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A proposed method for analyzing historical adaptation pathways of coupled natural-human systems

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ABSTRACT

Historical adaptation pathways (HAP) analyses identify sequences of multi-causal factors that shape climate change adaptation actions. Such analyses can be valuable for understanding why systems respond differently to climate risks, assessing important adaptation drivers and constraints, and identifying potential path dependencies. This paper synthesizes existing (and still emerging) HAP methods in order to present a more standardized and generalized approach to studying historic adaptations. The proposed method combines inductive and deductive approaches and draws on established practices from grounded theory to increase validity, including process tracing, memoing, construct definition, and member checking. This approach is designed to provide historical and contextual information that can be incorporated into a decision model or be shared with stakeholders and community members. In addition, future comparative studies based on this replicable approach could allow for theorization as to the casual mechanisms that engender successful adaptation. The approach is illustrated using a coastal adaptation case study in South Carolina, USA, with one of the main insights being that the island would not exist in its current form without the actions taken by concerned citizens, whose efforts ultimately helped combat the erosion caused (in part) by local jetties. Several areas for methodological improvement and theoretical development are also noted, as the aim of this work is both to enable cross-study comparisons of future HAP research – which can inform adaptation practice – and to provide a method that can be improved upon in future iterations.

1. Introduction

Adaptation actions are being taken by many actors at different scales and in different sectors to mitigate the risks posed by global climate change (for a definition of 'adaptation actions', see Table 1). Yet choosing when and how to adapt has been difficult for decision makers given the uncertainties around climate estimates, the effectiveness and sufficiency of adaptation actions, and tradeoffs across different options (Haasnoot et al., 2020; Orlove et al., 2020; Siders and Pierce, 2021). Oftentimes, decision modelers may assume all options are equally available during a decision analysis. However, by failing to incorporate contextual information, the analysis is incomplete, as the decision space is informed not only by projections and data but also by resources, historical events, capabilities, public interest, path dependences, and other factors (Bosomworth et al., 2017). These factors can create pathways that shape the adaptation actions functionally available to a decision-maker (Adamson et al., 2018; Barnett et al., 2015; Fazey et al., 2016; Gajjar et al., 2019; Wilson, 2014).

Adaptation pathways have gained increasing recognition as an approach to inform future decisions by identifying prospective thresholds and decision sequences (e.g., Dynamic Adaptation Pathway Policy, Haasnoot et al., 2019, 2013; Ramm et al., 2018). A separate category of adaptation pathways research analyzes past decision pathways to understand the contextual factors that shape adaptation decisions (Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015; Seebauer et al., 2023; Tellman et al., 2018). This "past pathways" approach is called herein historical adaptation pathways (HAP) to distinguish from future projected pathways. HAP analysis can help identify drivers and barriers to adaptation and is particularly useful for understanding how path dependency may lead to

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Table 1
Key terminology for a HAP analysis.

Components of a HAP Analysis:	
Driver	Factors that influence adaptation actions and can affect the decisions available to the study area. Drivers may be exogenous or endogenous.
Adaptation Actions	Any action taken to adjust to a change in risk levels or perception, a historical gap in preparedness, etc.
Terminal Action	The last adaptation action in a pathway; the end outcome that the research seeks to understand.
Mechanisms	How triggers lead to actions (often multi-causal with multiple mechanisms involved simultaneously).
Outputs from Analysis:	
Historical Adaptation Pathways (HAP)	A sequence of adaptation actions and mechanisms over time, beginning with a trigger and ending with a terminal action.
Initial Trigger	Some pathways may have a clear onset that was possibly caused by an event (e.g., flood or other natural disaster). In this case, the pathway may be 'triggered' by a specific factor.
Path Dependency	How engrained the HAP is, also referred to as 'lock-in.'

lock-in (Adamson et al., 2018; Barnett et al., 2015; Fazey et al., 2016; Gajjar et al., 2019; Wilson, 2014).

Methods for establishing future pathways have become increasingly advanced (e.g., Gold et al., 2022; Trindade et al., 2020), but methods for HAP analyses remain relatively undeveloped. Individual HAP studies have employed a range of methods for study design, data collection, and analysis (see, Adamson et al., 2018; Barnett et al., 2015; Câmpeanu and Fazy, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015; Tellman et al., 2018; Wilson, 2014). Some similarities across these studies include the use of qualitative methods in the form of interviews, document review, and timeline synthesis, as well as discussions around path dependency (Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015). However, there is little consistency across studies regarding framing, and methods descriptions are sometimes vague due, in part, to the need for HAP analysis to reflect the local context. Câmpeanu and Fazey (2014), for example, describe the steps in a HAP analysis as "identify the local social structure," "identify main events affecting the village," and "identify responses and their patterns" (p 356). Flexible methods allow HAP studies to be tailored to context, but this also leads to fragmentation, which can prevent methodological advances, cross-study comparisons, replicability, and thereby limit the potential for policy-relevant insights and theory generation.

This study, therefore, synthesizes methods from the HAP literature (e.g., Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015; Seebauer et al., 2023; Tellman et al., 2018) to describe a generalized methodological approach. The study also identifies ways the method could maintain its flexibility to enable local tailoring yet strengthen validity by increasing transparency and incorporating established methodological practices from grounded theory such as memoing (Birks et al., 2008; Glaser and Strauss, 1967; Morse and Field, 1995), construct definitions (Gilliam and Voss, 2013; Kaplan, 1964), and process-tracing (Beach and Pedersen, 2016; Collier, 2011; Kay and Baker, 2015). The resulting approach is illustrated using a case study of coastal HAP on a barrier island off the coast of South Carolina, USA, but the method is intended to be globally applicable. The overall aim is, first, to improve the ability of future HAP research to compare insights – thereby informing adaptation practice – and, secondly, to provide a HAP method that future studies can improve upon through explicit deviation and comparison.

2. A general approach for historical adaptation pathways (HAP) analysis

Adaptation decisions are multi-causal and shaped by numerous factors (Tuler et al., 2020), so the goal of a HAP analysis is not to identify a single cause, but rather to understand a 'sufficient' explanation of the processes that shape adaptation decisions (Beach and Pedersen, 2016). To that end, HAP analysis generally connects adaptation actions (taken by the decision-makers of interest) with drivers that shaped the decision and decision-making process. The HAP approach presented herein is iterative and combines empirically-derived components (using inductive logic) with concept-driven components (using deductive logic) (Osman et al., 2018). Six steps in the HAP approach are presented sequentially in the text below, although we note that there is substantial iteration across the steps (see Fig. 1). For example, Steps 1 and 2 iterate with Step 3 and 4, since Steps 1 and 2 involve a deductive approach to defining boundaries and constructs that guide data collection and synthesis in Steps 3 and 4. Inductive insights from Steps 3 and 4 might, in turn, require revisions to the scope and definitions created in Steps 1 and 2. By combining inductive and deductive approaches, the proposed method provides systematic guidance for data collection and analysis while also allowing for unique elements to arise.

