural north South Africa collaboratively with international and local partners preparing for drought workshops (Rangecroft et al., 2018), we found it necessary to identify where our communication of information to participants might be challenging. Isolating important differences between our scientific vocabulary and the local dialect (e.g. drought, predictions) allowed us to identify the vocabulary that might not translate directly as intended with the participants. We facilitated discussions with our local research partners, who were also our translators, in a pre-fieldwork workshop training event to refine the key workshop messages and questions for planned communication. This consideration can be extremely important when working in regions where the core research team do not speak the local language/dialect. We found this to be a successful approach for overcoming this communication barrier and to help avoid miscommunication during field interactions with participants.

In a household survey on water security in Kwazulu-Natal, South Africa (Lebek et al., 2020), researchers tested whether the designed survey items were well understood by the participants in a 3-day pilot phase. With the help of the translators, they then refined the wording of survey items, improving their comprehensibility. In an example from India, where the research focused on how to develop participatory groundwater management with women from urban low-income areas, communication challenges during the project preparation phase arose not only from

scientific language and cultural barriers, but also from the personal ability of the researcher or the research team to explain a particular topic to outsiders. At the interaction phase with local participants, communication barriers were caused by the educational background of the participants and also by the assumptions they already had when they attended a meeting or workshop about water. For example, if the participants face severe water problems on a daily basis, their expectation on a project about water may be that the current situation will be improved in the short term because of the research project. This can lead to a situation, where, when the project finally starts, the participants already have certain expectations regarding the outcome of the project, which do not fit into the original project aims, or are not feasible.

When communicating science to participants, visual aids can be extremely useful in some situations for addressing communication and information barriers. Within the framework of an interdisciplinary research project in India, a cost-effective, transportable and reproducible physical groundwater model (known as a sand tank) was developed to provide visual insights into the structure of the subsurface and to elucidate important processes in it (Baldwin et al., 2012). A workshop with researchers and local partners about the groundwater model revealed that the visualization of processes otherwise hidden under the ground significantly improved the understanding of the participants. Furthermore, the possibility for the participants to be actively engaged with the model by filling in the ink or pumping water out of the well with the use of the syringe, or even to develop their own experiments, notably increased their motivation to learn about groundwater. Based on our experiences, we recommend that visuals should be chosen in collaboration with local partners, and/or participants, to make sure that the visuals can be interpreted well, thus avoiding cultural differences in visualization.

2.3.2 Communication of participants' local knowledge

Researchers who work with local participants in the field tend to generate local knowledge through their research. To overcome issues with research fatigue and lack of trust by research participants, researchers can be instrumental in making sure that the issues facing a marginalised group or community are communicated to actors with power, or to the general public to create awareness of the issues amongst a broader group. Disseminating this knowledge to powerful elites or policy makers, as long as it is with the explicit consent of the community, can help empower local communities (Krueger et al., 2016). However, when communicating local knowledge, researchers need to be very aware of power dynamics and their own positionality (Section 2.2). Communities and participants may have concerns about losing ownership of their knowledge, as well as about their anonymity, and these need to be addressed.

Across our various interdisciplinary water research projects, researchers have used a range of methods successfully to communicate local knowledge to policy makers. Research projects may include a final workshop to disseminate local knowledge, outcomes of the fieldwork and recommendations. Other approaches to communicate local knowledge include creating an open-source data platform (e.g. <http://riskprofilesundrr.org/riskprofiles/>), or participatory three-

dimensional mapping (Cadag & Gaillard, 2012) to help facilitate the community engagement process, which can lead to more robust methodologies for evaluating policy and decision making for water management. It is important to acknowledge that knowledge sharing can be two-way: data collection and/or communicating science. Several co-authors have used photography and film to communicate local knowledge beyond the participants. In this way, participants are able to become partners in the research, moving from objects of the study to actively participating subjects (IDEO.org, 2015). One research project engaged participants in videography projects or documentary filmmaking to visualise inequalities of water access and distribution, and uneven exposure to hydrological extremes (Rusca, 2018). For these forms of communication and outputs, video websites (e.g. YouTube, Vimeo) can host a range of community-developed videos.

