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ECOLOGICAL SENSEMAKING

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Karl Weick's classic study of "sensemaking" showed that there is much to be learned from a wildland fire. In this tradition, we present an ethnographic tale from the subarctic to introduce the concept of ecological sensemaking—the process used to make sense of material landscapes and ecological processes. We then reanalyze data from the Mann Gulch fire and conclude that ecological sensemaking and ecological materiality were underappreciated dimensions of this historic tragedy. Comparisons of incidents and actors suggest that ecological embeddedness enables sensemaking and that inability to make sense of subtle ecological cues introduces hidden vulnerability.

On the afternoon of November 11, 1996, the first author (hereafter, Gail) began an ethnographic study in subarctic Canada. Her intention was to analyze the management practices of Cree hunters, who have successfully lived in the north despite the harshness of the conditions. On that same day, she slipped down a rock face near a large set of rapids and almost died. This incident could have been the surprising end of the beginning of this study. Over thousands of years the Cree have learned how to make sense of, and respond to, subtle cues in their natural environment. On that first day, she learned this the hard way.

Making sense of ecological conditions is not a mainstream concern in management theory, where research on "sensemaking" has had a strong social and linguistic orientation (Chia, 2000; Maitlis, 2005). The following expresses the prototypical view: "When we say that meanings materialize, we mean that sensemaking is, importantly, an issue of language, talk and communication. Situations, organizations and environments are talked into existence" (Weick, Sutcliffe, & Obstfeld, 2005: 409). Without intending to diminish the importance of social processes to human understanding, in the current research we start with an obvious point from our opening story: landscapes can impose material constraints on human action, and ecological processes unfold independent of humanity's social constructions. In some contexts, making sense of ecological conditions affects microlevel outcomes such as personal survival and resilience—the ability to bounce back from surprise and learn about risk through trial and error (Weick, 1993; Wildavsky, 1988).

An appreciation of the power of materiality is emerging within organization studies (Leonardi & Barley, 2010; Nicolini, 2009; Orlikowski, 2007; Suchman, 2005). This new stream of research concerns how social processes create and, in turn, are influenced by, human artifacts, such as tools and other material objects, which are in themselves materially produced through human processes. In this article, we introduce the concept of "ecological materiality" to explicitly recognize that the natural environment consists of material and physical elements—for example, rocks, rain, fire, ice, volca-

This article could not have happened without Freddy Jolly—for both your life-saving skills and deep insight about living in the land, Meegwetch. We note with regret that large sections of Freddy's trapline were flooded in 2010 in the wake of new hydro development. The disappearance of Freddy's trapline underscores the point that there is more to sensemaking than the ecologic.

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noes, water, trees, animals, birds, and so forth. We argue that ecological materiality can also be relevant to sensemaking. Weick (1990), for instance, showed that landscape, winds, and clouds created complex environmental demands on pilots during the KLM airplane crash in Tenerife (Weick, 1990: 575). Despite these occasional acknowledgments, there is little understanding of how the natural world affects sensemaking (Gephart, 1996).

That absence is surprising, given that natural settings are a recurrent context for sensemaking research. A classic example is Weick's (1993) analysis of the Mann Gulch disaster. During that wildfire, 12 young firefighters (from a crew of 15) perished in an unexpectedly large blaze in Montana. Weick examined why team members perished in spite of the fact that the crew foreman, Wagner Dodge, had a solution to the crisis. The problem, according to Weick, was the team's inability to make collective sense of the problem and act on the solution. In his study, which is based on a talk he gave on social relations, Weick addresses social questions, analyzing the Mann Gulch tragedy as "the interactive disintegration of role structure and sensemaking in a minimal organization" (1993: 628). Weick did not analyze how the ecological materiality of Mann Gulch affected the sensemaking processes of Dodge and the Smokejumpers. Yet topography and ecological processes can be critical elements for sensemaking, as the accident experienced by Gail suggests. The same may hold true for Mann Gulch.

Learning how actors—both contemporary and historic—respond to changes in local ecologies has captured the attention of scholars in archaeology, ecology, natural resource management, political science, and economics (for a representative sample, see Elmqvist, Berkes, Folke, Angelstam, Crépin, & Niemelä, 2004; Folke et al., 2002; Forbes, Stammler, Kumpula, Meschtyb, Pajunen, & Kaarlejärvi, 2009; Gadgil & Berkes, 1991; Nelson & Schachner, 2002; Ostrom, Burger, Field, Norgaard, & Policansky, 1999). Common across these multidisciplinary works is the finding that local intergenerational knowledge of ecosystem functioning allows people to develop effective responses to ecological change and surprise. In our own field, an article by King in the *Academy of Management Review* emphasized that the "prompt discovery and use of information about ecological change" (1995: 961) enables local communities to manage common natural resources over the long term. Missing in such studies is a microlevel account of the process by which actors identify and make sense of complex ecological systems that unfold over space and time.

There is evidence that actors who are ecologically embedded—those who are deeply rooted in "the land" in a physical and cultural sense—are attuned to changes in ecological conditions and actively interpret material cues in different landscapes and at different times (Whiteman & Cooper, 2000). The members of cultures that value local ecological knowledge appear better able to notice changes in their natural surroundings and adjust their practices to anticipate surprise and build resilience. The members of cultures that miss important signals that arise from the local ecology are more vulnerable to surprise; in the past, such cultures have experienced greater hardship and resource stress (Diamond, 2005; King, 1995; Nelson & Schachner, 2002). Although some work has been suggestive of the enabling value of ecological embeddedness to sensemaking, research has not explored this idea at the micro level.

We address this absence by presenting research from two settings that share a similar characteristic: the need to respond quickly and mindfully in the face of surprise that originates from the local ecology. Although both cases share an element of danger, they differ in degrees of complexity and pose opposite types of threats to survival—fire and ice. The findings from our research in the two settings help explain how actors notice and "bracket" (pick out) ecologically material cues from a stream of experience and develop causal networks connecting various cues with each other and with their previously "enacted" (socially constructed) environments (Weick, 1988). In Study 1, conducted using a grounded theory approach, we present ethnographic data from Gail's apprenticeship to a Cree hunter in James Bay; these data include an extended ethnographic narrative about the accident described briefly in our opening paragraph. We show how actors may or may not bracket and make connections between topography and subtle changes in climate, water current, and ice formation. How actors make sense of a volatile local ecology is assessed in more detail in Study 2, where we reanalyze the data used in Weick's (1993) classic study of sensemaking during the Mann Gulch disaster in Montana. For Study 2, we also gathered additional data on local topography and ecological processes in play at Mann Gulch. By revisiting Mann Gulch, we show how the varied ability of the firefighters to make ecological sense contributed to their survival or demise.

For each case, we describe the process of ecological sensemaking—how actors notice and bracket ecologically material cues from a stream of experience and build connections and causal networks between various cues and with past enacted environments. We also assess approaches to "sensegiving" between team members. Comparison of the two studies (Charmaz, 2006) allows us to identify how differences in the degree of ecological embeddedness enable the process of ecological sensemaking and enhance or detract from resilience and survival. We argue that a routine inability to make sense of weak cues from a local ecology introduces significant vulnerability. Thus, ecological sensemaking appears to increase the survival rate of actors who are dependent on a changing ecosystem. We conclude by presenting propositions to guide future research and discuss practical implications of our research, including organization-level implications of local ecological expertise.

SENSEMAKING

Sensemaking organizes and brings meaning to "an undifferentiated flux of fleeting sense-impressions . . ." (Chia, 2000: 513). When actors encounter a field of experience, they enact an environment to make sense of the world (Weick, 1979, 1988). The process of enactment is described by the enactment-selection-retention model in which actors (1) notice and bracket parts of an undifferentiated flux of experience, (2) engage in cognitive work to label and connect meanings between "punctuated" moments and select a plausible story and, in a circular manner (3) retain this story for future enactments (Weick, 2005: 185–186; Weick et al., 2005).

Noticing and bracketing flux is the earliest and most basic process in sensemaking (Weick, 1979), and its role cannot be understated: "The only possible raw materials that are available for subsequent parsing and retention, are those materials initially generated and/or bracketed by enactment processes" (Weick, 2005: 187). Actors then connect bracketed phenomena with labels, with prior understandings and experiences, with other cues from their local context, and with action (Weick et al., 2005: 136). Once a plausible story has been selected, it is retained for future sensemaking (Weick, 2005: 237). The enactment-selection-retention sequence thus both focuses and constrains sensemaking processes (Weick, 1979, 1988).

Sensemaking ability varies among individuals. Schön's (1983) research on how "senior practitioners" utilize tacit knowledge suggests that the ability for "reflection in action" (1983: 49) is an expert form of sensemaking. Faced with surprise and ambiguity, practitioners engage in "a reflective conversation with the situation" (1983: 77) in which they frame their situation in understandable terms yet allow for unique elements to emerge. According to Schön, the "art of practice" is not unknowable; rather, it has common structures in different domains. For example, experienced practitioners build causal networks through experimentation with a repertoire of past meanings or actions, and they reflect upon the impact of these improvised actions while engaging in action. Schön argued that "even when the action-present is brief, performers can sometimes train themselves to think about their actions. In the split second exchanges of a game of tennis, a skilled player learns to give himself [or herself] a moment to play the next shot. His [her] game is better for this momentary hesitation, so long as he [she] gauges the time available for reflection correctly and integrates his [her] reflection into the smooth flow of action" (1983: 270). As will be seen in James Bay and Mann Gulch, senior practitioners have a strong advantage over less seasoned players: the former can anticipate the next shot and reflect while in action, while the less experienced may not even notice that the game has changed until it is too late.

Processes of *sensegiving* are also prominent in team activities. Sensegiving links individual sensemaking processes across actors. Sensegiving occurs when actors attempt "to influence the sensemaking and meaning construction of others toward a preferred redefinition of . . . reality" (Gioia & Chittipeddi, 1991: 442). Sensegiving among actors can be triggered by issue salience, perceptions of incompetence or inexperience, ambiguity, and complexity (Maitlis & Lawrence, 2007). Within temporary teams, such as those from our two case studies in James Bay and Mann Gulch, sensegiving processes are particularly reliant upon a swift form of trust, since actors have not had prior interactions that would allow them to develop experience-based confidence in each other. Swift trust can be used to guide responses to uncertain situations, diminish vulnerability, and facilitate quick (though fallible) decision making and action among temporary team members (Meyerson, Weick, & Kramer, 1996).

Ecological Materiality

To the unseasoned, the dynamics of nature may appear as undifferentiated flux, but to the more experienced, this ecological flux contains important raw data that can signal danger. Although human knowledge of ecology is socially mediated (Gephart, 1996), ecological processes and landscapes are not just by-products of social constructions or human artifacts (Barad, 2003; Catton & Dunlop, 1980; Dunlop, 2002; Latour, 2005; Lidskog, 1998). At the biophysical level, material aspects of nature unfold regardless of human consciousness (Catton & Dunlop, 1980; Odum, 1983).

Some of the emerging literature on materiality in the social sciences has positioned nature as an intrinsic part of "the material endeavor." For instance, Latour (2005) and colleagues in the sociology of science have specifically positioned humans and nonhumans as "symmetrical actants" within "co-created networks of action." Knorr Cetina (1997) also considered the role of grass and plants in her concept of "sociality with objects," whereby people (including scientists) can have social bonds and intimacy with natural and human-made objects. The implication of this work is that material aspects of human and nonhuman processes are "conjointly constituted" (Buttel, 1996) and the social sciences should develop approaches to explore these interactions.