2.1. Step 1: Study scope – setting temporal, geographic, and topical boundaries

The HAP approach presented here is designed to focus on coupled natural-human systems, whether that be how a community adapts to a specific natural hazard (e.g., flooding) or changes brought on by the co-evolution of a community with multiple systems (e.g., water and food). Studying a system requires decisions about the boundaries of the system to be analyzed: geographic, temporal, and topical. It is typically infeasible for a study to assess all interconnected human and natural systems over all of time and from all angles, and although grounded theory advocates for a researcher to enter a study without preconceptions (Glaser and Strauss, 1967), there are functional advantages for researchers to identify boundaries to focus their data collection and analysis. This could mean choosing to focus on how a city has adapted to heatwaves over the past decade, or how a nation has addressed coastal erosion over the last century, or how a combination of micro, meso, and macro actors have adapted to wildfires (Kay and Baker, 2015).

Setting geographic boundaries for the study system shapes data analysis by distinguishing between exogenous and endogenous elements. For example, if a researcher is studying how a coastal community has adapted to flood risk, an exogenous driver could be a national policy that limits floodplain development. However, from a national perspective, this type of policy could be viewed as endogenous to the system. Endogenous and exogenous elements have different consequences for pathway dependency since the system has more control, presumably, over endogenous elements.

Similarly, a topical focus (heat, drought, flood, urban biodiversity, etc.) both improves the feasibility of the study and distinguishes between adaptation actions that are intentionally pursued or unintentional side effects, as these have different implications for an analysis of drivers and pathways. This does not limit the ability of the researcher to focus on both intentional and unintentional actions; rather, it informs the insights gained from the different types of actions (Fazey et al., 2016). For example, farmland conservation may reduce flood risk by maintaining natural buffers, but the decision to conserve farmland may have been made without any consideration of flood management, meaning decision makers reacted to different drivers than if the decision had been made to intentionally reduce flood risk. The analyst will also have to decide which social group(s) to include in the analysis, and this will be tied to decisions about geographic and temporal scope (e.g., in a small town, one may be able to include all social groups; in a nation, this may not be possible).

Since the goal of HAP is to understand the pathway (i.e., set of actions) that led to a specific adaptation action of interest (i.e., the terminal action), that terminal action is the 'end' of the analysis (these end actions become a part of a pathway towards future actions the subject of

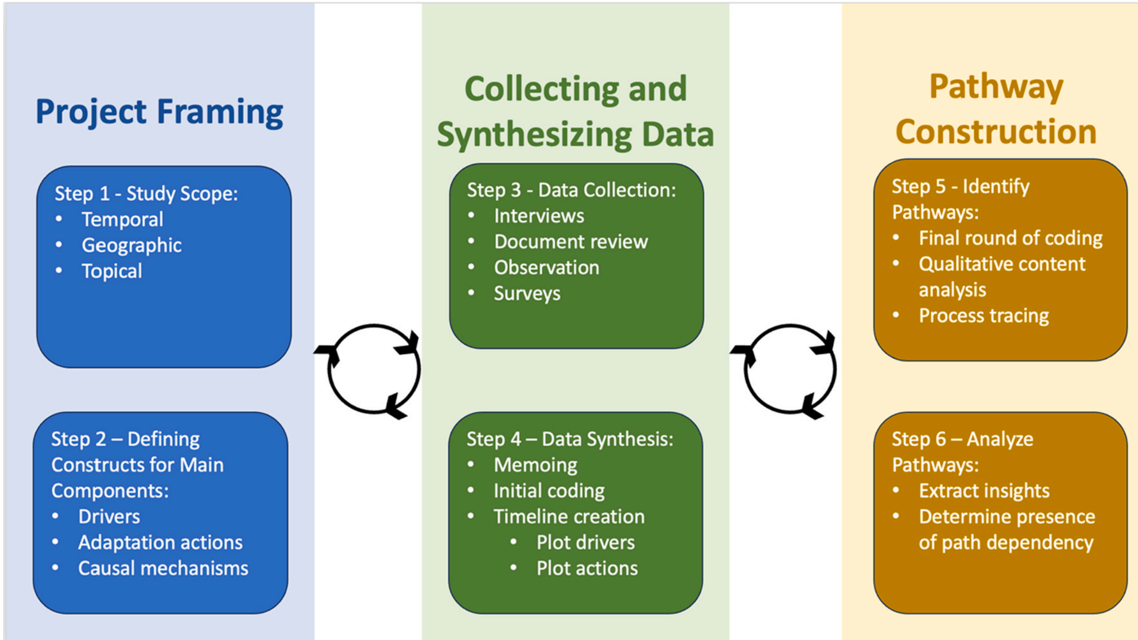

Fig. 1. Overview of synthesized Historical Adaptation Pathways (HAP) approach. Six steps are presented as a linear process, but the stages iterate with deductive boundaries and frameworks guiding data collection and analysis while remaining open to modification based on inductive insights that emerge from the data.

future analyses). The 'beginning' of a HAP analysis might start with a specific trigger, such as a natural event (e.g., a flood) or human event (e.g., the founding of a village). A researcher implicitly sets a 'beginning' when they decide whether to analyze how the geography of the region being studied has changed over millennia (e.g., how glaciers shaped local topography in the last ice age) or to focus on more recent events (e.g., how coastal erosion has changed in recent decades). Making that decision explicit focuses data collection and increases transparency if and when the researcher decides to change the "beginning" point. It is also useful to note that the historical analysis will ultimately be limited by the availability and quality of historical information, both interviewees' memories and written records.

All of these boundaries – geographic, topical, temporal – are established to focus data collection and analysis, but they can be revised as insights arise from the data (e.g., interview subjects describe a historical event that is outside the temporal boundary but is important to the analysis so the temporal boundary is shifted; or the geographic boundary is expanded to include a larger watershed or reduced to focus on a narrower community within a city). As with many methods, there is likely to be a tradeoff between the scale of the study and the depth of the analysis, with local studies enabling an analysis of individual perspectives and intrapersonal dynamics and national or regional studies enabling an assessment of broader trends without fine-scale in-depth information.

