

War and ecology: a heuristic for exploring the environmental disruptions of armed conflict

by

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B.S., United States Military Academy, 2006

M.A., Syracuse University, 2015

AN ABSTRACT OF A DISSERTATION

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Abstract

The interrelationship between war and the environment is a vibrant focus of academic research across several disciplines and subdisciplines including environmental war, militarized landscapes, military geography, environmental geopolitics, environmental history, and environmental security. Moreover, the body of literature examining the war-environment relationship is growing in both volume and diversity. Yet, despite the burgeoning of warfare-environment research, the literature examining this topic remains fragmented along disciplinary lines and lacks theoretical depth, prompting calls for further inquiry and new conceptual frameworks to unify research. In this research, I build upon recent work in this area to suggest and validate a heuristic tool for war-environment research that will help other researchers contextualize their work and locate it within the broader body of war-environment literature.

Recent trends in these fields have increasingly focused on the impacts that warfare exerts upon the environment, as opposed to earlier studies in which the environment more often served as a variable explaining the causes and conduct of warfare. This is a timely transition for the field, as global awareness of the environmental dangers posed by conflict continues to grow across the international community and even in the awareness and actions of military forces themselves. Moreover, the older and less active approaches to war-environment research, including the field of military geography, are regaining relevance due to the anticipated impacts of climate change upon the causes and conduct of warfare. This heuristic builds upon previous frameworks developed within the fields of military geography and warfare ecology.

To validate the suggested heuristic, this research applies the tool to analyze how three past military conflicts—the Soviet liberation of Northern Norway in 1944, the American and Japanese campaigns in the Aleutians in 1942-43, and the Falklands War of 1982—have wrought lasting change on high-latitude landscapes to suggest what the ecological costs of potential future conflicts might be in these and other regions. I selected high latitude conflicts as case studies on the informed assumption that these environments are highly sensitive to even relatively small disturbances. These disturbances can affect long-lasting changes that would be harder to detect, or have shorter durations, in the warmer and more humid climates common to lower latitudes. In executing these case studies, I build upon a wide range of research that has already examined many narrow aspects of the environmental and cultural legacy of these two campaigns, including

chemical, biological, geomorphological, economic, and cultural impacts. Using the heuristic tool to unify my own on-site field work examining these case studies with that of scholars who have already studied some of the environmental impacts that these conflicts incurred will validate the tool and demonstrate its value to other researchers seeking to contextualize the environmental costs of other conflicts both past and ongoing armed conflicts.

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Other contributors to this research over the past three years are far too numerous to list by name, but in they include fellow students, friends, pastors, and family members who all encouraged me and listened to me as this research grew from an idea into the tome that follows this acknowledgement. Having said this, any errors, mistakes, or missteps that appear in this document are entirely my own.

Dedication

This study is dedicated to the soldiers alongside whom I have been proud to serve during the forever wars of the past two decades, and to the civilians among whom we practiced our martial profession, all of whom are marked, in mind, body, or spirit, by the violence of war. My hope is that, in some small way, this study helps to advance us all towards the day when we can beat our swords into plowshares and our spears into pruning hooks.

Preface

One purpose of this project is to fulfill the requirements for earning a doctoral degree in Geography from Kansas State University. To this end, the project follows the structure of “multiple publishable papers” as opposed to that of a single dissertation monograph. Thus, a goal of each “chapter” in this project is to produce a standalone paper of sufficient quality and intellectual depth as to form the core of a publishable journal article. Each standalone chapter also contributes to the common research theme of better understanding the environmental effects of war.

Chapter 1 - Introduction, Scope, Key Concepts, & Structure

This chapter introduces this research project's objective: The creation of a heuristic tool to facilitate interdisciplinary research into the environmental effects of war. It further explains key concepts that underly this tool, delimits the study's scope, and outlines the structure and logic of the remaining portions of the overall project.