2.4 Fieldwork reflections

2.4.1 Research diaries, observations and debriefs

When in the field, we suggest that researchers should ideally keep a field/research diary to reflect upon their experiences and impressions, even if those go beyond the research questions and data collection methods. We note that research diaries can be very informal, and can be a more personal log of how things are going in the field. Information, observations, thoughts and questions can be noted by the researcher whilst in the field, and developed afterwards, either alone or with other researchers and local partners. By reflecting on those impressions in the diary, information from other sources can be contextualised. This practice of keeping a research diary would also support our above call for acknowledging positionality (Section 2.2.2), since, for example, one could reflect on the perceived positionality during interactions with different people (e.g. collaborating researchers, observed humans, etc.).

More formal than a research diary, targeted observations can be conducted in the field to gain insight and collect contextualised data to help with the interpretation of other data. For example, when exploring a field site, transect walks or systematic walks along a defined path(s) across the study area, alone or together with locals, can provide insight into cause-and-effect relationships, and challenges of local people, local technology and practices in relation to features along the transect. Research in Tanzania involved observational transect walks across farmers' fields in different villages to facilitate the collection of data in context and provide insight from participants (Höllermann et al., 2020). In another research project, in rural South Africa during a survey on household water insecurity, the research team noted observations and later discussed these together with the translators. These notes and debriefs helped clarify misunderstandings and inconsistencies, for example where observations did not match responses by the interviewees. They also pointed to new research questions; for example, the researchers started paying close attention to the type of housing (brick houses or round huts) when they realised its importance for water security (Lebek et al., 2020).

From experience, we have also found that another good practice in the field when working with a research team is to have daily team debriefing sessions after interactions with participants

(e.g. interviews, workshops, etc.). This could be especially important in an interdisciplinary team or in a team composed of local and international partners. These debriefing sessions allow all researchers involved to reflect upon the interactions, observations and perceptions of the fieldwork, helping to deepen understanding and interpretations of data. For fieldwork in regions where the researchers are non-native speakers, these discussions between the researchers and the translators directly after any participant fieldwork are extremely valuable. They allow the researchers to understand how the fieldwork went, and what the overall messages and issues were. Without these debriefing sessions, it would be difficult for the researchers to have an idea of the main themes within the data collected whilst in the field, as they would not get this information until the transcripts have been translated (if participants have been involved in conversations and have been recorded), which can be many months after the fieldwork. Furthermore, these debriefing meetings also allow for reflection on the methodology, and can encourage positive tweaks to the field approach (e.g. terminology used, timing, order of questions, use of prompting questions) and can strengthen the shared vision among all researchers, including those conducting the direct interactions (e.g. translators / facilitators).

2.4.2 Validation

Data generated by social science methods can be validated by participant validation or “member checks,” where research participants are asked to respond to the accuracy of initial data, such as transcripts of interviews or interpretative claims made by first drafts of reports (Torrance, 2012). Bridging scientific findings and local knowledge and creating a collective view, such member checks can take place in the form of an interview, focus group discussion or workshop with key participants (Birt et al., 2016). Workshops can be used as a validation exercise and to go beyond validation and help continue to co-create information, where researchers can present data, interpretations and results to the participants for feedback. For example, the researcher can present their results and ask participants ⊕ i) what they might add? (ii) what is surprising and needs double checking? (iii) what they might conclude from these results, and (iv) how they can together make a conclusion. Working with participants in a final science communication workshop, the researcher can thus validate research results together with local participants and distil a common conclusion, which can then be communicated with policy makers (see Section 2.3.2). For example, during research on drought and flood disaster risk in Sub-Saharan Africa, a first set of national stakeholder workshops was organized, after which improvements were suggested by the participants. After a collaborative effort to collect more local data and adjust the existing method, which also helped to increase trust in the end product, a second series of dissemination workshops were held. This allowed for a participatory formulation of disaster risk reduction recommendations endorsed by the national governments (UNDRR & CIMA, 2019a; 2019b; 2019c). However, not all forms of analysis can be validated by research participants and communities, and it may not be appropriate at all times to attempt to elicit participant validation. This could occur, for example, where conflicting views need to be reported, to avoid suppression of minority views, or to protect the anonymity of some participants.