We believe that the materiality of the natural world is relevant to the sensemaking literature, which, to date, has not explicitly addressed how this kind of materiality influences sensemaking. Importantly, we do not conceptualize the material aspects of nature as if nature were an "object" or "thing" (Knorr Cetina, 1997; Suchman, 2005), but rather as the dynamic materiality of a system of living entities, made up organic and inorganic matter (e.g., matter from living entities as well as from minerals) and energy flows (Odum, 1983). Thus, we define ecological materiality as the interaction of dynamic biological and biophysical processes and organic and inorganic matter over space and time.

Given our interest in the biological and biophysical materiality of the natural world, we integrate insights from the field of ecology, whose members seek to understand how biotic (living) and abiotic (nonliving) entities interact. Ecology has a rich foundation of theory and data that show how ecosystem composition, structure, and dynamics change over time and space and why this flux is relevant, indeed essential, for human interpretation (Chapin, Kofinas, & Folke, 2009; Heyerdahl, Lertzman, & Karpuk, 2007; Holling, 1986; Lertzman & Fall, 1998). Given our empirical focus on settings in which fire and ice are prominent, we drew on this literature to help us understand how ecological processes interact with specific topographies across space and time. Our point is not to move sensemaking research away from the examination of social processes; rather, we wish to extend sensemaking research in order to understand how social processes may be embedded within ecological contexts that are material and, in some cases, volatile.

We use the term "ecological" as opposed to "environmental" materiality to explicitly link our approach to the field of ecology in the natural sciences. We use the phrase "ecological sensemaking" in a similar way: to highlight the ecological context for sensemaking. In both of our empirical settings, we examine how ecological materiality impacts actors' sensemaking.

Ecological Embeddedness

An actor is said to be ecologically embedded within an ecosystem when he or she understands the local peculiarities and interactive effects—of terrain, climate, seasons, vegetation, and animals—and the impact of disturbances such as a fire or an insect outbreak (Whiteman & Cooper, 2000). At the opposite end of the spectrum are actors who are ecologically disembedded—those who do not have detailed knowledge of, or experience with, a specific ecosystem or ecological process. Actors may also be ecological experts who have knowledge developed in a variety of ecological contexts; that is, individuals may use expert knowledge that was developed in one locality in another one (e.g., firefighters). Actors may also have fragmented experience with natural systems: they know some aspects of an ecology but not others.

Sensemaking can be enabled by opportunity (Maitlis & Lawrence, 2007). Like Weick, who noted the power of previously enacted environments, Schön noted that "the practitioner has built up a *repertoire* of examples, images, understandings, and actions" (1983: 138; emphasis in original). Actors who are embedded in local ecologies have greater opportunities to engage in ecological sensemaking than do those who are disembedded, and embeddedness thus facilitates and refines this type of behavior. Archaeologists studying the adaptability of local societies in the U. S. Southwest over a 700–800 year period (around 650–1450 AD) have demonstrated that "economies that are locally managed have a greater likelihood of noticing and reacting to local conditions than those managed at more distant levels" (Nelson, personal communication; see also Diamond, 2005; Nelson, Kintigh, Abbott, & Anderies, 2010). Extending this idea, we argue that ecological embeddedness may enable ecological sensemaking for a variety of reasons: it may enhance the relevance of prior enacted environments, increase the opportunities for actors to bracket and interpret local topography and ecological processes over time (and thus expand their repertoires of skills), and facilitate learning through trial and error.

We expect that both ecologically embedded actors and actors with expertise in specific processes such as fire will be better able to make sense of changing ecological conditions because they can access a richer repertoire of actions and meanings, cues and consequences. Actors with some experience of ecological processes—or who have a general working knowledge of natural environments but only a fragmented ability to understand changing conditions—will have a less developed ability to make sense of the ecology in which they are located. Actors who are disembedded are at higher risk when ecological conditions change.

The acuity with which ecological sensemaking is done is likely to affect outcomes such as survival and resilience. Vulnerability, the flipside of resilience, arises when actors limit (or exceed) their ability to make sense of, and respond to, feedback from their natural environment (Farjoun & Starbuck, 2007; Weick, 1993). We examine vulnerability and resilience in both of our empirical settings. We also extend research on sensegiving by exploring how local ecologies trigger sensegiving among actors and point to implications of ecological sensemaking for organizations and organizational learning.

METHODS

This paper did not start with a gap in the literature; rather, it began with a surprise—the fall near the rapids described at the outset of this article. Instead of ignoring this surprise, we took the advice of Weick and Sutcliffe: "You'll probably know when something unexpected happens because you'll feel surprised, puzzled, or anxious. . . . Trust those feelings. They are a solid clue that your model of the world is in error" (2007: 31). This study emerged as Gail retrospectively struggled to make sense of the accident.

For both cases, we used a grounded theory approach (Charmaz, 2006; Strauss & Corbin, 1998) that fits with the emergent nature of our research. Our research design was iterative and included participant observation and interviews, followed by document analysis and further interviews (Charmaz, 2006). We intertwined data collection and analysis using NVivo to help us manage the large database. NVivo is a qualitative data software program that allows researchers to store and code various data sources and to link data "nodes" (conceptual categories). NVivo does not code the data on its own, but its electronic retrieval capacity allowed us to more easily compare and contrast large amounts of qualitative data on actors, incidents, and types of ecosystems. NVivo also allows researchers to electronically link evolving interpretations to data sources. In both studies, we carried out data collection and analysis in seven overlapping steps.

Step 1: Ethnography

Our study began when Gail was a participant observer in Cree territory in James Bay, Canada, for 18 months. Her ethnographic data encompassed three primary sites: the villages of Nemaska and Eastmain, and Freddy Jolly's trapline, located on a bank of the Rupert River, a large wild river and watershed system, 70 kilometers south of Nemaska. With Freddy, Gail traveled throughout the trapline for approximately 9 hours per day for more than 60 days (over 500 hours). In addition, she visited other villages and traveled to ten other bush camps by snowmobile. Gail took more than 200 pages of field notes, conducted hundreds of informal interviews and daily conversations with her key informant and others, and carried out 31 in-depth interviews with Cree trappers, elders, youth, teachers, Band Council members, and representatives from Cree regional organizations.

Step 2: Writing Narrative Accounts

Narrative accounts are particularly useful for capturing ambiguous process data (Langley, 1999) and for richly conveying tales from the field (Goodall, 2008; Van Maanen, 1988). "This strategy involves construction of a detailed story from raw data" and "provides a "vicarious experience" of a real setting in all its richness and complexity" (Langley, 1999: 695). Ethnographic field notes contain both the raw elements and basic storyline, which narrative crafting later refines into evocative stories (Goodall, 2008). During the ethnography, Gail prepared extensive daily field notes from which she wrote detailed narrative stories soon after. The narrative of Study 1 was written two months after the actual incident. This delay was related to the emotional shock of the accident, which was the only ethnographic incident not immediately described in field notes. The narrative, once developed, was discussed with Freddy for feedback and validation. Close reading of the narrative by both authors helped us identify a common understanding of the emergent themes.

Step 3: Initial Coding

Gail coded her participant observations and interviews in situ by hand (the trapline had no electricity) and did more detailed line-by-line coding after leaving the field using an early version of NVivo. We used in vivo codes (Charmaz, 2006) to capture local perspectives and observations on daily activities (bush life) and to categorize how actors interpreted the changing natural environment and how they adjusted their actions accordingly. For example, we used the in vivo code "the bush" to contain material descriptions of local ecology. We included subcodes on types of vegetation, animal patterns (e.g., population size, location, and changes such as thickness of animal fur), bird migration, climate (including moisture and precipitation), wind, water flow, ice flow, and temperature. We also categorized data by season and gathered Cree perspectives on temporal dimensions of ecological processes and subsistence living. Gail described daily ecological conditions and noted transitions (e.g., "freeze-up," "thaw," "forest fire").

We also used in vivo codes to describe categories of action such as "manage," the emic term Freddy and many other Cree hunters used to describe their daily actions in the bush. These included "hunting," "fishing," "trapping," "getting supplies," "giving back to the land," and "story telling," as well as nonroutine actions such as "dealing with surprise," "managing conflict," and "struggling with ambiguity." At the in vivo stage of data analysis, we asked ourselves, what aspects of the trapline are Freddy (and other hunters) paying attention to? How is he using these to make sense of his daily experience? How do his actions reflect this sensemaking? What happens when someone (such as Gail) is not paying similar attention? These data were used to help the authors interpret and extend the sensemaking processes used by Freddy and Gail in the extended narrative presented in this article.

Step 4: Identifying Emergent Themes through Reflexivity

After detailed in vivo coding, we took a step back from our field work to reflect on our data in light of the relevant literature. Gail engaged in personal "reflexivity," and both authors engaged in "epistemological reflexivity" by analyzing how the initial crisis triggered new conceptual insight on sensemaking. At this time, we identified the etic codes of "ecological materiality" and "ecological sensemaking"—the process by which an actor makes sense of material dimensions of local topography and ecological processes. We also contrasted narratives and in vivo codes with existing theory and gathered additional data (interviews, participant observation, documents from the Cree Trappers' Association) over an eight-month period (starting in March 1997) for further comparison.

Step 5: Analyzing Other Contexts (Study 2)

Study 2 consisted of a detailed document analysis (Hodder, 2003) of Weick's (1993) exclusive data source, Norman Maclean's (1992) *Young Men and Fire*. Maclean's book is a rich source for textual analysis (Gephart, 1993) because it synthesizes many divergent sources on the Mann Gulch disaster. Maclean presented highly detailed results of a 40-year investigation of the 1949 disaster based on a variety of sources, including rich archival data, public inquiry reports, participant observation of the Mann Gulch fire and subsequent conditions, various site visits (alone and with experts), interviews with survivors and experts, and mathematical models of fire spread.

We reanalyzed *Young Men and Fire* as a rich narrative (Langley, 1999) and coded the full text (301 pages) in a search to extend or disconfirm the conceptual insights drawn from Study 1. For example, we searched for data to describe the material dimensions of Mann Gulch in terms of topography and ecological processes (climate, vegetation growth, weather, fire spread), and explored how these entered into the sensemaking processes of the foreman (Wagner Dodge) and his crew. We also gathered additional documents on the Mann Gulch fire from the U.S. Forest Service and natural sciences research (Alexander, Ackerman, & Baxter, 2009; Lillquist, 2006; Rothermel, 1993), and contacted a key informant from Maclean's book—Richard C. Rothermel, a retired forest scientist who developed models of fire spread that Maclean used. From this data set, we developed a rich summary of the ecological processes unfolding in Mann Gulch over time.

Initially, we coded data on Mann Gulch as it related to the conditions of the local ecosystem. Later, we constructed a time line and analyzed spatial and temporal processes as they related to the fire conditions. We also used maps and spatial analyses by experts such as Rothermel (1993) to better understand how wind, fire, fuel, and other factors interacted with the topography of the Gulch. From this examination, we concluded that Weick's 1993 and 2007 accounts did not adequately describe critical aspects of ecological materiality.