2.2. *Step 2: Defining constructs - identify hypothesized drivers, adaptation actions, and causal mechanisms*

HAP analysis aims to generate theory by explaining the causal mechanism between adaptation actions (output) and drivers (input) (Edwards and Bagozzi, 2000). A fully inductive approach to research allows constructs as well as relationships among those constructs to 'emerge' from the data. However, functionally, a researcher often needs some guidance to understand the breadth and depth of data they should collect, and a deductive approach in which constructs are pre-defined can enable more consistent data collection, which in turn can promote cross-study comparability. We therefore recommend a hybrid approach in which researchers define an initial set of constructs to guide data collection and add or revise constructs as needed (similar to the qualitative coding process in which a researcher begins with an initial set of codes, allows new codes to emerge from the data, and re-codes the entire dataset using the final set of codes (e.g., Beach and Pedersen, 2016; Fereday and Muir-Cochrane, 2006)).

Three categories of constructs need to be defined to cover the main components of the HAP analysis: drivers, adaptation actions, and causal mechanisms (see Table 1). We identify possible ways to define drivers, adaptation actions, and causal mechanisms in subsequent sections, and the case study in Section 3 further elaborates on these examples. However, these are only examples, and others could be used so long as they are explicitly defined by the researcher; indeed, such explicit deviation would improve HAP methods by enabling future research to compare and contrast the benefits and drawbacks of different construct definitions and frameworks within a HAP analysis.

2.2.1. *Drivers*

Drivers may include either or both (a) risks that create a need for adaptation actions and (b) elements of the pathway that shape the actions taken. The path dependency literature describes drivers as "contingent events" as well as exogenous events that shape the pathway (Hanger-Kopp et al., 2022). Based on previous HAP studies, we recommend researchers explore at least four types of "drivers": (1) external adaptation actions (e.g., actions taken by a national government that shape local actions), (2) events (fast occurring changes, such as a hurricane or election); (3) processes (moderately slow changes, such as changes in erosion rates or shifts in political will); and (4) context (long-term factors that are extremely slow to change, such as geology, topography, or historical social context). Hanger-Kopp et al. (2022) give the examples of "past flood events" (event), "new legal enforcement" (external action), "innovations" (process or event), and "socio-political change" (process).

As the reader can see, these categories are not overly defined, but they provide some guidance for researchers about the breadth of data to collect (e.g., national legal changes and local personalities as well as disaster events and topography). A HAP study could choose to focus on only one type of driver (e.g., an in-depth analysis of how changes in personnel and leadership shaped adaptation). Doing so explicitly and with reference to the other three categories would help the researcher situate their work and would signal to readers that lack of information on other drivers reflects an absence of evidence rather than evidence of absence. A HAP study could seek to understand drivers of drivers (e.g., the drivers that shaped the adoption of a national policy that influenced local action), but this could create a network of infinite complexity. Boundary setting in Step 1 is therefore extremely important in setting the scope of the analysis (e.g., whether the researcher wants to understand drivers of national policy or focus on factors influencing local action).

2.2.2. Adaptation actions

Adaptation "refers to the process of change" in natural human systems "in response to a change in the physical or social environment" (Fischer, 2018). While seemingly straightforward, it can actually be quite difficult in practice to distinguish between climate adaptation, disaster risk reduction, and regular system maintenance (e.g., upgrading a stormwater drain). A researcher must decide whether they are interested in all actions that address a given risk, regardless of whether they are explicitly taken in response to climate change or to the hazard of interest. Many land-use and housing development decisions, for example, may affect exposure to climate-affected hazards, but those decisions and actions might be made without any reference to climate change (either explicit or implicit). Their risk-reducing (or risk-increasing) effects could be entirely unintentional. A researcher must, therefore, decide what actions they will consider 'adaptation actions' and what actions will be considered drivers (events, context, or procedural changes that shape the pathway). Adaptation actions taken by exogenous actors are considered drivers in the analysis, which ties back to the researcher's decisions about the scope of the analysis. For example, if analyzing a state's coastal adaptation pathway, a new living shoreline policy would be labeled an adaptation 'action.' If analyzing a town's coastal adaptation pathway, a state policy would be labeled a 'driver,' as an exogenous action that would influence the town's pathway. Similarly, the researcher must decide whether to include decisions and planning steps (e.g., laws passed, plans created) as adaptation actions or to consider only actions that directly reduce risk (e.g., infrastructure changes). Again, such decisions should be made explicitly during the project framing phase. Making these decisions a-priori will help guide the data collection and analysis.

One way to categorize adaptation actions is around the three "I"s framework - investments in infrastructure, institutions, and information - that has been utilized in the water management sphere (Grey et al., 2013; Sadoff et al., 2015). *Infrastructure* can refer to broad categories of natural and built infrastrcuture that can be both green (e.g., mangroves) and gray infrastructure (e.g., dams). *Institutions* refer to organizations (e.g., community groups or local governments) as well as policies and practices (e.g., formal land use regulations or informal beach use norms). *Information* includes reports, plans, education, outreach, and communication or data-gathering initiatives. A broad conceptualization of 'adaptation actions' would include all three elements, but a researcher could choose to focus on just one category. Again, entering the analysis with some ideas about the types of adaptation actions central to the research question will guide both data collection and analysis. Other typologies could be used, such as one explored by the Global Adaptation Mapping Initiative, which categorized adaptation actions as ecological, technological, behavioral, and institutional (Berrang-Ford et al., 2021). As HAP research draws upon more such frameworks, the field will be able to compare and contrast the relative merits of different frameworks, but only if future works are explicit about the frameworks they use to define the adaptation action construct.

2.2.3. Causal mechanisms

HAP analyses are generally focused on causal relationships: factors that drive, constrain, or shape adaptation actions. Not all drivers identified by the researcher will have a causal relationship with the adaptation actions of interest (i.e., they will not be a direct part of the adaptation pathway), and not all drivers will be related to all adaptation actions (e.g., a new law might influence one adaptation action but have no relationship with a second). HAP research connects specific drivers to specific actions, thereby signaling causal pathways (albeit not predictive ones). The validity of the causal claim is strengthened by identifying the mechanism by which the driver influences a subsequent driver or action.