In interdisciplinary research, validation might mean investigating correspondences and discrepancies between the data generated by social science methods and the hydrological data. Discrepancies and conflicting data can point to gaps in knowledge and understanding, and may lead to new research questions and further data gathering (Torrance, 2012). Such discrepancies may also be an interesting result in themselves. When social and hydrological data are treated as equally valid, they can yield valuable insights on human-water relations and the different meaning that water has to different people (Linton & Budds, 2014). This is exemplified by results from narrative group interviews in South Africa where participants spoke about different drought events. Major droughts identified by participants differed in discussions with people in different occupations, and sometimes differed from hydrological drought events identified from physical data, suggesting differences in the perceived impacts of drought and the timing or longevity of these impacts on occupational groups depending on their relationship with water, experiences and memories (Rangecroft et al., 2018).

3. Interdisciplinary collaborative working

In the previous section, we mentioned various examples of interdisciplinary water research and the important considerations in the interactions between researchers and research participants in the field. However, it is also important to consider the interactions between researchers of different disciplines and to develop practices for successful collaboration. We believe that interdisciplinary collaboration is essential for tackling current and future global and local environmental problems. Therefore, where possible, we believe that hydrologists should not seek to work on their own to address these research problems, even if they have carefully considered all the aspects mentioned in this paper, but to strengthen their research with interdisciplinary collaborations. Collaborative discussions and research between the social and natural sciences can significantly enhance the research design and process, producing holistic outputs. Whilst it has become increasingly evident that there is a need to understand global water challenges from different disciplinary perspectives and methodologies (Phillipson et al., 2009; Lowe et al., 2013; Rusca & Di Baldassarre, 2019), it is still often reported that social scientists may only play a “service role” in interdisciplinary projects. For example, this service role may be to satisfy the requirements of research funders (Viseu, 2015; Barthel & Seidl, 2017), an add-on to a project to create impact, or to communicate the results to the public, rather than being part of the research during conception and throughout. Therefore, despite the importance of designing research tackling these challenges with an explicit collaborative approach from the start, there are claims that many “interdisciplinary” projects may not have a truly integrated approach (Martin, 2019) and, as a result, do not optimise opportunities for working between disciplines and jointly shaping research.

There are several barriers that can prevent collaborative research, and it is important to identify these and develop practices to overcome them during interdisciplinary research projects. Due to differences in backgrounds, approaches and desired outcomes, hydrologists and social scientists can easily end up remaining disconnected during research (Evers et al., 2017). A lack of

integration and collaboration may be due to a lack of time and consideration in the initial scoping phase, which can be key to encouraging integration whilst developing the research ideas (Strang, 2009; Phillipson et al., 2009; Lowe et al., 2013), and a lack of experience and awareness of the other discipline (Beaumont, 2020). Lowe *et al.* (2013) found two main interlinked issues hampering successful interdisciplinary collaboration: (i) a lack of common language to discuss core concepts, and (ii) a lack of shared research methodologies to apply to the topic. These barriers prohibit open discussions and a shared vision, and ultimately prevent cohesion within the interdisciplinary project.

Our guidance for hydrologists on fieldwork with participants in Section 2 helps to produce shared research methodologies and considerations, improving awareness of “the other” discipline (Beaumont, 2020). If hydrologists can start to become familiar with the unfamiliar, dialogues can be opened and research questions can be co-designed (Lowe et al., 2013; Xu et al., 2018). Improved understanding of the other discipline(s) can help to bridge the gap between the different disciplines, so that a stronger collaboration can arise, allowing for truly interdisciplinary working across a research project. To further tackle the two main issues identified by Lowe *et al.* (2013), we discuss both challenges here, a lack of common language (Section 3.1) and different disciplinary philosophies (Section 3.2), with recommendations to overcome these barriers with the aim of further enabling hydrologists to successfully collaborate with other disciplines. We hope that by considering these aspects, this paper will help hydrologists (and social scientists) to work across disciplinary divides and to engage with questions that address both hydrological changes and power in society. Importantly, the barriers and potential solutions discussed here are not restricted to just hydrologists and social scientists, but can also be applied to a wider view of researching alongside different disciplines.