Step 6: Further Integration of Theory and Refinement of Coding

In the sixth step, we again compared our understanding of the subarctic and Mann Gulch with the existing literature on sensemaking. At this stage, we recoded the data sets from Studies 1 and 2 to identify the microlevel processes that different actors used to make sense of their environments, including the role played by ecological materiality in the two settings: How did actors notice and bracket raw data and select connections between ecological cues? What was the prior experience of these actors? How did this experience influence their selection and interpretation of cues?

Here we moved away from in vivo coding to a more conceptual level of coding (Charmaz, 2006; Strauss & Corbin, 1998) in which we analyzed the process of ecological sensemaking as it relates to the questions of "when, where, why, who, how, and with what consequences" (Strauss & Corbin, 1998: 125). For example, in Study 1, we coded the extended narrative to identify how Freddy and Gail bracketed material cues from the subarctic and how they were (or weren't) able to make connections among cues, over time, and how they drew upon prior experiences to shape meaning. In Study 2, we examined how various Smokejumpers (including Dodge) appeared to notice and bracket material cues that emerged from the natural environment and the varying degrees to which they were able to connect ecological cues and immediate actions. This last stage of data analysis occurred in 2008–09.

We used the comparative method in grounded theory in a variety of ways. By combining data from the Canadian subarctic with data on the Mann Gulch disaster, we utilized comparative study of incidents (Charmaz, 2006: 53) and compared data from two different incidents (crises) arising from the natural environment—black ice on rocks near rapids in James Bay and the "blowup" in western Montana. We analyzed how these incidents were similar and different and how this combination of similarity and dissimilarity affected the process of social and ecological sensemaking. Note that our use of etic terms such as "ecosystem," "topography," and "ecological processes" was not meant to reify or obscure the specific qualities of Freddy's trapline or of Mann Gulch (Gephart, 1996), but rather was meant to facilitate comparison. Within and between incidents, we compared data from different actors. Finally, we used the combined data sets and existing theory to generate propositions regarding how different patterns of sensemaking may influence critical outcomes in dynamic ecosystems.

Step 7: Validity Checks

For both studies, we utilized multiple data sources to triangulate data gathered by participant observation, informal and in-depth interviews, scientific documents (including maps), and narrative descriptions (e.g., Maclean, 1992). For Study 1, we used respondent validation (cf. Locke & Velamuri, 2009) with Freddy Jolly and other Cree hunters. For Study 2, we asked Richard C. Rothermel to check the accuracy of our account of Mann Gulch. We further checked our interpretation of ecological processes and topography with a fire ecologist, Ken Lertzman, School of Resource and Environmental Management, Simon Fraser University, and with Rob Walker, an experienced wildlands fire manager from Parks Canada.

FINDINGS: STUDY 1

We open our findings with an ethnographic tale from the field (Goodall, 2008; Langley, 1999; Van Maanen, 1988, 2010). In this narrative, the first-person singular refers to Gail.

Ethnographic Narrative

One Sunday afternoon, I began a field study of managers in the subarctic. Although I had been in James Bay for nearly a year, this was the first day that I was collecting data from the local hunting ground. It was not a social visit—I had arrived alone, to see if I could "shadow" Freddy Jolly as he worked as a Cree tallyman, the lead manager in charge of the family trapline. In a sense, it was a check to see if my proposed study of Indigenous management had value. On that day, with temperatures well below freezing, I slipped and fell in the river. It was the single most important event of my fieldwork.

I didn't know that at the time. I was following Freddy on what seemed like a straightforward task: we were going to a hidden cache of gasoline, located down an arm of the Rupert River, about an hour by boat. We were going to bring back ten liters for the snowmobile, an important tool for the fast approaching winter. The cache was located below a set of steep rapids a few kilometers from camp. They were not the largest rapids on Freddy's trapline, but they were sizeable. The water was already cold, although it was still before freeze-up. As we approached the rapids, Freddy called to me, "Bush lady [his nickname for me], grab the paddle. If the motor stops, paddle us to shore while I try to start it again."

Paddle it to shore if the motor stops! At first I thought he was kidding. But he didn't seem to be. Then I thought that if the boat went down the rapids, it was unlikely that we would survive the fall, or if we did, that we'd survive the hypothermia. I nervously held the paddle, a cheap plastic emergency model, and started to sweat: I had doubts about my ability to paddle our combined weight of nearly 400 pounds (plus the boat) over to shore against a strong current and the pull of the rapids. I was small. Freddy was large. I would not be able to do this. I thought, he must be testing me.

"Don't worry! It probably won't happen," he said. Then Freddy started to laugh. But I didn't relax until he had safely steered the boat into a cove away from the rocky drop-off. We got out and started walking along the edge of the river, down toward the cache at the bottom of the rapids.

Freddy, as usual, was in the lead, walking and carrying his rifle, looking out for animals and other game. The Cree survive on subsistence hunting, fishing, and trapping. I followed him, carrying the backpack and an empty box to put the gas can in. It was below freezing, but I was dressed fairly lightly—down vest, big wool sweater, Gore-Tex® mitts, rain pants, and my Sorrel® boots. We were walking across an inclined rock face and we stayed pretty far back from the edge—probably six feet or more. It was a clear day and I watched Freddy intently, watching how he behaved in the bush, thinking about how at home he was, watching how he behaved as a manager (the label he used for himself), noting how he knew the terrain. I was busy thinking about my fieldwork, how I was finally in the bush, starting my ethnography. I was excited and alert, anticipating all the tales I could soon tell.

Then I slipped.

Before I knew what was happening, my legs shot out, and I fell down the rock face. I hadn't been watching my feet, partly because I was carrying a box that blocked my view, and partly because I hadn't really thought to. I hadn't known about the possibility of black ice[1] on rocks. And so, not knowing, I slipped. Later, Freddy told me that I started screaming like crazy. All I know is that I started clawing at the rocks, trying futilely to stop my fall. Damn the Gore-Tex—I couldn't get my mittens off and they had no grip on the ice. I sunk into the winter current. Very quickly I was hip-high in water and being pulled by the river.

At that point, I knew real fear. The current was starting to pull me away from the rocks, closer to the rapids. They were about 30 feet away. I wasn't all the way in the water, but I could feel that I didn't have the strength to hold on to the rocks for much longer. I forgot about remaining marginally outside the moment. I forgot that I wanted to write a Tale from the Field. I yelled out. But I don't remember screaming. I don't remember that at all.

Hours later, Freddy told me that if I hadn't been screaming so loud, he'd never have heard me over the roar of the water. He did not see me fall. He was too far out front to notice. All I remember are his big hands grabbing at me—and missing, the first time. I remember that on the second try, he dropped his rifle, caught my right wrist, and started to haul me out. He also yelled at me to grab the rifle as it fell down the rock face. I was surprised but didn't stop to think. With my left hand I grabbed the rifle just before it disappeared into the water, and just as Freddy pulled me onto the rocks, onto safety. Everything seemed to go very slowly.

Once out of the water, Freddy shouted at me, "Where are you wet? How wet? GET THOSE PANTS AND BOOTS OFF! NOW BUSH LADY! NOW!" Freddy seemed like he was still in crisis mode while I was suddenly calm. Later I realized that I was probably in shock with mild hypothermia. I do remember that I was embarrassed to take off my leggings and stand in front of a Cree hunter in just my wet underwear, which I delicately kept on. But he kept yelling at me and I did as he said, took off my rain pants, my tights and my boots, and stood on the bare rock face. My legs were incredibly red. Freddy took out the insoles of my boots and wrang them out. He took off his own boots, gave me his woolen socks, and put his boots back on. "Here, put these plastic bags over the socks . . . Put them on quick. Warm up." I put my rain pants back on. I was still very cold.

I thought, "Now let's get home."

Freddy sighed. "Come on bush lady, let's go get the gas."

The gas? I wanted to go back to the bush camp. I wanted to go inside and sit by the warm fire. Have some hot tea. Rest. Maybe take a nap. I assumed that we'd leave immediately. But Freddy needed the gas. It was the reason we set out for the river in the first place. "Come on," he said. I was amazed that we were not leaving. But I was too numb to argue. So we continued our journey and made our way slowly and carefully to the cache. Freddy talked nonstop, about his father, about other accidents, about life in the bush. I have little recollection of any of these stories, except that his father had liked the blueberries that grew nearby in late summer.

We stood looking up at the rapids when we finally reached the bottom. The rock face was flat at the bottom, and Freddy stood near the edge. I stood well back. "Take a picture," he said. "Take a picture." For once, I didn't want to. "Come on bush lady. I'll take your picture. Stand in front."

As he photographed me, he said, "I was going to jump in. When I missed you the first time, I was

[1] Black ice has few air bubbles and is transparent. On wet asphalt it looks black, hence the name.

going to jump in front . . . to block your path and maybe throw you out." Freddy looked at me. "I'm heavier," he said simply. "Maybe I could fight the current better." We were quiet then. I knew that Freddy could not swim.

I helped Freddy lift up a heavy old canoe, grab the big gas can, and then load it up on his back. He used a head tie to balance the weight. I was so tired I was nearly dropping. But I was warm. On the way home we were silent. As we neared the camp, Freddy said, "Bush lady . . . I was thinking . . . I was thinking about what it would be like if I had to take this journey home by myself."

"I was thinking that too," I said. We anchored the boat.

Back at the camp, Freddy, Annie (his wife), and Freddy's youngest brother, Tommy, and another Cree hunter were there. A few white teachers were also visiting. Freddy and I walked into the front room and I just stood there, saying nothing. I moved toward the stove while Freddy explained in Cree what had happened. Everyone was upset. Annie got me some tea, and the teachers left. It started to snow.

Tommy and the other man came over and stood by me. The man I didn't know started talking slowly in English. He told me about the time he had fallen near those same rapids, how he'd gone in wearing hip-waders (hip-high rubber boots), no knife, how he had managed to keep one leg up, on the rock face, while the left wader started to fill up with water. He told me how he'd hung there, with his bare hands and one foot, clinging, pulling himself up. He'd made it. He told me to always carry a knife if I wore hip-waders, so that I could cut a drainage hole before they became lead weights in water. Freddy emphasized again that if I hadn't been screaming so loudly, he'd never have heard me.

That night, I refused to stay over in the bush camp or in the nearby village. Instead, I drove back to my apartment in Eastmain, driving seven hours through a blizzard. It was another unwise idea. This time I arrived home, nerves frayed but without further incident. I did not think that I would go back to the bush. I did not ever want to wear hip-waders. I wanted to go home. My idea of studying Cree management was deeply shaken. I put my ethnography on hold.

Ecological Materiality in James Bay

James Bay is located between the 51st and 54th parallels and is part of the boreal forest biome, with many large wild rivers and extensive watersheds. It is a harsh environment where subtle ecological change is an ongoing fact of life (Chapin et al., 2009). Northern regions such as James Bay are complex landscapes: topographically diverse, with both high and low amounts of sunshine (depending on the season). James Bay is covered in snow and ice for most of the year and has low species diversity, yet each species has high functional diversity (Chapin et al., 2004; Elmqvist et al., 2004). The region is also prone to fire and insect outbreaks. Taken together, this diversity "gives rise to a wide range of microclimates, ecosystem types, and successional stages within a small area, providing a wide range of local environmental adaptations" (Chapin et al., 2004: 345). These "radically different local microenvironments" (Chapin et al., 2004: 345) require expert local sensemaking to ensure successful human-nature interactions over time.