In this respect, HAP is a type of process tracing that "can be used to identify and describe policy events and to elaborate on the single or multiple paths by which they come about" (Kay and Baker, 2015). Notably, process-tracing goes "beyond correlations by attempting to trace the theoretical causal mechanism(s) linking X and Y" (Beach and Pedersen, 2016). Process-tracing may be either theory-testing, where "the researcher looks for a series of theoretically predicted intermediate steps" (Checkel, 2006), theory-building, or explanatory, where the researcher seeks to explain a set of outcomes. HAP studies have been mainly explanatory to date. As the field develops, future theory-testing studies will use pre-identified, hypothesized causal mechanisms. At the moment, however, explanatory and theory-building efforts should use a combination of pre-identified causal mechanisms (deductive) and empirically-derived mechanisms (inductive). For the pre-defined, hypothesized causal mechanisms, we recommend that researchers use one or more existing frameworks, so when additional causal mechanisms emerge inductively from the data, it is clear how these emergent mechanisms relate to existing frameworks.

For example, the Adaptive Capacities Framework ACF (Siders, 2018) presents a set of hypothesized causal mechanisms. Drivers are expected to affect the adaptation pathway by affecting one of the five direct ACF capacities – access to resources, authority, information, motivation, or management practices – or one of the three indirect elements – culture, demographics, or social networks. When a national law is identified as a driver, we consider whether the law affected local adaption actions by increasing local authority and responsibility for adaptation (authority), providing additional funding for adaptation actions (resources), requiring adaptation planning (information and management), another mechanism (outside the ACF, an inductively-identified mechanism to be added), or a combination of the above. This analysis goes beyond noting a correlation between 'new legislation' and 'adaptation action' to assess *how* the legislation caused or shaped the adaptation action. The ACF provides categories of mechanisms that guide researchers to consider multiple ways a driver might affect the adaptation pathway. If a novel mechanism arose that was outside any of the ACF categories, this would both be a notable insight into the adaptation pathway in question and suggest a possible modification to the ACF.

The ACF is just one framework that could be used. A researcher might instead consider the Five Capitals framework and consider how a driver influences natural, manufactured, human, social, or financial capital (Porritt, 2005). A HAP researcher could also develop a built-for-purpose set of hypothesized mechanisms. This would have the advantage of being tailored to the specific geographical, topical, and temporal scale of the study but would reduce connections to and insights for established frameworks in the adaptation literature. Regardless of which mechanism framework is used or purpose-built, a HAP researcher should begin with a set of hypothesized mechanisms to inform their analysis and either ensure that they are considering a wide range of causal mechanisms or to help them situate their focus (e.g., if they choose to focus on only mechanisms that affect authority or resources, they should do so explicitly and consider how this focus affects their interpretation of their results). The driver and action frameworks primarily guide data collection, but the mechanism framework directly shapes the creation and validity of the adaptation pathway identified, so the framework chosen here should be carefully considered.

2.3. Step 3 – Data collection

Data collection will be guided by the constructs defined for drivers, adaptation actions, and hypothesized causal mechanisms. Numerous methods can be used for data collection. Previous HAP studies have commonly used interviews, surveys, document analysis, and literature reviews (Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015; Seebauer et al., 2023; Tellman et al., 2018). Other methods are also likely to prove useful, including legal analysis, archival research, and stakeholder network analysis, depending on the scale of the study (Step 1: Scope). As is common in case study designs, we suggest a mix of methods to enable triangulation and reinforcement.

2.4. Step 4 – Data synthesis

Data collection and synthesis are also iterative processes in a HAP study. We present them as linear steps; however, in reality, Steps 3 and Step 4 are intertwined. Data synthesis occurs alongside data collection, and we recommend a preliminary coding of qualitative data (e.g., interview transcripts and documents) to identify drivers and actions. We also recommend that researchers engage in memoing, an established practice in grounded theory research and many social science fields. Memoing involves writing reflections and notes on content gathered (e.g., interviews) as they occur. There are several guides to writing memos as a methodological technique (Charmaz, 2006; Glaser, 1978; Richards, 2005; Strauss and Corbin, 1998), but as Birks et al. (2008) conclude, “how the researcher produces their memos is inconsequential, that they are produced and in a form that is indelible, secure and easily retrievable is vital” (Birks et al., 2008). We recommend memoing as a key element of data collection in HAP studies because of the iterative relationship between data collection and construct definition. In a HAP study, a researcher must make numerous judgements to identify and categorize drivers, actions, and mechanisms. Throughout, the researcher is required to reflect on the sufficiency of their pre-determined construct frameworks and to modify those frameworks as needed. Memoing provides an established method to assist in and to document this iterative process, increasing both rigor and validity.

In addition, timelines have been used in multiple HAP methodologies (Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015). The HAP researcher plots possible drivers and adaptation actions on a timeline throughout the data collection and synthesis phases (and reflects upon the timeline in their memos to assess gaps in the data collection or to assess when saturation has been reached) (see Fig. 2). Initial versions of the timeline are likely to include many drivers that are ultimately determined to be tangential or unrelated to the adaptation pathway in question (e.g., an initial version of the Folly Beach case study in Section 3 contained more than 100 drivers and actions). The timeline is a tangible output from the HAP analysis that, along with an accompanying narrative, can be used for member checking (respondent validation) to further validate findings (Birt et al., 2016). Timelines across multiple cases may also enable cross-case comparisons (Sadoff et al., 2015).

2.5. Step 5 – Identify pathways

To begin to construct the pathways, coding, qualitative content analysis, and process tracing can be useful tools. Researchers could identify mechanisms during the initial coding phase during Step 4, but we recommend a second coding phase to specifically focus on mechanisms once the drivers and actions are identified. Some mechanisms will be drawn explicitly from the data (e.g., an interviewee will say that a flood increased local support for flood mitigation actions, or the text of a law will state that it provides local authority for action). Others will be inferred by the researcher based on their immersion in the case . These inferred mechanisms should be identified (e.g., marked or color-coded on the timeline) as the researcher may wish to collect further