1. Introduction

1.1 Purpose

This project seeks to develop a heuristic tool to examine how the direct violence inherent in the application of military power creates conditions of slow violence in the environment at various scales and in different contexts. In doing so, it follows the suggestions for future research directions outlined by Machlis and Hanson (2008). Specifically, Machlis and Hanson (2008, 734), in their elucidation of the concept of *warfare ecology* as a framework for studying the environmental effects of war, called for the “development and testing of theoretical frameworks to organize interdisciplinary advances,” and “research strategies to test theory, including case studies.” This project builds upon the warfare ecology framework by expanding several key concepts inherent in Machlis and Hanson’s model, including scale, context, and ecological theory, and by overlaying other key concepts including ideas about direct and slow violence, social power, and earth system science. In doing so, the heuristic tool lays the groundwork for a better integration of other disciplines that examine the war-environment relationship, particularly

military geography, environmental geopolitics, militarized landscape research, and environmental history, into a broader warfare ecology framework.

While a more thorough review of each of the categories of literature directly relevant to this study will appear in the next chapter, a brief discussion of the theoretical foundations for the contributions that military geography—the most estranged of these disciplines—can provide is appropriate here. Indeed, concepts inherent to military geography form the basis for many of the contributions that this project hopes to make to the field of warfare ecology through the medium of the heuristic tool.

1.2 Military Geography

The subdiscipline of military geography provides an effective lens through which to examine several key concepts relevant to the war-environment problem. However, before this project can lean too heavily upon ideas provided by military geography researchers, several critiques leveled against the current state of the subdiscipline must be addressed. These criticisms include assertions that military geography fails to engage sufficiently with its theoretical foundations, that it is too mired in an applied case study approach focusing on wartime tactics, and that the subfield is too heavily embedded within the institutional structures of US military power (Woodward, 2005; Pearson, 2012; Francis, 2014; Lohman & Fuhrman, 2019).

Woodward (2005) criticized military geography for not engaging with or developing forms of theory that can contribute to broader understandings of geography and conflict. While Lohman and Fuhrman (2019) responded to this criticism by outlining the theoretical roots and history of the subdiscipline, a canvas of recent military geography research indicates that the

field still does not address this rich and complex legacy. Specifically, military geography would benefit immensely by engaging more overtly with the theories of war and violence put forward by the early 19th century Prussian soldier-philosopher Carl von Clausewitz in his unfinished work, *On War (Vom Krieg)* (Clausewitz, 1993). Clausewitz posited numerous ideas about war and violence that remain influential today across numerous disciplines, including military art and science, philosophy, and geopolitics (Simpson, 2017; Treiber, 2022; Milevski, 2020 & 2023). Most relevant to this research, and to military geography more generally, are Clausewitz's concepts of scale, the relationship between war and violence, and the inseparability of theories of war from historical case studies of military actions. A greater emphasis by military geographers upon the implicit but insufficiently acknowledged Clausewitzian theoretical roots of their discipline provides a promising venue by which to better reintegrate military geography research into the broader academic community, and into war-environment research in particular. Therefore, this study relies upon Clausewitz's theory of war as a vehicle with which to engage military geography with other disciplines that examine the war-environment relationship.

A second criticism leveled against military geography research is that the field is too mired in "applied" case studies designed to reveal overly simplistic principles of the effects of terrain and the environment upon military operations (Woodward; 2005). Lohman and Fuhrman (2019) have defended this "terrain and tactics" approach, noting that much of the community conducting military geography research within the US defense establishment feels an understandable responsibility to equip young military officers with knowledge and tools that could, in the extreme, help keep them alive in a wartime context. Here too, a more explicit engagement with Clausewitz, specifically his thoughts on the dialectical nature of war in the form of his analogies of the duel (*zweikampf*) and of the wrestlers, can provide not only a richer

understanding within military geography of how competing perceptions of terrain can shape military operations, but also provide researchers outside the subfield with a theoretical foundation upon which to build a greater understanding of why and how military forces view and act upon landscapes (Clausewitz, 1993, 83). Moreover, such a dialectical approach can yield a better understanding of the complex interplay of interests that continue to shape geographies of slow violence in pre- and post-war contexts, as demonstrated by Farish (2010) in his studies of Cold War landscapes.