Ecological Sensemaking

Cree have lived in James Bay for more than 5,000 years, adhering to traditional management practices such as hunting, trapping, and fishing. They organize these activities to vary with season and topography: the Cree spatially rotate their hunting, fishing, and trapping to adapt to changing climate, vegetation growth, and animal, bird, and fish populations. They call this management process "bush life." Freddy's trapline covers approximately 546 square kilometers (211 square miles) of wilderness, including the Rupert River, which has many sets of rapids. In this locale, a variety of raw elements are available for sensemaking. Table 1 identifies how Freddy and Gail differed in their processes of enactment, selection, and retention.

Freddy was born and raised in this bush and had apprenticed with his father for more than a decade, after which he had been leader of the family hunting ground for nearly 20 years. Freddy spent nearly eight months of every year living off the land, and he personally identified with it, sometimes saying "This is Freddy-bush speaking." The bush was his home, and making sense of the natural environment was a routine focus of his daily life. As Freddy said repeatedly, "We never get books, never read the books about animals. All we see is our land. The tracks of the animals, that's our book." Tacit knowledge was reinforced by his long apprenticeship and a multigenerational storehouse of knowledge passed down through story and myth. Freddy had expert knowledge of a vast wilderness area: "Here in our land, our trapline, we know the hills. We know where the lakes are. We know where to go in our trapline." He had also trained himself to expect surprise and to improvise. He was alert, skilled, confident, and humble; he knew that at any time he could be faced with a life-threaten-

TABLE 1
Ecological Sensemaking in James Bay

Actor	Retention: Prior Enacted Environments	Enactment: Noticing and Bracketing Flux	Selection: Selecting Plausible Stories
Freddy	Born in the bush. Decades-long apprenticeship. Routinely gathers ecological information about trapline. Intergenerational knowledge of land. Expects surprise. Has fallen through ice previously.	Actively looking for raw data on weather, river, rapids and landscape. Identifies problem with motor. Does not see her fall.	Actively interpreting changes in weather, river, rapids, and landscape. Knows Gail is a novice but doesn't know she isn't watching for ice. Hears scream, runs back. Yells "Grab the rifle." Creates contingency plan: Jump in river. Recognizes hypothermia; improvises dry clothing; continues task, prevents hypothermia, gets gas
Gail	Doctoral studies. Lived in village, visits Freddy's camp. Trusts him. No prior experience with accidents in nature. No knowledge of James Bay.	Notes weather, but doesn't bracket local conditions. Carries box that blocks view. Doesn't notice signs of hypothermia.	Recognizes seasonal weather, but not where ice forms. Aware of her paddling limitations. Watches Freddy watching surroundings; doesn't understand need to do this herself. Doesn't recognize risk of hypothermia; wants to return to camp.

ing situation in the bush. Despite his expertise, he had once fallen through the ice and directed his children to form a human chain to pull him out. Freddy had a broad perspective on safety and risk in the natural environment—both would occur with regularity, and he was prepared to improvise in the face of surprise (Wildavsky, 1988).

Setting out to get the cache of gasoline was something Freddy did each year before the river froze. He was well aware of the annual seasonal changes on this part of the trapline. He knew that the river was dangerously cold, and that black ice was possible. In the incident, Freddy was (literally) paying attention to the ground, the bush itself, which was not a decorative backdrop. He was actively bracketing and making connections between the wind, conditions of the river, temperature, strength of current, and the landscape (e.g., the cove, the sloped rock face, the route home). He spotted potential problems in advance (e.g., the motor) and identified potential solutions. Freddy did more than save Gail from the rapids: he also had the presence of mind to save the rifle, get her to take off her boots and wet clothes, and insist they continue with the task at hand and only return home once body heat (and gasoline) was restored. These actions prevented hypothermia (and secured supplies for the winter).

Freddy was adept at ecological sensemaking, but found this "sticky knowledge" difficult to pass on to his non-Cree apprentice, particularly during the first day of her apprenticeship (cf. Argyris & Schön, 1978; Szulanski, 2003). Although he made note of Gail's lack of experience, he was not able to effectively make sense of her vulnerability. He did not realize she was not paying attention to the bush: this was beyond his experience.

Gail was paying attention to Freddy. Her enacted environment was social in nature, in keeping with her past experiences. Freddy was (literally) the figure she was watching as she struggled to learn how he operated. Gail's sensemaking process was restricted, most notably by noticing, bracketing, and creating connections exclusively among social data, leaving her oblivious to all but the most rudimentary ecological processes (sunny day, cold, icy river, new snow). She was not aware of the need to bracket local ecological elements in the field and organize them into a coherent network of causal sequences; instead, she just carried the box in a way that obscured her view. She therefore missed important raw material—which shortly became salient.

These differences had consequences for the two actors' abilities to make sense of the situation. When a subtle material cue appeared on the bank of the river—the formation of black ice—Freddy detected it and paid respect to its danger by staying back and walking carefully. Gail didn't notice the ice, and her failure to bracket it put her at risk.

Sensegiving

Sensegiving processes emerge at various parts of the story (Maitlis & Lawrence, 2007). During the emergency, Freddy was very clear in his directions ("Grab the rifle;" "Now bush lady! Now!" "Let's go get the gas"), framing Gail's responses (grabbing the rifle, taking off her boots, getting the gas). Explicit narrative ability thus facilitated effective sensegiving (Dunford & Jones, 2000; Gioia & Chittipeddi, 1991; Maitlis & Lawrence, 2007). The incident also illustrates the importance of "swift trust" (Meyerson et al., 1996) within sensegiving and receiving—during the crisis, Gail immediately followed Freddy's directions. Additionally, we note the process of "swift sacrifice"—Freddy was prepared to jump in the river to throw Gail out (despite his inability to swim).

After the accident, Freddy and other hunters used this experience as an important moment for retrospective (Weick et al., 2005) and prospective sensemaking (Gephart & Topal, 2009). Not only did they try to explain how she should deal with a similar situation, but they also identified related threats and collectively shared stories on how they had learned to avoid death (e.g., carry a knife if you wear hip-waders).

Freddy's sensegiving process was also very experiential. Here is another example: One weekend in March 1997, Gail and a visitor were assigned the task of getting more slow-burning firewood from the forest behind the camp. She and Freddy had done this task often (two or three times each week over a four-week period) and she became quickly focused on debarking and debranching fallen trees. The visitor, who was an experienced outdoorsman, operated the Husquvarna chainsaw.

Suddenly, a freshly cut 30-foot tree got caught in a cross-wind and fell upwind. Gail was dangerously unprepared. She had not been listening to the saw. She had not been paying attention to the wind. The visitor yelled but she had only seconds to respond, and it was difficult to run in snowshoes through deep snow. She made a last-ditch choice of direction and leapt as the top branches clipped her shoulder and dropped her to the ground. Freddy, who had been working a kilometer or so away, showed up shortly. He said he knew something was wrong when he heard the chainsaw stop and stay stopped. Gail was again lucky, though shaken, scraped, and bruised. Afterward Freddy took to calling her "the wounded hunter" after one of his poems. The serious use of humor was a linguistic technique that Freddy used to trigger more ecological sensemaking.

Freddy also engaged in sensegiving-through-action by physically demonstrating an act or skill (e.g., hunting, chopping wood, checking wind direction or ice thickness). This material aspect of sensegiving was an important element of apprenticeship as Freddy purposely and repeatedly put Gail in situations that experientially tested her evolving skill in making sense of the ecological surroundings. After the tree incident, whenever they needed firewood, Freddy used to purposely drop trees near her to see if she was paying attention. This type of sensegiving (and receiving) helped Gail develop the ability to "reflect-in-action" (Schön, 1983) and build resilience through risk management, as opposed to risk suppression (Wildavsky, 1988).

FINDINGS: STUDY 2

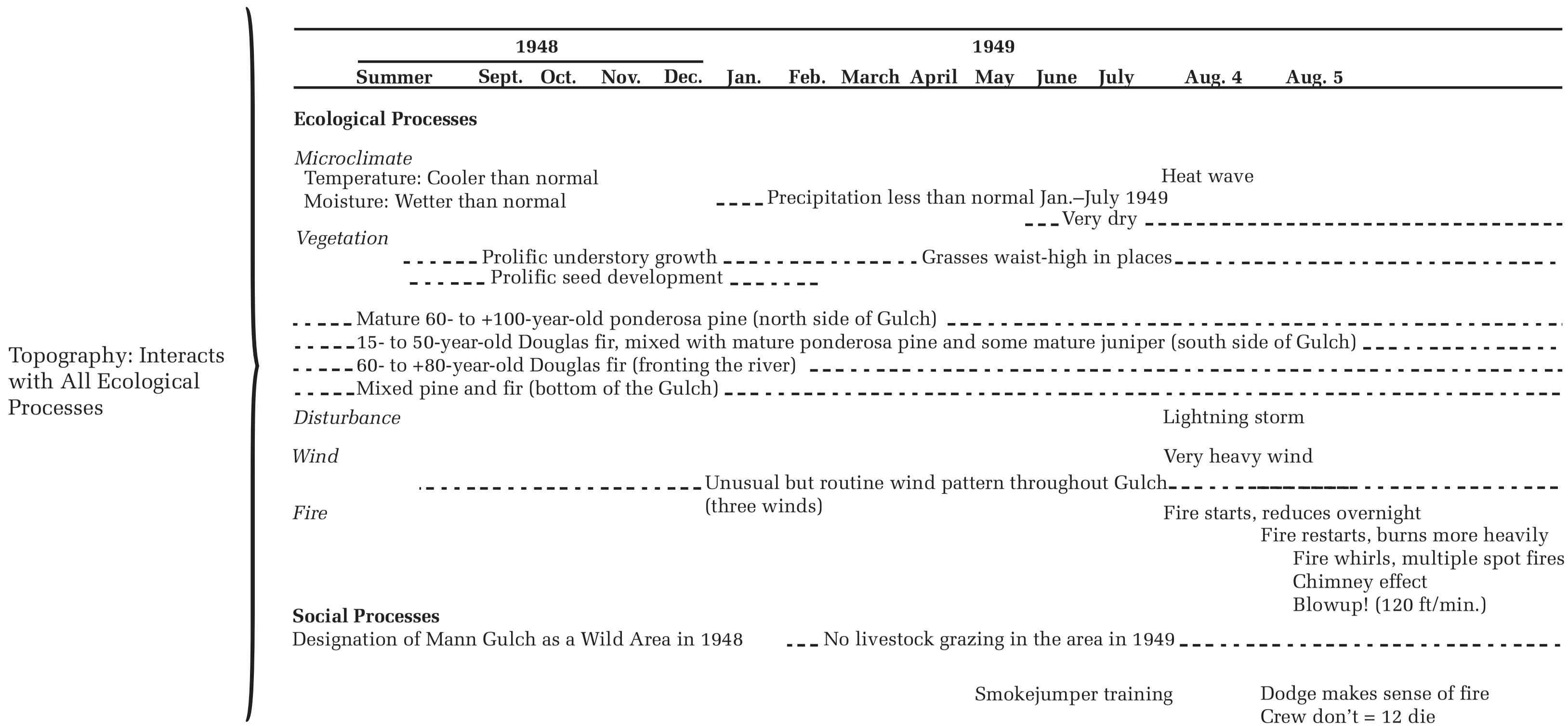
Norman Maclean's 1992 book, *Young Men and Fire*, provided a detailed account of the ecological materiality of Mann Gulch, starting with Maclean's first sighting of the fire in August 1949, through many trips to investigate the local terrain, culminating in his resolution of its many ecological mysteries in 1989 (the book was published after Maclean's death in 1990). Maclean also provided "thick" descriptions of how the Mann Gulch crew failed to make sense of the topography and local ecological processes and to explain how this inability contributed to the deaths of many and the survival of a few.