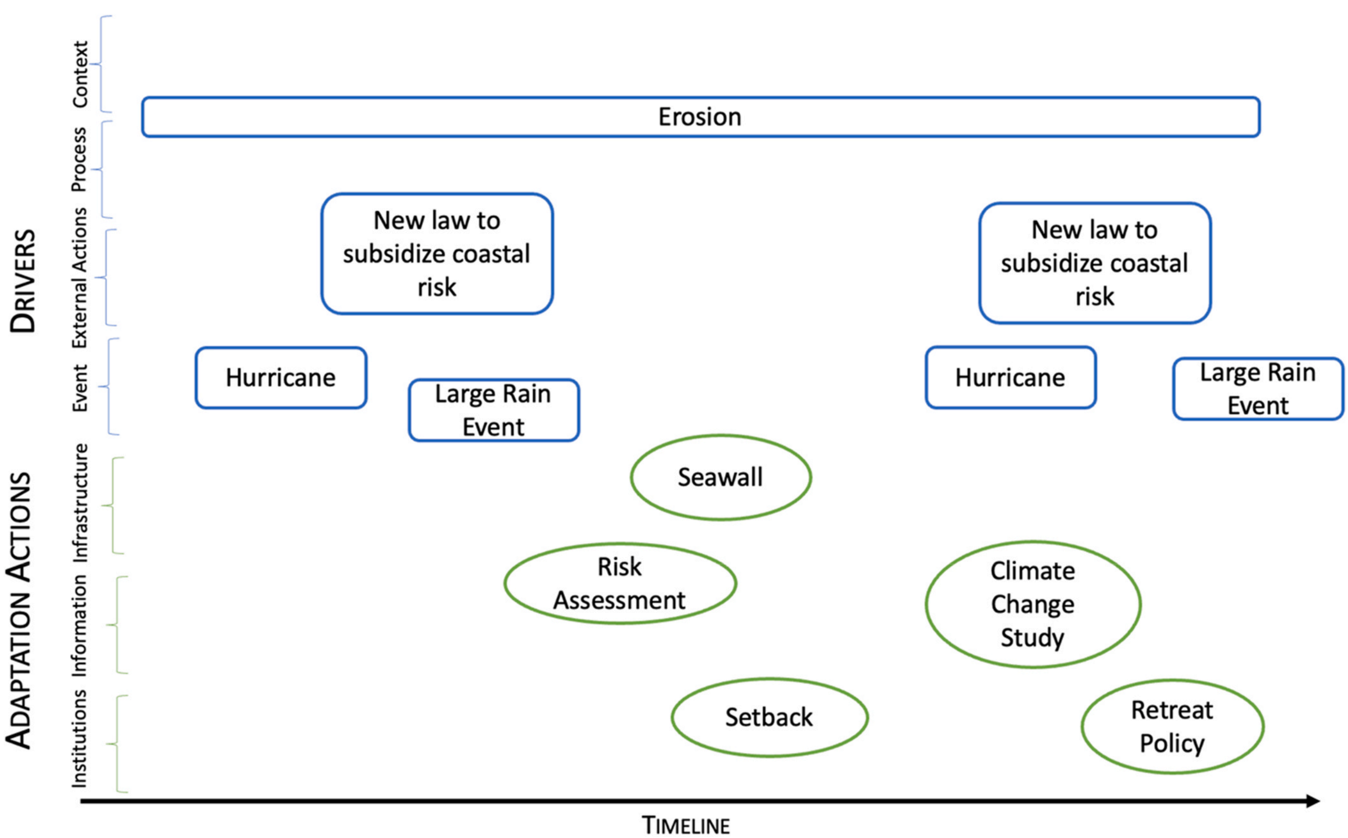

Fig. 2. Illustration of a timeline generated during data collection. Throughout the data collection phase, the researcher plots possible drivers and actions on a timeline. This figure illustrates one such timeline with unconnected drivers and adaptation actions for a hypothetical coastal community.

information about those connections (e.g., to look up town hall meeting minutes about a specific regulation or to look at budgets for a given year). Mechanisms can be added to the timeline as text explaining the nature of the connecting line (the edge, to use network analysis lingo). Once connections are drawn between drivers and adaptation actions, any drivers that are unconnected should be re-evaluated and removed from the timeline if the data suggests that they are truly unconnected (only after a researcher revisits the reason for their initial inclusion, e.g., the large rain events were removed from the actual pathway in Fig. 3 upon determination that they did not influence public perceptions of coastal risk). Adding these connecting lines and labeling them with mechanisms turns the timeline into a type of concept map that illustrates not only the flow through time but also the relationships between steps.

Several HAPs are likely to emerge from these steps: sequences of drivers and actions leading to one or more terminal actions of interest (Fazey et al., 2016). The researcher must now decide whether to report all observed HAPs or to focus on specific HAPs for further analysis, a decision that will be made based on the research question motivating the study. A HAP is complete when "it can be substantiated that there are no important aspects of the outcome for which the explanation does not account" (Beach and Pedersen, 2016). One way to assess whether all "important aspects" of the adaptation action are accounted for is to use the causal mechanism framework developed in Step 2 and to consider whether each of the direct adaptive capacities (resources, motivation, information, management, and authority) in the ACF (or Five Capitals or another framework) has been assessed. For example, the HAP in Fig. 3 is likely incomplete because it does not account for public support for managed retreat (a notoriously controversial policy). Possibly, the recent hurricane increased local motivation, but that connection is currently not established. Noting its absence, we would return to our data to consider what drivers we have missed or collect more data focused on this question. An example of going from a timeline to producing the HAP can be seen between Figs. 2 and 3.

2.6. Step 6 – Analyzing insights

Once one or more HAPs have been identified, the researcher will analyze those HAPs (or a subset) for patterns, focusing on patterns relevant totheir particular research question. They might seek to understand the most common or most important drivers and constraints that shaped adaptation decisions and how these may affect future decisions (Fazey et al., 2016). They might focus on the role of motivation or finances or how interactions across multiple levels of government or coordination (or lack thereof) across institutions shaped the pathway. For example, Gajjar et al. (2019) assessed how urbanization affected flood risk and how policies affected farmers in India. We do not provide guidance on this specific step of the analysis, as the nature of the analysis will be shaped by the research question and the scope of the study (e.g., perhaps a narrative analysis is appropriate at one scale and a statistical or spatial analysis at another).