3.1 Lack of a common language

Whilst there can be communication barriers between researchers and participants (Section 2.3.1) and local partners (Section 2.2.3), there can also be communication barriers and challenges between researchers, especially when working across disciplines. Different terminologies and vocabularies can be problematic at the conception of research projects when formulating the initial research idea, and, unless addressed, can remain a key challenge for interdisciplinary research moving forward. A lack of a common language among the various researchers involved can prevent discussions on core concepts and applications (Lowe et al., 2013). Different disciplines, and even those taking different approaches within the same discipline, may have different starting points for thinking about specific words (Krueger et al., 2016). For even what seems to be common terms - such as, for example, “environment” - those from different disciplines may have quite different associations with this word. Krueger *et al.* (2016) highlight that it is particularly problematic when scientists communicate without noticing that a particular word or term has a specific disciplinary interpretation, unknown or different to other disciplines. To help overcome this challenge, within one interdisciplinary project, the core team of hydrologists and social

scientists had dedicated meetings to discuss some specific terms that were being used for the research by the different disciplines (e.g. forecasts, projection, validation, preparedness, resilience, narrative). This also helped later during fieldwork, as the process had identified some of the key terms around drought prediction and forecasting that also needed discussion and clarification with local partners during a kick-off workshop in the field. Going beyond this, as part of the research development, it can be important – perhaps essential - to develop a shared vocabulary to work as a research team (Beaumont, 2020).

3.2 Different disciplines, different philosophies

Another challenge that arises natural and social scientists, as well as local partners and project participants, can be their different scientific philosophies, which can be a barrier to understanding each other's practices and ways of working. Different disciplines have different positions on ontology (the form of what is known) and epistemology (how knowledge is formed) which may be in tension with each other. It is an important starting point of interdisciplinary work to acknowledge these differences across disciplines, especially as they may affect interpretations of the context and results. Traditionally, hydrology would tend to the positivist end of the research philosophy spectrum, while many areas of social science would be more on the constructivist end. Taking drought as an example, a positivist researcher might argue that a drought is a “real” phenomenon that can be identified and measured objectively (e.g. through hydrological variables such as rainfall, river discharge and soil moisture). On the other hand, a constructivist researcher would see drought as a socially made category (a construct), and the characterization of drought as subjective, dependent on experience and positionality, and hence varying between people. This was observed in South Africa when collecting narrative interviews on drought experiences whereby the impacts of drought, and therefore the definition of drought events, were different among various participants. Depending on their relationship with water systems and the land (e.g. agricultural farmer, livestock farmer, domestic), and their memory and experience, participant-defined drought events sometimes differed from the hydrological drought events identified from physical data (Rangecroft et al., 2018).

To take another example, the delineation of a flooding area regarding its spatial and temporal extent generally follows a positivist approach, following modelling processes including feedbacks and interactions regarding vulnerabilities and responses to hydro-climatic impacts. However, from a constructivist perspective, the flooding area is considered a social construct and a negotiated result of socio-political and engineering discourses based on rules and regulations, and on norms and values (Fuchs & Keiler, 2013). Both approaches highlight equally valuable aspects of flooding area and, thus, water-related issues are in need of engaging both perspectives in an equal manner (Evers et al., 2017). Therefore, the aim of integration may not be to merely agree upon one common methodological approach (Bergmann et al., 2012), but rather to come to a mutual recognition of the different concepts, hereby creating a new understanding in a relational sense (Linton, 2010). Additionally, it is important to note that whilst there might be discrepancies in the data obtained from the different methodologies, this does not mean that one approach and

its results may be “valid” and the other not; instead, the differences can be an interesting and significant result in themselves (see Section 2.4.2).