Ecological Materiality in Mann Gulch

The interaction of local topography and ecological processes in Mann Gulch is central to both Maclean's book and subsequent analyses (e.g., Alexander et al., 2009; Lillquist, 2006; Rothermel, 1993). Maclean was convinced that "like most stories of the woods this one must begin with the ground" (1992: 164). Maclean took this dictum to heart and made many visits to the area. The visits allowed him to experientially discover the unusual wind patterns in the Gulch, to correctly identify these winds as critical factors in the blow-up, and to learn that they were a result of the spatial interaction of terrain with the course of the Missouri River. The topography of Mann Gulch influenced all key ecological processes such as vegetation growth and climate. Figure 1 presents a timeline of ecological processes relevant to the fire.

Our timeline shows that the fire's incubation period stretches over the preceding year. "The summer of 1948 was cooler and wetter than normal . . . thus allowing for prolific understory growth and subsequent seed development. . . . While 1949 area temperatures were slightly cooler than normal, precipitation was less than normal. . . . Grasses . . . were plentiful and had grown waist-high" (Lillquist, 2006: 565). The spring rains were less heavy than normal, and the vegetation became very dry by early August. Spatial variabil-

FIGURE 1
Timeline of Mann Gulch Fire



ity also interacted with vegetation and climate: for instance, Ponderosa pine and Douglas fir grew on the south side of the Gulch, and Ponderosa pine and bunch and cheat grasses grew on the north because of local microclimatic processes (cf. Rothermel, 1993). The U.S. Forest Service reported that a "distinct moisture gradient is evident in the gulch; the lower slopes receive more moisture than the upper slopes. This influences the vegetation found in the understory beneath the forest canopy. At the time of the fire, lower elevations had heavier undergrowth, which gave way to scattered timber and grass in the drier areas farther up the gulch" (Rothermel, 1993: 2).

Topography also aided fire spread and intensity in terms of radiation and convection and hindered effective human response (Alexander et al., 2009; Lillquist, 2006; Maclean, 1992; Rothermel, 1993, 2000, and personal letter, 2009). In particular, "the exceptionally steep terrain" with a "76% slope" (an approximately 45 degree angle) drove extreme fire speed (360–610 feet per minute [Lillquist, 2006: 565]) and the spread of both the main fire and Dodge's escape fire (Alexander et al., 2009: 4; see also Maclean, 1992, Ch. 3; Rothermel, 1993). As Maclean concluded near the end of the book, "This is a story in which cartography and plot are much the same thing: if the tragedy was inevitable, it was the ground that made it so" (1992: 224).

Ecological Sensemaking in Mann Gulch

Maclean presented data on a key difference between Wagner Dodge's pattern of (what we are calling) ecological sensemaking and the approaches followed by the rest of the crew. We summarize this difference in Table 2.

The Smokejumpers knew they were there to fight a fire, and all had general woodsman skills that can be useful for fighting fires. However, the crew had only fought small fires in the past, did not have extensive fire training or firsthand understanding of large fires, thought the fire looked "more or less routine" (Maclean, 1992: 43), were on land that was "unfamiliar to them" (Maclean, 1992: 43), and could not organize a causal sequence that made sense of the interaction of terrain, moisture, changes in vegetation, wind, and the emergence of fire whirls and spread (given convection and radiation). Nor could the Smokejumpers make sense of

TABLE 2
Ecological Sensemaking in Mann Gulch

Actor	Retention: Prior Enacted Environments	Enactment: Noticing and Bracketing Flux	Selection: Selecting Plausible Stories
Dodge	Little prior knowledge of Gulch. Prior experience on category C and D fires. "Dodge's life as a woodsman shaped his thoughts in an emergency."	Did not bring maps. Noted turbulence while in airplane but doesn't relate this to fire. Used time to analyze fuel (trees, grass, moisture) and changing wind and landscape. Saw fire jump Gulch and noted upgulch wind.	Was not part of crew training; didn't realize implications for trust. Concerned that the ridge had no place for emergency rescue. Didn't like what he saw, but not sure where the danger lay. Decided ridge wasn't a safe place to attack fire. Understood interaction effect = death trap. Realized crew could not outrun fire and improvised escape fire. Realized the crew was ignoring his invitation but didn't know why. Located survivors.
Smokejumpers	All tough and very fit. Not much prior knowledge of Gulch. Past experiences with small fires limits attention to fire spread. Sallee and Rumsey attributed survival to growing up in the woods.	Did not have maps. One did not jump, but rest don't consider this. Proceeded down Gulch, walked into strong headwind. Didn't see fire jump the Gulch. Watched fire but didn't consider it dangerous.	Don't connect headwind to fire spread. "A very interesting spectacle. That was about all we thought about it." Didn't recognize consequences of fuel change. Realized danger too late, and ran. Saw Dodge light a fire but didn't understand why. Kept running. Sallee and Rumsey made correct topographical choices and climbed through crevice to safety.

the actions of their leader: Dodge kept motioning for the crew to follow his lead (Maclean, 1992: 99), saying "this way, this way" (Maclean, 1992: 93), pointing to the path cleared by his escape fire, which they all ignored. One of the crew said "To hell with that, I'm getting out of here," according to the recollection of a survivor (Maclean, 1992: 94). The Smokejumpers had never worked with Dodge (Maclean, 1992: 40), didn't "know much about [Dodge] and he knew almost nothing about them" (Maclean, 1992: 40) except their names (Maclean, 1992: 42). Hence our point: Mann Gulch was a tragedy fueled by failures to make sense of both ecological and social processes.

In contrast, Wagner Dodge's enactment of the environment was focused on the ground—the specifics of the local topography and vegetation—enhanced by his nine years of firefighting, which had included one category C fire (10–99 acres) and one category D fire (100–299 acres) (Maclean, 1992: 33). This experience helped Dodge make sense of the landscape and prevailing ecological processes and helped him reflect while in action (Schön, 1983), interpret the dynamics of fire spread and intensity, and invent his escape fire. As detailed in Table 2, Dodge was continuously trying to bracket and connect topography and the unfolding ecological processes. Dodge's "life as a woodsman shaped his thoughts in an emergency [in which] he thought with his hands" (Maclean, 1992: 103). But he was less focused on the figures of his crew, only three of whom he knew (Maclean, 1992: 103). Experience-based trust between Dodge and his crew was low, and swift trust did not emerge to take its place.

According to Rothermel, "They would have had opportunity to observe the general lay of the land from the air before jumping, and they landed well up the Gulch and as they walked down the Gulch toward the river had almost two hours to observe their position relative to their surroundings. . . . Dodge had further opportunity to see the terrain when he walked up the north facing slope to meet Harrison. Their bad luck was when the fire spotted from the ridge above them to the mouth of the canyon. With any experience or training in fire behavior they should have immediately known that they were in an extremely vulnerable position" (personal correspondence with first author). But they didn't know. The accounts of the two surviving crew members (Sallee and Rumsey) indicate that no one except Dodge was actively making sense of the fire. One Smokejumper stopped to take photographs.

Just as the fire was about to overtake them, the Smokejumpers chose to ignore Dodge and started running. In our conversation, Rothermel said: "What they were concerned with was primarily two things, the slope of the ground over which they would have to run, and the conditions of the terrain, i.e., was there dense vegetation that would impede their flight or uneven ground over which they could not run, rocks etc.? Here is where the life and death choice was made; four of them, including Sallee and Rumsey, chose to go up the steepest slope directly toward the rim-rock. A very wise choice. The rest of the crew chose to flee up the Gulch, presumably at an angle that was not too steep, and allowed them to move at their fastest rate without going downhill. It now became a matter of physical capability, a condition in which all Smokejumpers take great pride. Unfortunately none of them were fit enough to outrun the fire, two of them even chose to run down hill where one broke his leg. . . . Sallee and Rumsey were exhausted, but once they had decided to flee, they had made the only choice that would save them. It must have been very hard to go up the steepest slope, and, given one man's hesitation, it was apparently difficult to decide to go through the gap in the rim-rock." Sallee and Rumsey survived because they made the right decisions about topography, choosing the steep slope and the gap in the ridge.

The collapse of social sensemaking did not, on its own, kill the Smokejumpers. Their inadequate process of bracketing and making connections between local terrain and the complex ecological processes of fire, wind, vegetation growth, and moisture put them in the precarious position of facing an unanticipated blowup. At this point, they tried to outrun a fast-moving grass fire up a very steep slope. If they had had prior local understanding of Mann Gulch, they might have known that there was an "upgulch" wind in Mann Gulch for much of the summertime. They might have anticipated that the wind conditions were very difficult in this exact spot. Local experience over time would also have provided information about changing climate and its impact on the vegetation that was the fuel for the fire. Maclean put this succinctly: "There are differences between the behavior of grass and timber fires, and the differences can be tragic if firefighters don't know them." (1992: 44).

But they didn't know the terrain: they parachuted in blind; their radio smashed on impact with the ground; they had no maps and little time; and they were reduced to relying upon general woodsman skills, some prior experience with small fires, and physical fitness. These factors were insufficient for most of them, given the unusual topography of Mann Gulch and the highly volatile ecological processes at play. Dodge was able to improvise because he was continuously noticing and bracketing raw data about topography, vegetation, wind, and fire spread, and he had a richer causal network (gained from prior experience with category C and D fires) that helped him interpret the Mann Gulch fire. The others were reduced to flight.

Revisiting Weick

At the start of his 1993 article, Weick provided a short summary of the Mann Gulch disaster. To do so, he tells us that he wants to "strip Maclean's elegant prose away from the events of Mann Gulch and simply review them to provide a context for the analysis" (1993: 628). Weick emphasized the following in his description of the incident: "As Maclean puts it, at its heart, the Mann Gulch disaster is a story of a race (1993: 224)." Topography plays only a cursory role in Weick's (1993, 2007) account, when he notes how the steepness of the north Gulch limited the ability of the Smokejumpers to win a race to the top of the ridge.

This is an incomplete description. Our reanalysis indicates that Maclean certainly describes Mann Gulch as a race, but also as the story of three winds (Maclean, 1992: 133) and of the ground and cartography (Maclean, 1992: 164, 224). In stripping away Maclean's "elegant prose," Weick unintentionally took away essential features of the story. Documents show that Mann Gulch was also the story of microclimate change over time and that the incubation period for the disaster was much longer than a few hours or days (see Figure 1). Mann Gulch is not simply a story of how a team ran a race they could not win because of leadership failure, disintegrating group dynamics and role structure, poor team bonds, and the powerful yet misleading expectation that they were facing an "initial attack fire," one that could be quickly suppressed.

The stripped-down version in Weick (1993, 2007) reduces the ecological context or ground of the story to the role of a secondary player in the tragedy. A more comprehensive account of sensemaking in Mann Gulch acknowledges the interactive effects of both figure (the humans trying to make sense of each other during an unexpected blowup) and ground (winds, fire, topography, vegetation, and microclimate). These are not decorative elements. To be able to anticipate and understand social and ecological processes across space and time is the essence of sensemaking in Mann Gulch.