Nevertheless, one analysis that merits mention is a path dependency analysis. Identifying an adaptation pathway is not the same as assessing that pathway for path dependency. A HAP describes the path that was taken, while path dependency indicates how locked-in the pathway is for the study area (i.e., whether this was the only path that could have been taken and how limited options may be moving forward). They are not equivalent. Path dependency is an area of growing interest in the adaptation literature, but it remains difficult to define and assess

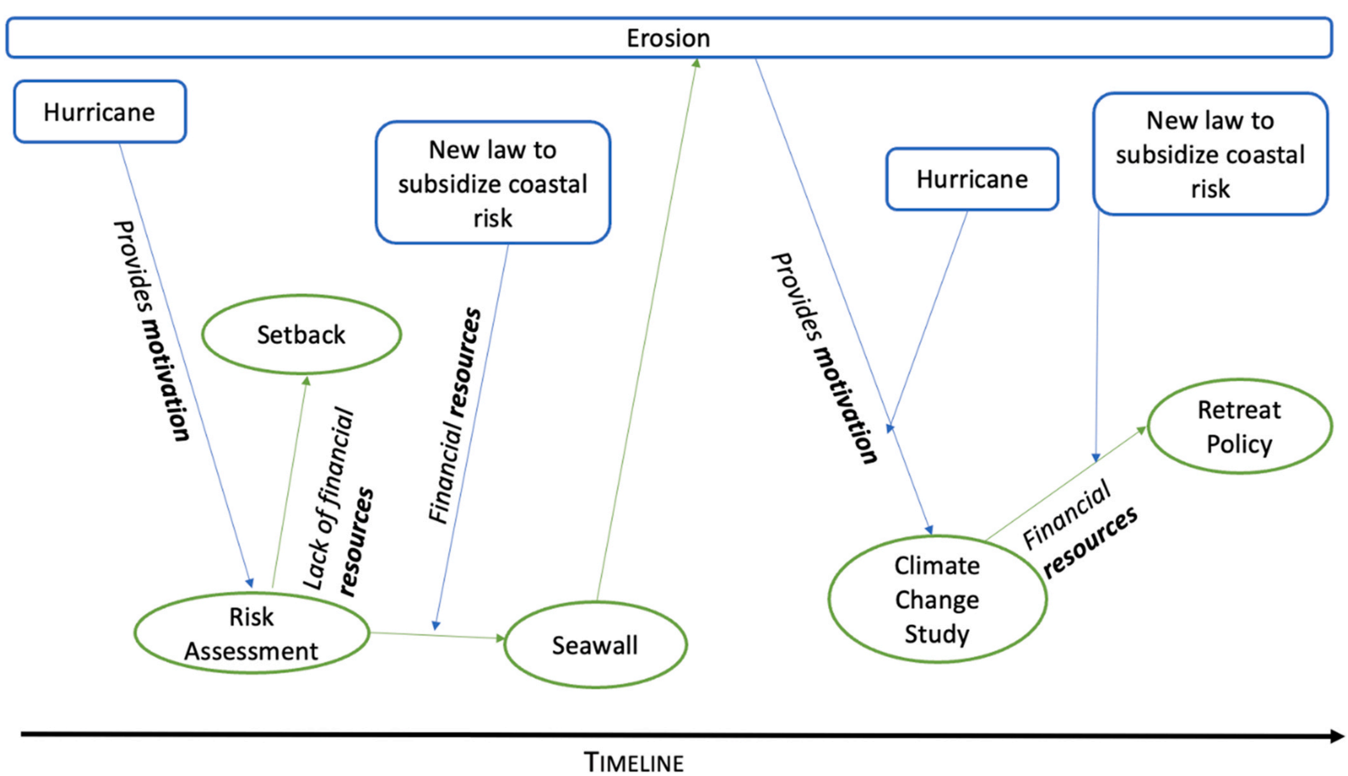

Fig. 3. Possible Adaptation Pathway. In this hypothetical pathway, a hurricane motivates a community to perform a risk assessment, which recommends an increased setback distance (regulation) and a seawall (infrastructure). At first, the community is unable to secure funding for the seawall, so they implement the setback policy, and construct the seawall once funding becomes available. The seawall causes additional erosion, and this, coupled with an additional hurricane, motivates the city to conduct a climate change study. This report recommends that the community begin the process of managed retreat, which they do. In this pathway, the terminal action was a policy of managed retreat, and the previous steps explain at a broad level how the town arrived at this policy. Interim drivers included erosion and an additional hurricane, and interim actions included information-gathering activities (risk assessment and climate change study), a policy increasing the setback, and the infrastructure project of a seawall. The mechanisms that linked these drivers and actions primarily included motivation and access to financial resources.

(Hanger-Kopp et al., 2022; Moallemi et al., 2020; Vergne and Durand, 2010). Hanger-Kopp et al. (2022) identify four characteristics that could indicate the presence of path dependency: (1) lock-in, (2) sub-optimality, (3) contingent events and initial situation, and (4) self-reinforcing mechanisms. These characteristics have been operationalized in the context of adaptation pathways for flood risk management (Seebauer et al., 2023). They can serve as a starting point to assess whether path dependency is present in the HAP identified in the analysis. For example, in the sample pathway shown in Fig. 3, we can see the pathway that led to a sub-optimal adaptation action (i.e., a seawall led to increased erosion) and the reasons for lock-in that limit future adaptation options (due to the perception of the seawall as permanent), with self-reinforcing mechanisms at work (i.e., the seawall increasing the erosion problem).

3. Application of approach to coastal adaptation in Folly Beach, South Carolina

The HAP approach outlined above was applied to assess historical coastal adaptation pathways for Folly Beach, South Carolina, USA. (Complete methods and results are available in Doeffinger (2024). In Step 1, the study was bounded to coastal adaptation (topical) for the barrier island of Folly Island (geographic) from 1890 to 2022 (temporal). Initially, the temporal focus was 1980–2022, but this was revised when interview subjects referenced several earlier historical events as important drivers. Step 2 defined constructs using the events, process, context, and external actions framework for drivers; the three-Is framework for adaptation actions; and the ACF for theorized causal mechanisms. The drivers framework, in particular, was refined through iteration during data collection as interviewees and documents referenced additional elements. Data collection (Step 3) drew on semi-structured interviews with local stakeholders (key informant interviews and snowball sampling), document analysis, local government archives, and ethnographic observations. Over 150 drivers and adaptation actions were plotted on a timeline (Step 4), including actions like beach nourishment projects, setbacks, and building code policies, and drivers like hurricanes (events), national legislation (external actions), lawsuits (events), mayoral elections (events), increased rates of coastal erosion (processes), context (barrier island topography and geology), and increased public appetite for aggressive coastal management (process). Three terminal actions of interest were used to filter the timeline and to identify HAPs that explained those actions (Step 5). The resulting analysis (Step 6) identified several HAPs across multiple scales that are complexly intertwined. A condensed version of one of the pathways is discussed below (for a more in-depth analysis and discussion of additional pathways, please see Doeffinger (2024).