Furthermore, there may also be power dynamics among the researchers themselves, and partner organizations, based upon these personal values, experiences and backgrounds, which might impact upon shared vision and collaboration and should be navigated carefully. It must be remembered that research projects are not just bringing disciplines together, but also bringing people together (Beaumont, 2020). Beaumont (2020) recommends bringing the researchers from different disciplines together towards the start of an interdisciplinary project and exploring how individuals experience and interpret the same space. For example, a research team could visit a field site together and team members could explain what they see, paying attention to the differences in their perceptions and interpretations. This can help highlight the differences between the disciplines and at the same time build an understanding of how others approach the same research topic.

3.3 Recommendations for strengthening collaborations

Barriers to truly collaborative working, such as the ones discussed here, often require time to overcome and the openness of researchers to learning about other disciplines. However, they can be addressed in a project during its research design, approach and management. Encouraging researchers to have equal input into the design of all stages of the research is argued to be beneficial (Strang, 2009). Literature on interdisciplinary research highlights that collaboration requires a significant amount of time to be spent in communication between the researchers, especially to achieve at least a basic common understanding of the types of theory, methods, aims, data and analysis used by the others (Phillipson et al., 2009; Strang, 2009; Lowe et al., 2013). Based on this, and our own experiences, our recommendations for future interdisciplinary research projects are to consider the importance of these exchange activities from the conception of the research idea through to the dissemination of the results, and consider how best to facilitate collaborations within the project, building time and funding into the process to enable this (Strang, 2009). Another recommendation for collaborative interdisciplinary working would be to accommodate meetings for specific discussions on vocabulary, research methodologies and design, and workshop design amongst researchers. Building these collaborations from the start will also help to prevent social scientists (or any discipline) being in a “service role” or an add-on to the research for impact and dissemination (Viseu, 2015; Barthel & Seidl, 2017). Encouraging input from experts on all sides, rather than just using tools or results from one discipline in another, will help to foster successful interdisciplinary research. It is important to note that it may take longer to merge expertise (Beaumont, 2020), but it is worth spending the time to develop it.

Furthermore, as stated previously (Section 2.2.3) a good local partnership provides an important entry point to participants in the field and their selection according to good scientific practice. The basis for such partnership is trust (Weichselgartner & Kasperson, 2010). This trust will need to be built among researchers, local partners and participants, but also among the

researchers on the project themselves. It is important to spend the time building trust within the core research team, especially towards the start of the project (e.g. kick off meeting) and to accommodate time for active facilitation and enhanced understanding across disciplines. This trust can be hard to build, or can take time and experience, but building it is essential for successful fieldwork. Therefore, it is important to build additional time into project timelines for these trust building and interdisciplinary activities, and especially for meetings to enable discussions across disciplines. For example, in an Australian research project in the Northern Territory, trust was built progressively between the researchers and the Indigenous community over a 3-year period. Beaumont (2020) highlights that to do interdisciplinary research well, it should be resourced well, which facilitates the extra time, resources and activities required for true collaboration and trust.

However, interdisciplinary research can be significantly constrained by the funding opportunities available and the length of project dictated by funding bodies. Whilst in recent years there have been funding streams dedicated to interdisciplinary research (e.g. in the UK the Global Challenges Research Fund, and on a European level, H2020), many funding opportunities may not enable the necessary activities and time investments required for successful interdisciplinary research. For instance, short-term funding does not allow for the sensible lead time necessary for good interdisciplinary collaborations, and does not take into account the time needed to gain ethical approval, and build a shared language and understanding across disciplines. Funders need to explicitly acknowledge the value of these activities and support them with longer project times and sufficient funds for team-building activities.

As illustrated throughout this paper, collaborative discussions and research can significantly enhance the research design, methodology and outputs, and, fundamentally, can ensure that the correct considerations are taken when working with participants. As discussed, it is important to have a real collaboration among experts on all sides, rather than just using tools or results from one discipline in another. Whilst this paper has focused on one side of the relationship (social science for hydrologists), from our experiences, social science researchers have also greatly benefitted from working with hydrologists; successful collaboration is a two-way relationship. Recently, there has been an increasing trend for early career researchers to be trained in both natural and social sciences, gaining invaluable experience as interdisciplinary researchers. These interdisciplinary scientists are perfectly placed to be intermediaries in interdisciplinary projects, supporting hydrologists and social scientists to overcome the barriers in language and research methods. As this is an opinion piece within the *Panta Rhei* Opinion Paper series, we call for other interdisciplinary scientists to share their experiences with others to help further guidance on these important considerations.