Across Incidents and Actors

Taken together, the two incidents illustrate the vulnerabilities that arise when actors cannot make sense of ecological materiality. Taken separately, the two incidents have different characteristics in terms of hazards. In our ethnographic episode, the subarctic field was complex, but local ecological processes were not undergoing volatile change. The hazard of black ice on rocks only became a hazard because of disembedded and (thus faulty) ecological sensemaking by Gail. In contrast, the sensemaking arena of Mann Gulch was complex in terms of both topography and volatile ecological processes that were changing at different rates over time (e.g., slow change of climate, moisture, and vegetation, followed by rapid changes in wind, fire intensity, and fire spread). The fire was triggered by a natural disturbance to the field of experience—a lightning storm. The blowup produced a managerial crisis because of incomplete enactment (noticing and bracketing of flux) and faulty interpretations (of the terrain, the fire, and Dodge's actions). Comparing actors from each of the incidents allows us to identify four different patterns of sensemaking based on the degree to which each actor was ecologically embedded in the local terrain. Table 3 summarizes this analysis.

Freddy Jolly, Wagner Dodge, the Smokejumpers, and Gail can be scaled along a continuum that reflects their degrees of ecological embeddedness, operationalized as time spent in a local ecology and our assessment of how much local knowledge of, and experience with, the terrain each actor had. Comparing data across studies, we note that Freddy Jolly and Wagner Dodge have similarities: both are highly experienced woodsmen with a talent for reflection-in-action (Schön, 1983). But they differ in time spent in the local ecology and amount of site-specific knowledge. Neither the Smokejumpers nor Gail had site-specific knowledge, and (respectively) they had fragmented or no expertise at reflection-in-action.

Our assessment is that Freddy Jolly was in the strongest position to notice subtle ecological change in his environment. He is an example of a deeply embedded manager trained to routinely gather ecological information and physically and culturally located in a specific local environment for decades. He has long-term immersion in the bush, continuously brackets and connects information from his ecological surroundings, self-identifies with the bush, and believes in the importance of respecting and protecting local processes such as vegetation and animal growth. As a reflective practitioner, he tailored his actions to the constraints and opportunities presented in the local ecology, which helped him identify both emergent hunting opportunities and potential crises. His ecologically embedded approach influenced his men-

TABLE 3
Patterns in Sensemaking

Pattern of Ecological Sensemaking	Representative Actor	Sensemaking Approach
Ecologically embedded	Freddy Jolly	Sensemaking processes • Retention: lifetime resident of subarctic. • Retention: learning from ecological surprise to improve improvisation skills. • Enactment: focus on natural environment in talk and action. • Enactment: using site-specific ecological information. • Selection: routinely making sense of changes in the local ecology. • Selection: anticipating ecological change and surprise (reflecting-in-action). Sensegiving-through-action with trust.
Expert-driven	Wagner Dodge	Sensemaking processes • Retention: expert wildlands firefighter. • Retention: drawing on skills and knowledge developed in other ecological locations. • Enactment: focus on fire in talk and action. • Enactment and selection: actively bracketing and making connections in new local environment to develop site-specific information. • Selection: anticipating ecological change and improvising an escape fire (reflecting-in-action). Sensegiving-through-action without trust.
Fragmented	Smokejumpers	Sensemaking processes • Retention: Novice firefighters with woods experience and prior knowledge of small fires. • Enactment: focus on prior expectations in talk and action (initial attack fire). • Enactment: missing important ecologically material cues. • Enactment and selection: fragmented bracketing and connection making in local ecology. • Selection: didn't understand the threat until the fire was upon them. Ignoring expert solution and running.
Disembedded	Gail Whiteman	Ecological sensemaking processes • Retention: urban resident. • Enactment: focus on social relations in talk and action. • Enactment: not bracketing local ecological conditions. • Selection: missed important ecologically material connections.

tal maps of the world, grounded his ability to reflect while in action (Schön, 1983; Whiteman & Cooper, 2000), and influenced his approach to sensegiving-in-action.

In contrast, Wagner Dodge lived in the area of Mann Gulch but did not have extensive knowledge of the locale. He (literally) parachuted into hot spots, fought the fires, and left when they were put out. He is an example of a manager who is not locally embedded but who has expert skills at ecological sensemaking. He was a skilled woodsman, had detailed knowledge of fire processes, continuously bracketed raw data, and attempted to interpret the surroundings of Mann Gulch, but he lacked specific knowledge of the local ecosystem over time and had no detailed mental map of conditions in the Gulch. To compensate for being an outsider, he used his time in Mann Gulch to study the topography, wind direction, and vegetation, noticing, bracketing, and integrating this study with his knowledge of fire processes observed elsewhere. Although the ecological materiality of Mann Gulch was a powerful trigger for Dodge's sensemaking and his escape fire, he had insufficient time to translate this sensemaking into effective sensegiving, given the weak social bonds between him and the crew.

The Smokejumpers are examples of fragmented actors: although not ecologically embedded, they had general woods skills and basic understandings of fire processes. Unfortunately, they did not know the topography of Mann Gulch, had no experience with large fires, and were only sporadically noticing and bracketing data about the terrain and fire. Despite being young and tough, they were not able to anticipate ecological surprises, and most were not able to make connections among elements of the available ecological feedback—even when they noticed them—and were left with the only available improvisation: flight. When faced with a life-threatening situation that was beyond their experience, only two were able to make the correct topographical choices.

Finally, Gail is an example of a disembedded actor. She had no knowledge of the subarctic, no woods expertise, and limited outdoor skills, and she was not actively bracketing or interpreting the terrain and was unaware of the need to do so. She surely would have died at Mann Gulch, and she was lucky that she was not faced with a more volatile natural hazard (or a less capable guide).

DISCUSSION

Both of our cases are novel microlevel crises in unusual locations. Although perhaps idiosyncratic and certainly extreme, these situations can help illuminate processes that are less apparent in more mundane settings (Bamberger & Pratt, 2010; Weick, 1976). Put plainly, sensemaking research that takes place in natural environments should be sensitive to how ecological materiality affects the sensemaking process. The cases also make a modest methodological contribution by illustrating how a small-scale personal experience can be used as the basis for theorizing about unexplored phenomena that may also be manifest in more complex, large-scale events or settings.

Our accounts of sensemaking in the subarctic autumn and in the wilds of a Montana summer illustrate how ecological materiality is relevant for sensemaking. We have described the process of ecological sensemaking—the way actors notice, bracket, make, and select connections and act on spatial and temporal cues arising from topography and ecological processes. We illustrated how this process affects survival and resilience when topography and ecology are prominent parts of a setting. Here we offer propositions to guide future research on ecological sensemaking and identify some implications for theory and practice.

Ecological Materiality as a Construct

Material objects shape human interpretation and action, and this is a reciprocal process (Barad, 2003; Latour, 2005; Leonardi & Barley, 2010; Nicolini, 2009; Orlikowski, 2007; Suchman, 2005; Weick, 2005: 226). Human understandings of—and responses to—the natural world are mediated, but natural environments (rocks, rain, climate, fire, ice, and so forth) exist in their own right. That is, we believe that if a tree falls in a forest without any person noticing, local species such as microbes, fungi, termites, and birds will consume the tree, despite its being unnoticed by humans. Ecology can also impose significant material limits or challenges to human action (Dunlop, 2002). For example, gravity ensures that if we fall, the only direction is down. Similarly, when a forest fire burns there is heat and smoke, and people nearby will inhale and choke unless they can materially remove themselves from the equally material combustion. Organization studies has shown little appreciation of how material characteristics of the natural world are enacted, selected, and retained for future use by human actors. Instead, the focus of research has been on understanding the social processes that generate raw data from a field of experience (e.g., Weick, 2005: 187). Though perhaps applicable to denatured settings, this perspective ignores, or diverts attention away from, the coexistence of ecological processes and topography embedded and evolving within what actors may perceive as an undifferentiated flux.

From our perspective, the construct of ecological materiality encompasses topography, such as land mass and water bodies, and ecological processes, such as biodiversity and functional diversity of species, climate, precipitation, soil resources, and their interactions. Topography moderates most ecosystems, including climate, vegetation, wind, water flows, and the likelihood and severity of disturbances such as fire (Heyerdahl, Lertzman, & Karpuk, 1998; Lertzman & Fall, 2007). Changes to ecological processes vary in speed, magnitude, linearity, and predictability (Chapin et al., 2009). Changes in ecological materiality can occur abruptly, as with fire or volcanic eruption; slowly, as with ice formation; and even more gradually, as with global warming. Some changes may be seasonal and predictably linear, while others may be extreme, nonlinear, and unpredictable (Holling, 1986). Ecological materiality has low complexity when topography is uniform and ecosystem processes are stable. Ecological materiality has high complexity when there is large spatial variability and unpredictable, extreme, or nonlinear changes in ecological processes.

The salience of ecological materiality—and hence the need to mindfully bracket and interpret material cues—is affected by several factors, including the dependence of actors on natural environments and the volatility of ecological change, topographical complexity, and subtle, cumulative ecological changes over time (Chapin et al., 2009). Ecological sensemaking is most critical to survival when actors are dependent on complex and changing topography and ecological processes. Making sense of changes to ecological materiality is particularly relevant to managers whose professions call for them to interact with, and depend upon, the natural environment. These professions include forestry, mining, mountaineering, fishing, farming, construction, tourism, aviation, space exploration, seafaring, and emergency responses to hurricanes, earthquakes, oil exploration, and so forth.

Proposition 1. The salience of ecological materiality to sensemaking processes increases with actors' dependence on their natural environment and on the complexity of change in that environment.

Sensemaking research that uses the construct of ecological materiality could operationalize it with existing measures from the fields of ecology, biology, and geography (e.g., see Chapin et al., 2009; Heyerdahl et al., 2007; Lertzman & Fall, 1998; Lillquist, 2006). These might include measures of vegetation and animal growth, CO_2 emissions, air pollution, and precipitation, or spatial measures derived from Geographic Information Systems. However, the environmental sociologist Frederic Buttel acknowledged that "there is much work to be done in specifying the array of mechanisms through which social and biophysical forces interact" (1996: 70). Future research can help unravel these processes of interaction, particularly in terms of power and agency (Barad, 2003; Leonardi & Barley, 2010).

Ecological Embeddedness

Our two cases suggest that ecological embeddedness facilitates more accurate ecological sensemaking because it enhances the relevance of prior enacted environments and increases opportunities to bracket and accurately interpret local topography and ecological processes over time (Fazey, Proust, Newell, Johnson, & Fazey, 2006; Whiteman & Cooper, 2000). Ecological embeddedness allows for subtle understanding of context (King, 1999; Tyre & von Hippel, 1997), greater reflection-in-action (Schön, 1983), enhanced learning, and easier transfer of knowledge within and between settings (Maitlis & Lawrence, 2007); further, it provides opportunities for sensegiving-in-action and encourages more innovative responses to complex problems (King, 1999; Tyre & von Hippel, 1997). Physical proximity to, and knowledge of, local ecosystems can contribute to resilience because "in many cases proximity and direct dependence on the resource base make it easier to filter out and discard practices that are clearly unsustainable" (Folke, Pritchard, Berkes, Colding, & Svedin, 1998: 8). Research on high-reliability organizations has indicated that local maintenance personnel are well situated to "spot unexpected problems and improve organizational learning" because of their location on the front lines of operating systems (Weick & Sutcliffe, 2007: 48; cf. Orr, 1996). These qualities can increase survival and reduce vulnerability (Elmqvist, 2004; Fazey et al., 2006; Forbes et al., 2009; Gadgil & Berkes, 1991; King, 1995; Nelson et al., 2010; Ostrom et al., 1999).