Finally, military geography has long come under criticism for its intimate relationship to institutions of US military and political power (Woodward, 2014 & 2019). Palka and Galgano (2005 & 2012) note that much of this criticism was rooted in deep concern and skepticism about US actions in Vietnam in the 1960s and other Cold War applications of US military violence. However, others have traced military geography's estrangement further back in time, tying it to fundamental debates about the place and role of geography that occurred in the immediate post-WWII era (Barnes & Farish, 2006). These critiques include concerns about the potential for the weaponization of academic research and the subdiscipline's failure to navigate the quantitative turn in geography in the 1960s. Even so, numerous scholars have begun to argue recently that these concerns should not preclude researchers from engaging with military-related studies (Woodward, 2014 & 2019). Indeed, Farish (2015) has noted that knowledge generated by defense institutions over the past several decades represents an important and neglected potential addition to the established canon of geographic knowledge. Observations from Farish and others have facilitated a slow ongoing softening of the boundaries that have existed between military geography and the broader academy in recent years (Woodward, 2019). This is an encouraging trend, as military geography is ideally suited to fill identified gaps in knowledge about how

military organizations understand geography and how this understanding shapes military actions across contexts.

Having briefly addressed some of the relevant criticisms of military geography's contributions to the corpus of war-environment research, what follows is a discussion of how key concepts drawn from a Clausewitzian interpretation of military geography and their interaction with concepts important to other fields such environmental geopolitics and ecological theory, form the building blocks for a framework to better integrate inter- and multi-disciplinary war-environment research in the form of a heuristic assessment tool.

2. Key Concepts

An underlying assumption of this research is that one way to build effective interdisciplinarity into research is to integrate key concepts from across disciplines and sub-disciplines. As such, the heuristic framework suggested here draws upon ideas about scale, social power, violence, context, and ecology from across a range of disciplines, including military geography, militarized landscape research, environmental geopolitics, environmental history, warfare ecology, and earth system science.

2.1 Context: War and Peace

In delimiting its scope, this research accepts Clausewitz's assertion that war is a distinct and separate form of human activity. Clausewitz variously defines war as "a continuation of policy by other means," as "an act of violence to compel our enemy to do our will," and as "a

clash of major interests, which is resolved by bloodshed” (Clausewitz, 1993, 173). Some prominent political theorists have contested the distinctiveness of war from other activities, including Michel Foucault who reversed Clausewitz’s famous dictum to contend that “policy is a continuation of war by other means” (Treiber, 2022). However, as Treiber (2022) notes, defining everything as war is problematic, as this view conceives violence as a normal occurrence, thus normalizing it, with potentially frightening implications. Moreover, for this effort, , defining everything as war does nothing to delimit the study's scope. As such, it accepts Clausewitz’s assertion that what distinguishes war from other forms of human discourse is the presence of intentional violence. Moreover, this intentional violence is tied to political or policy motives. This chapter will further discuss concepts of social power below, but for the purposes of this research “war” occurs when a political organization (state government, insurgent group, etc.) decides to use intentional, direct violence to achieve their policy goals.

However, as Machlis and Hanson (2008) assert, war encompasses many activities that are not directly related to battlefield violence. In their framework for warfare ecology, they divide war-related actions into three categories: *preparation for war*, *war*, and *postwar activities*. This framework is not at variance with Clausewitz’s theories of war, as he acknowledged that “war is served by many activities that are quite different from it; some closely related, others far removed” (Clausewitz, 1993, 147). These can include, according to Clausewitz, activities that help ensure fighting forces are “recruited, clothed, armed and trained,” or that relate to soldiers’ “sleeping, eating, drinking, and marching” (Clausewitz, 1993, 109). Thus, in a prefiguring of Hanson and Machlis’ framework, Clausewitz contends that “activities characteristic of war may be split into two main categories: those that are merely *preparations for war*, and *war proper* [emphasis in the original]” (Clausewitz, 1993, 151). As he further notes, “preparations [for war]

will be concerned with the creation, training, and maintenance of the fighting forces,” a useful, though not exhaustive definition of what sort of activities can fall into this context (Clausewitz, 1993, 151). Though Clausewitz does acknowledge war’s relationship to the post-war context, he does so only in terms of the political outcomes of the conflict and not in terms of how military forces and their effects continue to operate after fighting ceases. This is a limitation, though one that concepts of direct and slow violence (as described later in this chapter) can overcome.