4. Summary

In this paper we have highlighted the importance of, and the need for, true collaborative, interdisciplinary research in the context of hydrologists and social scientists working together to explore and address current and future water-related issues. Fundamentally, this paper is about

facilitating these partnerships between the natural and social sciences. Our focus here has been on helping to identify a number of important considerations for hydrologists (and natural scientists) working with participants in the field and together with social scientists. With an increasing number of hydrologists becoming involved in fieldwork with participants in order to study the dynamic connections between social and hydrological systems, facilitating these stronger interdisciplinary practices and understandings of the considerations for fieldwork is essential. Working between disciplines with their disparate philosophies, methodologies and vocabularies can bring challenges; however, it can also provide the perspective and complexity needed for understanding real-world problems and potential solutions. Therefore, it is important for researchers to consider how best to approach these collaborations, and how to equip the other disciplines to enable them to expand beyond their own. Whilst this paper is aimed at a hydrology audience, we understand this process as two-way, and the reciprocal exercise for social scientists working with hydrologists would also be extremely beneficial, but is beyond the scope of this manuscript.

In this paper, we aimed to guide hydrologists regarding social science approaches and considerations (Section 2) to improve the awareness of the other discipline. There are key aspects of social science practices (e.g. good ethical practice), methods and philosophies (e.g. power dynamics, positionality), which, if better understood by natural scientists, can help foster a stronger joint research vision, thereby maximizing research design, data collection, interpretation and impact. The planning and conduct of good ethical practice may be an unfamiliar process for a hydrologist with limited interdisciplinary or social science research experience, yet the ethical process is essential for researchers and participants, and can significantly enhance the research process (Section 2.1). The importance of hydrologists working with the social sciences and local partners is especially evident when identifying and addressing potential power dynamics and positionality challenges during fieldwork (Section 2.2). Building a deeper understanding of these considerations will help hydrologists to ask the right questions when working collaboratively. To help guide and develop best practice in the field, our main recommendations for hydrologists conducting fieldwork with participants are based on our own interactions working collaboratively between natural and social scientists in various settings. These recommendations include the following: (i) good ethical principles should underpin all research with participants, protecting both the participants and the researchers; (ii) differences in power and positionality of researchers and participants, and amongst participants themselves, can affect data collection and interpretation and should be considered and planned for in the research design; (iii) building trust among researchers, local partners and participants is essential for successful fieldwork, and can often require dedicated time and activities; (iv) pre-fieldwork training with translators/field assistants and post-fieldwork debriefing sessions can improve communication and knowledge exchange between researchers and local partners about data collection and interpretation; and (v) hydrological and social data should be treated as equally valuable, because both datasets can yield valuable insights on human-water relations, and the discrepancies between them can also reveal important findings.

We advocate meaningful collaboration between hydrologists and social scientists (Section 3) in order to carry out high quality interdisciplinary research. Opening the channels of dialogue between the different researchers to encourage discussions on differences can promote the growth of a common understanding and shared vision. However, interdisciplinary collaborations can suffer from a number of challenges and barriers due to differences in philosophies, methods and vocabularies, and potentially researchers' lack of experience in the other discipline. Yet it is precisely these differences in perspective and complexity that are needed for understanding real world problems and finding potential solutions. Based on theory and our experiences, we argue that it is important to learn how to collaborate between disciplines and overcome these interdisciplinary challenges by: (i) investing time between researchers to build understanding across the disciplines, to foster improved collaborations and to encourage researchers to have equal input into the design of all stages of the research; (ii) placing importance on and investing time in exchange activities that can encourage integration and understanding between disciplines, such as meetings amongst researchers for specific discussions on vocabulary, research methodologies and design, and including these in the project timeline; and (iii) sharing knowledge between disciplines to enable them to expand beyond their own, and to establish a common language for the interdisciplinary research team. Ultimately, building these stronger collaborations enables more holistic, meaningful and successful research and understanding of the complex interface between water and society.

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