The degree to which ecological embeddedness aids survival is likely to vary with the complexity of a field. For example, the complexity of the Mann Gulch fire was potentially lethal, even for an expert practitioner such as Dodge, because he lacked local knowledge and the conditions were extreme. Schön discovered that, faced with surprise and ambiguity in a unique situation, the expert practitioners he studied manifested reflective engagement with action; that is, they experimented with a repertoire of actions and reflected as the situation unfolded to determine what they could do differently. These efforts increased their ability to deal with complex and unpredictable change.

Proposition 2a. Ecologically embedded or expert-driven ecological sensemaking is most likely to increase the likelihood of survival when the complexity of ecological materiality is high (e.g., high spatial variability and volatile and/or nonlinear changes in ecological processes are present).

When the natural environment is not undergoing rapid or extreme change, the advantage offered by an embedded awareness of ecological change is more limited.

Proposition 2b. Fragmented or disembedded sensemaking is sufficient to facilitate survival when the complexity of ecological materiality is low (e.g., uniform topography and stable ecosystem processes are present).

Routine Detection of Weak Cues

Blowups such as the Mann Gulch fire are hard to ignore, but by the time they invite rapid sensemaking, it may be too late. At the other end of the immediacy spectrum are gradual changes that are harder to notice. They invite unawareness or denial. A slow process of ice formation illustrates the latter, but an even more difficult case is change in microclimate over time, an underappreciated part of the Mann Gulch fire. Subtle or nonlinear variability in ecological processes (such as climate) may be hard to bracket and make sense of unless one is paying close and continuous attention. One strategy to address this is for actors to "scrutinize the minutiae of their local environment" (Schell, cited in Weick, 2005: 470). Such practices enhance the visibility of cues, and this enhancement provides actors with early opportunities for ecological sensemaking.

Proposition 3. The routine bracketing and creation of causal networks among subtle ecological cues increase the likelihood of early detection of changes in ecological materiality.

Sensegiving

In both of our cases, the ability to quickly "give sense" affected survival, as did the ability to quickly trust the survival value of this sensegiving. We also note the importance of adequately assessing competency gaps in both cases. Freddy's clear directions (discursive ability) during the rescue helped Gail survive, but his failure to see that she was not paying attention put her at risk because he did not share with her his understanding of context before they started. However, because swift trust developed between the two actors, Gail trusted his advice unquestioningly and was able to survive. In contrast, there were low levels of trust between Dodge and his crew, and Dodge did not know his crew's competencies; he had not participated in the Smokejumpers' training sessions and he did not have firsthand knowledge of the skill levels of most of the crew. The low trust made it hard to convince his crew to lie down in the fire because they had no experience base for trusting his judgment. This suggests the following propositions:

Proposition 4a. Actors are more likely to engage in ecological sensegiving when they perceive a competence gap in team members.

Proposition 4b. Actors are more likely to accept ecological sensegiving when the level of trust between a sense giver and receiver is high.

Research has also indicated that when actors are faced with surprise and ambiguity, expert practitioners engage in structural, interpretive, and behavioral processes that they attempt to share with newcomers (Schön, 1983). Our subarctic case shows how Freddy engaged in sensegiving-in-action to help Gail become aware of, and interpret, changes in ecological materiality. In the more complex setting of Mann Gulch, Dodge was not able to convey his understanding of the escape fire—leading to the demise of most of his team.

Proposition 4c. The survival value of sensegiving-in-action increases with the complexity of ecological materiality.

Freddy Jolly provides a model of sensegiving-in-action, and Wagner Dodge provides its opposite: one gave clear guidance and one did not. Although their actions took place in natural settings, their implications are not limited to such settings. When newcomers enter novel settings, they are hypersensitive to cues but often don't know what to do with them (Louis, 1980). Effective sensegiving-in-action can provide newcomers, such as Gail, with the interpretive schemes that help make sense of a new setting and permit survival in it. We therefore encourage future research on sensegiving-in-action in a variety of contexts, and not only within ecological settings. In particular, we suggest that sensemaking scholars should investigate how sensegiving-in-action enhances individual and organizational learning.

IMPLICATIONS

A recent article in *Nature* warned that although "the planet's environment has been unusually stable for the past 10,000 years," this stability is unlikely to continue, and "the result could be irreversible and, in some cases, abrupt environmental change, leading to a state less conducive to human development" (Rockström et al., 2009: 472). In such a world, we believe it is useful to understand how people make sense of, and respond to, ecological change, whether subtle or abrupt.

Our call for more research on sensemaking and ecological materiality does not imply environmental determinism—the view that nature dominates how society is organized and how actors must behave (Lidskog, 1998). Rather, we offer a perspective that is similar to the environmental sociology approach to studying "the material/biophysical embeddedness of social processes" (Buttel, 1996: 60). We suggest that future sensemaking research in natural settings should address the varying ways that organizational actors socially mediate ecologically material conditions and the power relations inherent in these negotiations (Barad, 2003). We have argued that natural processes may unfold without people naming them and independent of human recognition, yet we do not suggest that human interpretations of ecology do not carry meaning, or that humans do not affect material conditions in the natural world. Rather, as Barad argued, it is "possible to acknowledge nature, the body, and materiality in the fullness of their becoming without resorting to . . . the theoretization of the human as either pure cause or pure effect while at the same time remaining resolutely accountable for the role "we" play in the intertwined practices of knowing and becoming" (2003: 812). Future researchers may also wish to explore the role of technology in this dynamic (Orlikowski, 2007; Suchman, 2005).

Research is also required to explicate the conditions under which ecological sensemaking has the most pronounced effects on survival and resilience, both human and other (cf. Dunlop, 2002). Although our study does not directly relate ecological sensemaking to sustainability issues, we think there are links. Many organizations depend on natural resources, yet 60 percent of global ecosystems are significantly degraded (World Resources Institute, 2005), and some economists have estimated that the costs of adaptation to climate change may be as high as 20 percent of the combined gross domestic products of the world's nations (e.g., Stern, 2006). Given these changing contexts, it is important for organizational actors to routinely make sense of these dynamic (and costly) changes to the natural environment.

We have focused on microlevel accounts of ecological sensemaking and have not addressed how that process occurring at the individual level can be linked across different localities and scales (Folke et al., 1998). However, we think that our work has collective implications for research on organizational resilience. Although different definitions exist, the term "resilience" usually refers to the ability to rebound after a stress or crisis (e.g., Coutu, 2002; Hamel & Valikangas, 2003; Rak & Patterson, 1996). Research has shown that the ability to make sense of such situations is a key factor influencing the resilience of an organization or team (Freeman et al., 2003; Riolli-Saltzmann & Luthans, 2001; Perrow, 2002; Weick, 1993; Weick & Sutcliffe, 2007). Studies have further suggested that highly resilient organizations are those that track small failures, are reluctant to simplify, build an evolving situational awareness and sensitivity to operations, anticipate and contain surprises, and take advantage of shifting locations of expertise (Weick & Sutcliffe, 2007). In particular, organizations that take advantage of the shifting locations of expertise may be more likely to survive when faced with changes in their natural environments.

Our findings suggest the potential value of local ecological sensemaking as a factor in organizational resilience under certain conditions. That is, organizational resilience may be increased by local bracketing of ecosystem dynamics for those organizations that are dependent upon natural resources as inputs (e.g., for sustainable forestry), through a reduction in environmental degradation, thereby preventing crisis (Gephart, 1993), through the anticipation of geographic risks inherent in specific organizational locations (e.g., from hurricanes), and through the enhancement of organizational preparedness for such ecologically driven emergencies (see Boin, 2009). Conversely, if local actors are not routinely engaging in ecological sensemaking, and/or this expertise is not effectively transferred "across scale," hidden vulnerability can escalate into crisis.

Future research can examine if organizations and communities that depend on natural environments are more likely to survive when "cross-scale" local ecological expertise is integrated into resource decisions. For example, Fisheries and Oceans Canada is establishing a small-scale monitoring project conducted by local communities on the west coast of North America. The project will link local knowledge to a large-scale science-based monitoring program in the Arctic. The objective is to build more resilience in river-marine ecosystems through better monitoring of resource decisions. This is an example of ecological sensemaking at the community and organization level that may enhance community survival by reducing regional ecosystem degradation.

Organizations may also benefit from local selection of employees for ecologically sensitive positions. For example, fire crews in the Rocky Mountains of Canada and conservation officers in Australia are experimenting with how to best integrate locally embedded ecological knowledge into fire crew deployment and conservation measures (Walker, personal conversation; Fazey et al., 2006). Drawing on knowledge of local ecological processes is a direct way in which organizations can increase the reflexivity of teams and draw on the lessons of past mistakes. Research on these practices would help to assess the practical value of ecological embeddedness.

Finally, it may seem obvious that contextual knowledge of local ecosystems can be useful in unfamiliar settings or those that are experiencing periods of instability. However, when an individual's expertise lies elsewhere (e.g., in social domains), she or he tends to overlook the obvious, as the story from Gail illustrates. A contribution of our study is to resist oversimplification by reexamining the obvious—the need to make sense of an ecologically material world.

REFERENCES

Alexander, M. E., Ackerman, M. Y., & Baxter, G. J. 2009. ***An analysis of Dodge's escape fire on the 1949 Mann Gulch fire in terms of a survival zone for wildland firefighters.*** Paper presented at the 10th Wildland Fire Safety Summit, International Association of Wildland Fire, Phoenix, April 27–30.

Argyris, C., & Schön, D. A. 1978. ***Organizational learning: A theory of action perspective.*** Reading, MA: Addison Wesley.

Bamberger, P. A., & Pratt, M. G. 2010. From the editors: Moving forward by looking back: Reclaiming unconventional research contexts and samples in organizational scholarship. ***Academy of Management Journal,*** 53: 665–671.

Barad, K. 2003. Posthumanist performativity: Toward an understanding of how matter comes to matter. ***Signs,*** 28: 801–832.

Boin, A. 2009. Meeting the challenges of transboundary crisis: Building blocks for institutional design. ***Journal of Contingencies and Crisis Management,*** 17: 203–205.

Buttel, F. 1996. Environmental and resource sociology: Theoretical issues and opportunities for synthesis. ***Rural Sociology,*** 61: 56–75.

Catton, W. R., Jr., & Dunlop, R. E. 1980. A new ecological paradigm for post-exuberant sociology. ***American Behavioral Scientist,*** 24: 15–47.

Chapin, F. S., III, Petersort, G., Berkes, F., Callaghan, T. V., Angelstam, P., Apps, M., Beier, C., Bergeron, Y., Crepin, A.-S., Danell, K., Elmqvist, T., Folke, C., Forbes, C., Fresco, N., Juday, G., Niemeld, J., Shvidenko, A., & Whiteman, G. 2004. Resilience and vulnerability of northern regions to social and environmental change. ***Ambio: A Journal of the Human Environment,*** 33: 344–349.

Chapin, F. S., III, Kofinas, G. P., & Folke, C. 2009. ***Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world.*** New York: Springer-Verlag.

Charmaz, K. 2006. ***Constructed grounded theory: A practical guide through qualitative analysis.*** London: Sage.

Chia, R. 2000. Discourse analysis as organizational analysis. ***Organization,*** 7: 513–518.