The primary terminal adaptation action of interest was beach nourishment (see Fig. 4), as this is directly related to coastal adaptation. The HAP that leads to beach nourishment in Folly Beach was initially triggered by the construction of the Charleston Harbor Jetties. Their completion in the late 1800s substantially exacerbated coastal erosion on Folly Beach (USACE, 1987). Coastal erosion reached its peak in the 1970s and 80s, at which point there was not much beach left. From there, a complex interaction of social processes (including a lawsuit, local committee, increased resources from federal agencies, and increased local motivation for action due to decreasing property values and increased risk awareness) led to the town committing to a recurring series of beach nourishment projects (terminal action) (Doeffinger, 2024). (This is obviously a much-condensed pathway.) It should be noted that although alternatives were considered in early discussions, the best option forward was seen as beach nourishment. Other alternatives would have included the removal of the jetty system or to implementing managed retreat, neither of which was pursued.

This complex interaction found in the pathway in Fig. 4 was partially explained by the adaptive capacity framework. The ability of the city to sue the federal government and to pursue a Section 111 study with the United States Army Corps of Engineers (USACE) are directly related to the city's motivation level, information (i.e., knowledge of the Section 111 process), and resources (i.e., money to pay consultants). The city's lack of authority to conduct beach nourishment independently (due to federal jurisdiction over navigable waters around the barrier island and funding constraints) influenced Folly Beach's need to pursue federal

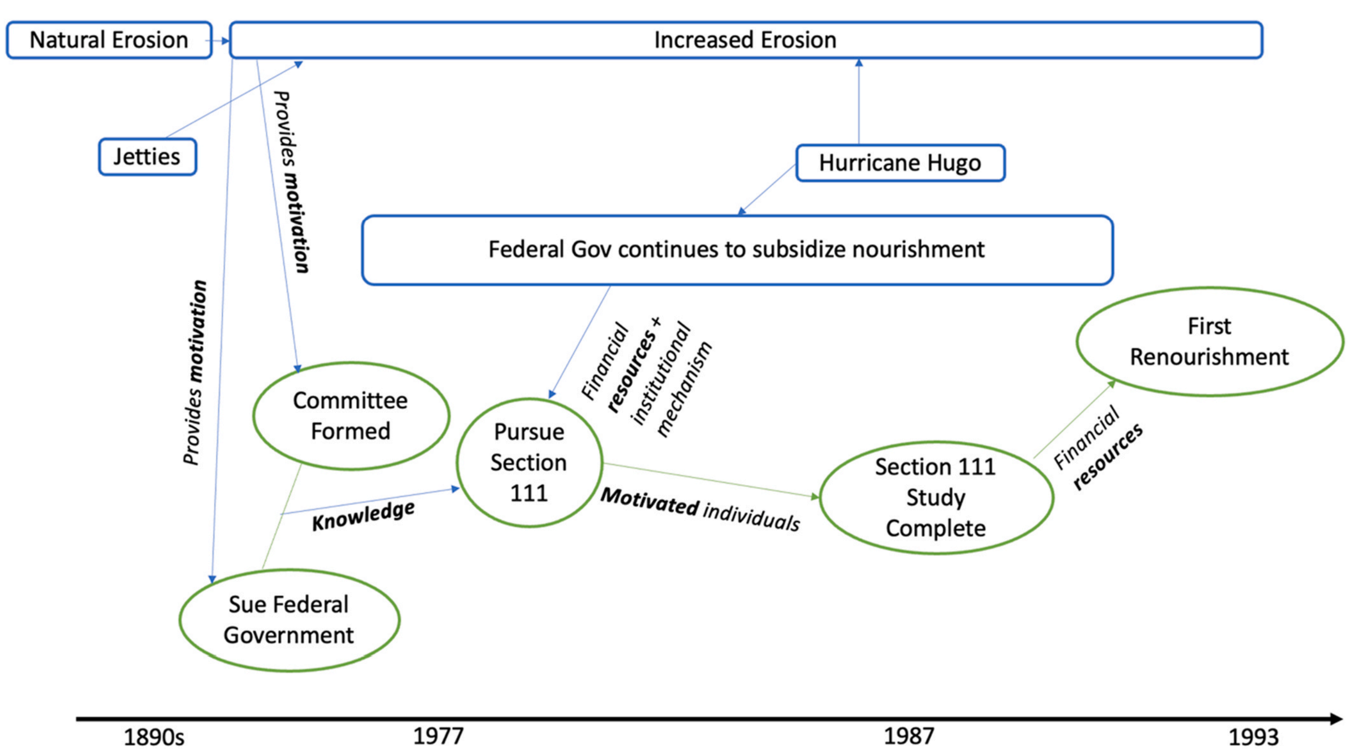

Fig. 4. HAP of beach nourishment for Folly Beach.

action. Management (the final ACF direct element) played a smaller role, precisely because Folly Beach lacked the authority to manage its beach nourishment independently. Consistent motivation and leadership were the most important drivers of the pathway. The Section 111 study took close to six years to complete and required consistent support from the mayor and a city consultant engineer. The consistency of motivation is difficult to capture in the timeline, but it emerges in the interview data and is signaled by the initial pursuit of the Section 111 study in 1981, and its final completion in 1987.

When assessing this HAP for the presence of path dependency, the four characteristics proposed by Hanger-Kopp et al. (2022) were used. For the first, lock-in, we find this within the pathway. Although not specifically shown in Fig. 4, the Section 111 that was completed in 1987 (USACE) was initially planned for a 50-year agreement. The first nourishment occurred in 1993, and there have been subsequent nourishments since, indicating that for 50 years, Folly Beach is locked-in to this pattern of beach nourishment. The second characteristic, sub-optimality, is somewhat trickier to identify. From the perspective of the City government, if their overall goal was to generate the maximum income from tourism and protect homeowners, beach nourishment could be considered optimal. From the perspective of ecosystem management or federal cost-savings, the nourishment may be suboptimal. The contingent event, in this case, would be the construction of the jetties. The analysis illustrates how important perspective is in identifying a sub-optimal path dependency, and how decision-making options might be limited regardless of the desirability of the decision.

Finally, there are self-reinforcing mechanisms, which can be thought of as a positive feedback loop or a process, that once embarked on - will continue to gain momentum (Meadows, 2008). Once the commitment to pursue beach nourishment was made and the 50-year agreement was signed, a self-reinforcing process was created. The jetty system will continually starve Folly Beach of sand, so the renourishment process will need to be completed cyclically every 5–10 years throughout the duration of the agreement. The renourishment project is its own feedback loop, which is reinforced or self-perpetuating due to the availability of funding. Therefore, as long as there are funding mechanisms in place and the project is financially viable, the cyclical process of beach nourishment will continue.