Whereas Clausewitz (1993) and Machlis and Hanson (2008) situate context in a framework that centers war as a distinctive event with pre- and post-war activities that relate to it, military geographers Palka and Galgano (2012) approach context differently. They proposed a framework that places military actions on a spectrum of violence that ranges from peacetime activities through full-scale warfare between well-equipped state militaries. This interpretation of context considers the intensity of violence in a conflict as being a product of the kind of operations military forces consider themselves to be conducting. A reinterpretation of this framework could understand “stability and support” operations as post-war activities in the vein of Machlis and Hanson’s model. A disadvantage of this framework is that it assumes the perspective of a state-sponsored and state-equipped military force. This is understandable, as their literature is primarily intended to educate students of military geography within the US defense establishment (Lohman & Fuhrman, 2019). However, their perspective risks running afoul of the pitfall of “single-scale myopia” as identified by O’Lear and Diehl (2007) by remaining primarily state-centric. Furthermore, their framework is designed to study how the environment influences the types of military operations being conducted and not necessarily the reverse.

A framework for studying the environmental effects of military operations, by contrast, should focus on how military forces, state-sanctioned or otherwise, cause change upon landscapes. In this sense, a spectrum of violence as conceived by Palka and Galgano may be less helpful than might initially appear. For example, the impact of an artillery shell will produce the same effect upon a local landscape whether it is fired during peacetime training or in wartime, and whether it is fired by a state-sanctioned military force or a non-state military organization. As such, Clausewitz's imperative to focus on the *engagement* as the smallest unit of military activity appears to be the best starting point for studying how military actions disrupt landscapes. One might assume that more artillery shells might be fired during a large inter-state war than during a war framed as "stability and support" operations, but the effects of individual engagements will not differ materially between these contexts on a spectrum of violence. In this sense, for students of the environmental effects of war, Palka and Galgano's framework is useful for understanding how state military forces conceive of the context of their actions, and thus how engagements become distributed over time and space, but less so in understanding the environmental consequences of those actions. Moreover, Palka and Galgano's concept for context, which assumes the existence of established military forces, does not explicitly account for actions associated with raising, equipping, maintaining, and supplying military forces that Machlis and Hanson place into their "preparation for war" context.

Put another way, Palka and Galgano's framework is a useful gauge of the level of violence within a war, but less so in delimiting the boundaries of what "war" is. As stated, Clausewitz defines war by the presence of intentional violence. However, not all intentional violence necessarily constitutes war. Non-military actions, such mining or construction, can use extensive violence to alter landscapes in contexts outside of war, whereas relatively non-violent activities,

such as the recruitment of new troops, can be directly related to war. Thus, this study requires another concept to differentiate non-war violence from actions that are war related. A framework through which to accomplish this differentiation exists in the form of concepts of social power resident within the field of environmental geopolitics.

2.2 Types of Social Power

O’Lear (2010), building upon the work of Mann (1986 & 1993), defines four types of social power: *ideological*, *economic*, *political*, and *military*. While each of these types interacts with the others and can overlap in many ways, this study is primarily concerned with the environmental effects of the application of *military power*, which O’Lear (2010, 18) defines as being organized “around the need for physical defense and for possible aggression.” The emphasis on “physical” defense and “possible” aggression is important, as it implies both the preparation for and actual use of direct violence, corresponding to the “preparation” and “war” contexts of Machlis and Hanson’s (2008) framework. “Physical” defense and aggression can be read to correspond to the actual use of military force, which will produce effects of direct violence on the landscapes where this use of force occurs. The preparation for “possible” defense or aggression then corresponds to the actions of raising, training, equipping, and maintaining military forces, which can cause disruptions to landscapes far removed from theaters of actual combat. Stated in a more Clausewitzian way, military power involves the creation and use of the capabilities of violence necessary for making war.