Coutu, D. L. 2002. How resilience works. ***Harvard Business Review,*** 80(May): 46–55.

Diamond, J. 2005. ***Collapse: How societies choose to fail or succeed.*** New York: Penguin.

Dunford, R., & Jones, D. 2000. Narrative in strategic change. ***Human Relations,*** 53: 1207–1226.

Dunlop, R. E. 2002. Environmental sociology. In R. B. Bechtel & A. Churchman (Eds.), ***Handbook of environmental psychology:*** 160–171. New York: Wiley.

Elmqvist, T., Berkes, F., Folke, C., Angelstam, P., Crépin, A.-S., & Niemelä, J. 2004. The dynamics of ecosystems, biodiversity management and social institutions at high northern latitudes. ***Ambio: A Journal of The Human Environment,*** 33: 350–355.

Farjoun, M., & Starbuck, W. H. 2007. Organizing at and beyond limits. ***Organization Studies,*** 28: 541–564.

Fazey, I., Proust, K., Newell, B., Johnson, B., & Fazey, J. A. 2006. Eliciting the implicit knowledge and perceptions of on-ground conservation managers of the Macquarie Marshes. ***Ecology and Society,*** 11: 25. http://www.ecologyandsociety.org/vol11/iss1/art25/. Accessed December 2008.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., Walker, B., Bengtsson, J., Berkes, F., Colding, J., Danell, K., Falkenmark, M., Gordon, L., Kasperson, R., Kautsky, N., Kinzig, A., Levin, S., Mäler, K.-G., Moberg, F., Ohlsson, L., Olsson, P., Ostrom, E., Reid, W., Rockström, J., Savenije, H., & Svedin, U. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations. ***ICSU Series on Science for Sustainable Development,*** 3: 1–74.

Folke, C., Pritchard, L., Berkes, F., Colding, J., & Svedin, U. 1998. ***The problem of fit between ecosystems and institutions.*** Working paper no. 2, International Human Dimensions Program on Global Environmental Change, Bonn.

Forbes, B. C., Stammler, F., Kumpula, T., Meschtyb, N., Pajunen, A., & Kaarlejärvi, E. 2009. High resilience in the Yamal-Nenets social-ecological system, Western Siberian Arctic, Russia. ***Proceedings of the National Academy of Sciences,*** 106: 22041–22048.

Freeman, S. F., Malz, M., & Hirschorn, L. 2003. Moral purpose and organizational resilience: Sandler, O'Neill & partners in the aftermath of September 11, 2001. In D. Nagao, (Ed.), ***Academy of Management Best Paper Proceedings.***

Gadgil, M., & Berkes, F. 1991. Traditional resource management systems. ***Resource Management and Optimization,*** 18: 127–141.

Gephart, R. P., Jr. 1993. The textual approach: Risk and blame in disaster sensemaking. ***Academy of Management Journal,*** 36: 1465–1514.

Gephart, R. P., Jr. 1996. Simulacral environments: Reflexivity and the natural ecology of organizations. In D. M. Boje, R. P. Gephart, Jr., & T. J. Thatchenkery (Eds.), ***Postmodern management and organization theory:*** 202–224. Thousand Oaks, CA: Sage.

Gephart, R. P., Jr., & Topal, C. 2009. ***Prospective sensemaking and the management of institutional risk.*** Paper presented at International Symposium on Process Organization Studies (PROS), Cyprus.

Gioia, D. A., & Chittipeddi, K. 1991. Sensemaking and sensegiving in strategic change initiation. ***Strategic Management Journal,*** 12: 433–448.

Goodall, H. L., Jr.. 2008. ***Writing qualitative inquiry: Self, stories, and academic life.*** Walnut Creek, CA: Left Coast Press.

Hamel, G., & Valikangas, L. 2003. The quest for resilience. ***Harvard Business Review,*** 81(September): 52–58.

Heyerdahl, E. K., Lertzman, K., & Karpuk, S. 2007. Local-scale controls of a low-severity fire regime (1750–1950), southern British Colombia, Canada. ***EcoScience,*** 14: 40–47.

Hodder, I. 2003. The interpretation of documents and material culture. In N. K. Denzin & Y. S. Lincoln (Eds.), ***Collecting and interpreting qualitative materials:*** 110–129. London: Sage.

Holling, C. S. 1986. Resilience of ecosystems: Local surprise and global change. In W. C. Clark & R. E. Munn (Eds.), ***Sustainable development and the biosphere:*** 292–317. Cambridge, U.K.: Cambridge University Press.

King, A. 1995. Avoiding ecological surprise: Lessons from long-standing communities. ***Academy of Management Review,*** 20: 961–985.

King, A. 1999. Retrieving and transferring embodied data: Implications for the management of interdependence within organizations. ***Management Science,*** 45: 918–935.

Knorr Cetina, K. 1997. Sociality with objects: Social relations in postsocial knowledge societies. ***Theory, Culture and Society,*** 14: 1–30.

Langley, A. 1999. Strategies for theorizing from process data. ***Academy of Management Review,*** 24: 691–710.

Latour, B. 2005. ***Reassembling the social: An introduction to actor-network theory.*** Oxford, U.K.: Oxford University Press.

Leonardi, P. M., & Barley, S. R. 2010. What's under construction here? Social action, materiality, and power in constructivist studies of technology and organizing. In J. P. Walsh & A. P. Brief (Eds.), ***Academy of Management annals,*** vol. 4: 1–51. Essex, U.K.: Routledge.

Lertzman, K., & Fall, J. 1998. From forest stands to landscapes: Spatial scales and the role of disturbance. In D. L. Peterson & V. T. Parker (Eds.), ***Ecological scale: Theory and applications:*** 339–367. New York: Columbia University Press.

Lidskog, R. 1998. Society, space and environment. Towards a sociological re-conceptualisation of nature. ***Housing. Theory and Society,*** 15: 19–35.

Lillquist, K. 2006. Teaching with catastrophe: Topographic map interpretation and the physical geography of the 1949 Mann Gulch, Montana wildfire. ***Journal of Geosciences Education,*** 54: 561–571.

Locke, K., & Velamuri, S. R. 2009. The design of member review. ***Organizational Research Methods,*** 12: 488–509.

Louis, M. R. 1980. Surprise and sense making: What newcomers experience in entering unfamiliar organizational settings. ***Administrative Science Quarterly,*** 25: 226–251.

Maclean, N. 1992. ***Young men and fire.*** Chicago: University of Chicago Press.

Maitlis, S. 2005. The social processes of organizational sensemaking. ***Academy of Management Journal,*** 48: 21–49.

Maitlis, S., & Lawrence, T. 2007. Triggers and enablers of sensegiving in organizations. ***Academy of Management Journal,*** 50: 57–84.

Meyerson, D., Weick, K. E., & Kramer, R. M. 1996. Swift trust and temporary groups. In R. M. Kramer, & T. R. Tyler (Eds.), ***Trust in organizations: Frontiers of theory and research:*** 166–195. Thousand Oaks, CA: Sage.

Nelson, M. C., Kintigh, K., Abbott, D. R., & Anderies, J. M. 2010. The cross-scale interplay between social and biophysical context and the vulnerability of irrigation-dependent societies: Archaeology's long-term perspective. ***Ecology and Society,*** 15(3): 31.

Nelson, M. C., & Schachner, G. 2002. Understanding abandonments in the North American Southwest. ***Journal of Archaeological Research,*** 10: 167–202.

Nicolini, D. 2009. Zooming in and out: Studying practices by switching lenses and trailing connections. ***Organization Studies,*** 30: 1391–1418.

Odum, H. T. 1983. ***Systems ecology: An introduction.*** New York: Wiley.

Orlikowski, W. J. 2007. Sociomaterial practices: Exploring technology at work. ***Organization Studies,*** 28: 1435–1448.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. 1999. Revisiting the commons: Local lessons, global challenges. ***Science,*** 284: 278–282.

Perrow, C. 2007. ***The next catastrophe: Reducing our vulnerabilities to natural, industrial, and terrorist disasters.*** Princeton, NJ: Princeton University Press.

Rak, C., & Patterson, L. 1996. Promoting resilience in at-risk children. ***Journal of Counseling and Development,*** 74: 368–373.

Riolli-Saltzmann, L., & Luthans, F. 2001. After the bubble burst: How small high-tech firms can keep in front of the wave. ***Academy of Management Perspectives,*** 15: 114–125.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., III, Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, W. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., & Foley, J. A. 2009. A safe operating space for humanity. ***Nature,*** 461: 472–475.

Rothermel, R. C. 1993. ***Mann Gulch fire: A race that couldn't be won.*** General technical report INT-299, United States Department of Agriculture Forest Service, Intermountain Research Station.

Rothermel, R. C. 2000. The great western wildfires: Predicting the future by looking to the past. ***National Woodlands,*** October: 10–12.

Schön, D. A. 1983. ***The reflective practitioner: How professionals think in action.*** New York: Basic Books.

Stern, N. 2006. ***The economics of climate change.*** London: UK Treasury.

Strauss, A., & Corbin, J. 1998. ***Basics of qualitative research: Techniques and procedures for developing grounded theory.*** Thousand Oaks, CA: Sage.

Suchman, L. 2005. Affiliative objects. ***Organization,*** 12: 379–399.

Szulanski, G. 2003. ***Sticky knowledge.*** Thousand Oaks, CA: Sage.

Tyre, M., & von Hippel, E. 1997. The situated nature of adaptive learning in organizations. ***Organization Science,*** 8: 71–84.

Van Maanen, J. 1988. ***Tales from the field.*** London: Sage.

Van Maanen, J. 2010. A song for my supper: More tales from the field. ***Organizational Research Methods,*** 13: 240–255.

Weick, K. E. 1976. Amendments to organizational theorizing. ***Academy of Management Journal,*** 17: 487–502.

Weick, K. E. 1979. ***The social psychology of organizing*** (2nd ed.). Reading, MA: Addison-Wesley.

Weick, K. E. 1988. Enacted sense making in crisis situations. ***Journal of Management Studies,*** 25: 306–317.

Weick, K. E. 1990. The vulnerable system: An analysis of the Tenerife air disaster. ***Journal of Management,*** 16: 571–593.

Weick, K. E. 1993. The collapse of sensemaking in organizations: The Mann Gulch disaster. ***Administrative Science Quarterly,*** 38: 638–652.

Weick, K. E. 2005. ***Making sense of the organization.*** Malden, MA: Blackwell.

Weick, K. E. 2007. The generative properties of richness. ***Academy of Management Journal,*** 50: 14–19.

Weick, K. E., & Roberts, K. H. 1993. Collective mind in organizations: Heedful interrelating on flight decks. ***Administrative Science Quarterly,*** 38: 357–381.

Weick, K. E., & Sutcliffe, K. M. 2007. ***Managing the unexpected: Assuring high performance in an age of uncertainty.*** San Francisco: Jossey-Bass.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. 2005. Organizing and the process of sensemaking. ***Organization Science,*** 16: 409–421.

Whiteman, G., & Cooper, W. H. 2000. Ecological embeddedness. ***Academy of Management Journal,*** 43: 1265–1282.

Wildavsky, A. 1988. ***Searching for safety.*** Edison, NJ: Transaction Publishers.

World Resources Institute. 2005. ***Millennium ecosystem assessment: Ecosystems and human well-being—Synthesis.*** Washington, DC: Island Press.

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