4. Discussion

Applying the HAP approach to Folly Beach produced a swath of historical and contextual information. An important finding that emerged from the case study was the importance of motivated actors to bring about change. It also highlighted what factors provided such motivation (i.e., personally witnessing the erosion of the beach). The implications of the information gathered and such findings are not limited to understanding the past; they can also improve our understanding and predictions of the future. For example, an improved understanding of how adaptation actions and extreme weather events have combined in the past to change public opinion may inform the ability of future pathways analyses to predict acceptable adaptation options moving forward. Decision models, such as those created using Dynamic Adaptive Policy Pathways (DAPP), discuss the importance of contextual information, but often do not describe how to gather said information (Haasnoot et al., 2019, 2013; Ramm et al., 2018). A HAP analysis is one way to fill this gap and could serve as the first step in a DAPP study.

The potential for HAP analyses to contribute to adaptation theory and practice will be strongest if the method is improved upon. A starting point for improvement is to synthesize diverse existing practices into a generalized method and to integrate established methods and practices from grounded theory, including construct definitions, memoing, process-tracing, and stakeholder validation. The HAP approach described herein combines inductive and deductive approaches because it is intended primarily to inform explanatory and theory-building studies. Further refinement will be necessary to apply HAP to theory-testing studies, especially with respect to the hypothesized causal mechanisms being studied. However, we believe the method outlined here provides a useful starting point and that explanatory and theory-building works that combine explicit pre-defined causal mechanism frameworks with inductively derived mechanisms will be best positioned to generate theory to be tested in the future.

The proposed method also provides a useful starting point for cross-case comparisons. By following the six steps and being clearer on researcher choices regarding the scope and constructs used to identify a HAP, there is greater opportunity for case replicability. Cases that use similar methods could begin to answer questions as to what drives communities to adapt and to what level of adaptation to improve adaptation policy. Essentially, we can use the knowledge gained from cross-case HAP analyses to determine what mechanisms have led to better outcomes in the past. However, since the proposed HAP method still allows for flexibility in each of the outlined steps, cross-study comparability may still be difficult, especially as we move to a more theory-grounded, generalized method through future reiterations.

Memoing and stakeholder validation practices are commonly used to assist researchers in identifying the elements and themes that 'emerge' through inductive research and to increase validity. It is critical for any emerging method to have procedures for establishing rigor and validity, if only to be able to identify quality research practices, and drawing on established practices from other methods is one way to achieve this end. Similarly, HAP analysis is, in many ways, a type of process tracing. Previous works have not labeled it as such, but drawing on techniques from the more established process tracing literature (or by deviating purposefully from those practices) will further refine HAP as an analytical method.

The method presented in this paper has numerous limitations. The first is the potential for bias or political implications, as many of the choices made in the project framing phase are at the researcher's discretion. Essentially, the method's flexibility is related to subjectivity. Second, the method focuses more on the initial definition of constructs that guide data collection and organization than on analyses, in part because a consistent approach to definitions, scoping, data collection, and organization will produce timelines and datasets that can be analyzed in numerous ways and even lead to future works that could analyze different aspects of published HAP datasets. For example, a future study might re-analyze an existing HAP dataset using a political ecology lens. Analytical approaches are also the least developed in the existing HAP literature, so we are least confident in synthesizing current practices in this area. The approach we describe is therefore presented as a baseline for future work to refine and alter. For example, Seebauer et al. (2023) employed a version of HAP analysis to identify path dependency, but more research will be needed to refine the methods by which this is done. Future work will also be needed to assess not only whether path dependencies exist, but also to what degree a path is 'sticky' or 'locked-in'. The multiple stakeholder perspective of HAP raises questions about the definition of path dependency as resulting in 'sub-optimal' outcomes, since different stakeholders might disagree about the optimal outcomes or degree of lock-in and since 'optimal' outcomes, if they exist, might not be possible given the particular historical context and current constraints facing a decision-maker. Future improvements to path dependency analysis within HAP will hopefully tackle these issues.

Another area for future improvement in the HAP method is in the application of frameworks for defining the constructs of adaptation actions, drivers, and mechanisms. We identified possible frameworks here to illustrate the value of having an explicit framework to structure data collection and analysis, but we do not argue that these are the optimal frameworks for all HAP analyses. We look forward to future works that use other frameworks and to being able to compare the relative merits of different construct frameworks. We particularly encourage future HAP research to include the community's culture, power relations and dynamics, and equity considerations in the analysis. These elements were not incorporated in our current method, nor have they been well-addressed in the existing HAP literature. Stakeholder network analysis, driver frameworks focused on people and power, and fine-scale studies could all enable more systematic analyses of the role of power dynamics in adaptation pathways. The incorporation of these elements could be of significant interest to the decision modeling field, as the incorporation of such information would only improve the accuracy of decision models. A recent study incorporated power dynamics into their multi-objective optimization model of water management in the Sendento Valley (Gold et al., 2022). Therefore, the inclusion of power dynamics in the next iteration of the HAP method would only make it more useful to decision modelers and planners.

5. Conclusion

HAP analyses are recognized as a valuable method to understand the multi-causal drivers of adaptation and how environmental and social factors combine to influence adaptation outcomes (Câmpeanu and Fazey, 2014; Fazey et al., 2016; Fischer, 2018; Gajjar et al., 2019; Sadoff et al., 2015; Seebauer et al., 2023; Tellman et al., 2018). This approach is designed to provide historical and contextual information that can be incorporated into a decision model or be shared with stakeholders and community members. This resulting information highlights potential challenges and opportunities that were encountered when making decisions and could therein facilitate learning and improve decisions around adaptation in the future. A standardized approach to HAP analyses will enable a greater degree of cross-case and cross-study comparison, improve theory generation and testing regarding the causal mechanisms driving adaptation outcomes, and promote development and refinement of the method through purposeful deviation from the standard.

Although there is a large body of literature on modelling decisions (future pathways) and substantial scholarship centered on historical pathways (past), there is currently no literature linking the two. Some may argue that given the extent of the challenges posed by climate change, that the past is not a good place to look to assess the future: that risks will be new and motivations likely to change. Yet, without understanding how and why adaptation decisions have been made in the past, we can neither learn from the past to improve the future nor understand the importance of deviations from past practices (if we do deviate). History, in short, matters.

Author agreement statement

Tess Doeffinger & AR Siders confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship.

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A.R. Siders: Writing – review & editing, Conceptualization. **Tess Doeffinger:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Tess Doeffinger reports a relationship with World Bank that includes: consulting or advisory.

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Data availability

The data that has been used is confidential.

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