While the environmental effects of military power are the primary concern here, how this form of power is generated and applied is also an important aspect of the war-environment

relationship for researchers to consider. As Clausewitz (1993) understands in his maxim on the relationship between war and policy, the other three forms of power will also shape the ways in which the physical dimensions of military power act upon the landscape. Indeed, the interplay of economic, political, ideological, and military power can determine what types of violence are acceptable, or even possible, during a war. Aspects of economic power can determine the size and capabilities of elements of military power, while political and ideological forms of power can influence where, how, and what types of military power are used (O'Lear, 2010). Moreover, and perhaps most importantly, concepts of ideological, economic, and political power are vital for understanding how, or even if, environments that have been disrupted by war will be remediated in the post-war context.

Finally, concepts of social power are another key concept that students of the war-environment relationship can use to foster interdisciplinary research, particularly between the fields of environmental geopolitics and military geography. Indeed, Palka and Galgano (2012, 50) created a framework for military geographers to study how physical and cultural elements of geography contribute to economic, political, and military forms of power that reflects some influences of ecological theory as applied to warfare (Fig. 1.1). Their perspective differs from researchers within environmental geopolitics in terms of directionality, in that their concern is the impact of the environment upon elements pertaining to military power, as opposed to the impacts that military and other forms of power can exert upon landscapes. Alternately, Dalby (2009) has demonstrated ways in which the changing technologies of military power have in recent years reshaped how elements of political and ideological power interact with the environment. Even so, the common vocabulary of these two disciplines suggests concepts of

social power as another avenue through which to promote interdisciplinarity. Another such avenue, one at the core of geographic thought, is the concept of scale.

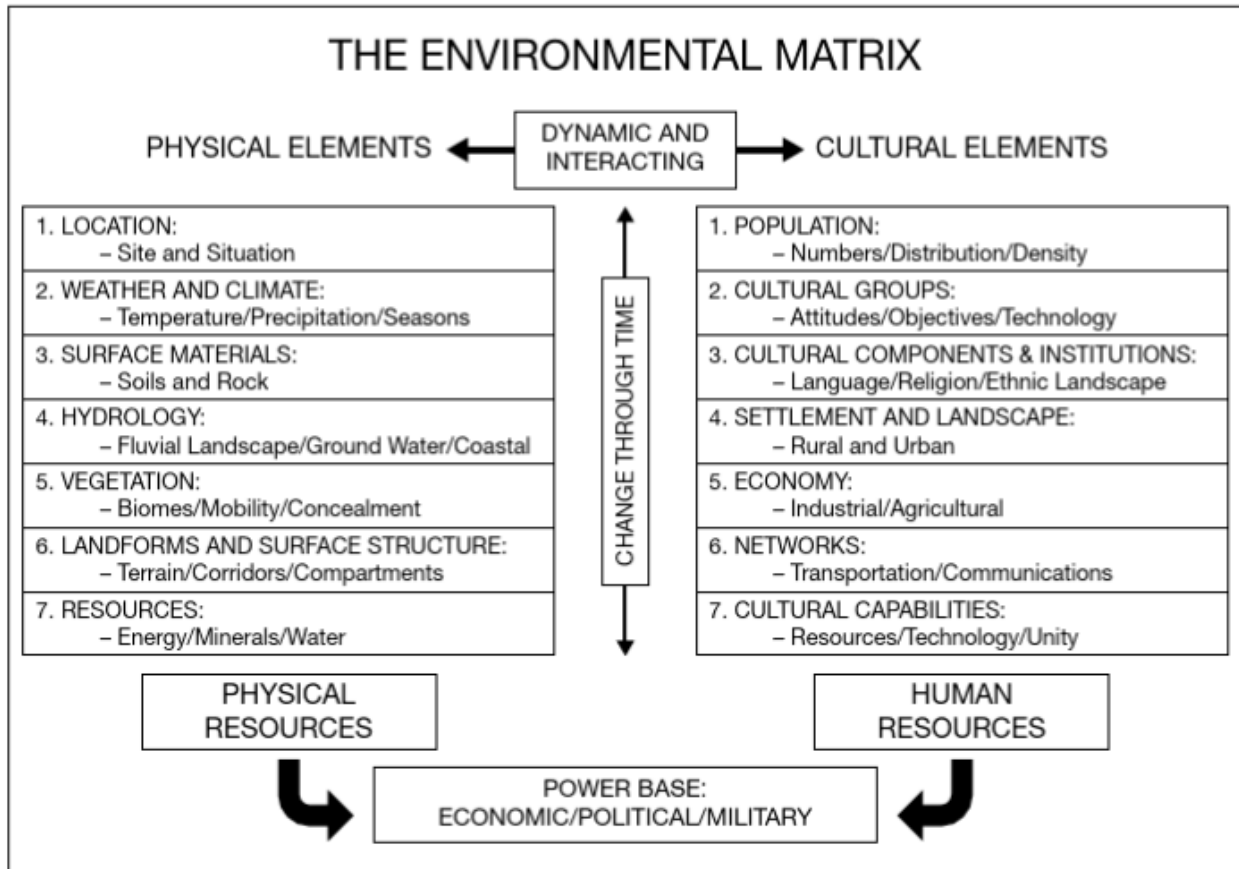


Figure 1.1. The “environmental matrix” outlined by Palka and Galgano (2012, 50) for studying how geographic elements shape economic, political, and military power.

2.3 Scale

Scale is another key unifying concept across the sub-disciplines studying the war-environment relationship. A review of the multi-disciplinary literature that examines the war-environment relationship reveals that different disciplines tend to specialize in certain scales of observation. To break out of this sort of scalar myopia, Machlis and Hanson (2008) structure

their warfare ecology model within a local-regional-global framework. This three-tiered structure bears at least cursory similarity to the tactical-operational-strategic scales suggested by Palka and Galgano (2012) for the study of military geography. Indeed, Palka and Galgano (2012, 46) overtly contend that the tactical-operational-strategic frame can map easily onto a local-regional-global one (Fig. 1.2). While this connection is a promising concept with which to link military geography with warfare ecology, both frameworks of scale and their potential connection require a more thorough analysis. Neither Machlis and Hanson (2008) nor Palka and Galgano (2012) provide a true definition of their proposed concepts of scale, leaving the potential for researchers to misapply their frameworks.

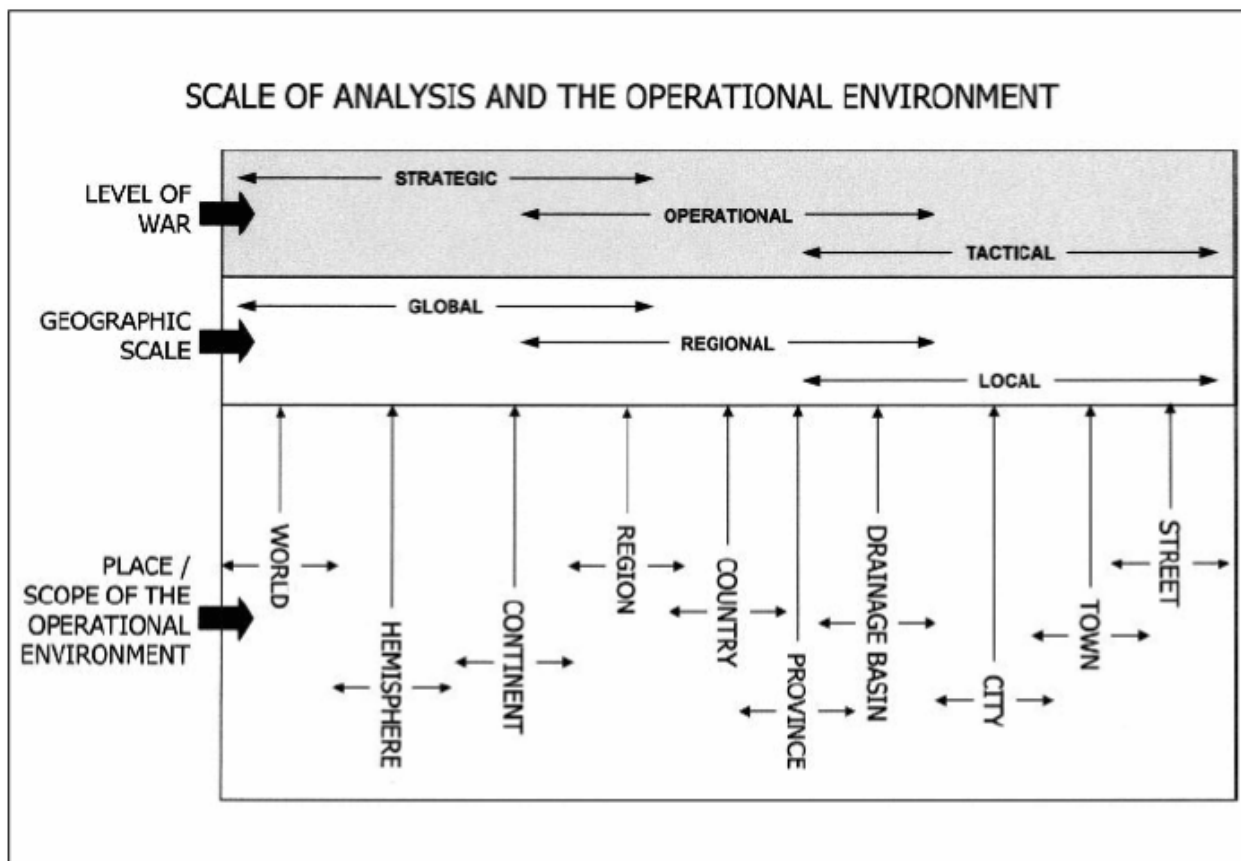


Figure 1.2. Palka and Galgano’s (2012, 46) framework for the overlap of the tactical-operational-strategic levels of war with a local-regional-global conception of scale.

As O’Lear (2010) notes, researchers across disciplines can misapply concepts of scale in several ways. These pitfalls include neglecting the type of scale relevant to a study, pre- or mis-selection of the scale at which to examine a problem, and assumptions that processes remain the same across scales (O’Lear and Diehl, 2007). To avoid these issues, this study employs a hybrid approach that draws upon concepts of scale from military geography and history, as well as environmental geopolitics. Specifically, this research expands upon Palka and Galgano’s (2012) assertion of a direct link between military geography’s tactical-operational-strategic framework and a local-regional-global one used by geographers more broadly to link military actions on landscapes with their resultant environmental effects. Such a hybrid concept of scale can account for O’Lear’s (2010) criticisms and provides a flexible and appropriate lens through which to examine the war-environment relationship.

The first step in defining this concept of scale is to identify which types are relevant. Wu and Li (2009) define at least six types of scale: *operational*, *observation*, *modeling*, *geographic*, *policy*, and *cartographic* (see also Lam and Quattrochi (1992)). Most relevant to this study are the *operational* and *observation* types of scale. *Operational* scale denotes the scale at which a certain process occurs or operates, while *observation* scale denotes the scale at which a researcher observes a phenomenon. Ideally, the scale of observation should match the operational scale of the phenomenon being studied (O’Lear & Diehl, 2007). An integrative framework of scale for war-environment studies provides one way to unite research from across disciplines. A complex phenomenon such as warfare that operates across multiple operational scales requires a correspondingly complex framework for the observation scale employed by researchers during its study.

Avoiding mis-selecting the level of scale at which to examine a phenomenon requires a more disciplined definition of the tactical-operational-strategic lens and its relationship with the landscape-regional-global framework. As O’Lear (2010) notes, different scales are not simply successively larger “baskets” in which to classify human activity, or successively larger classifications or groupings of the same basic activity. Rather, scale is something created *by* human activity. The tactical-operational-strategic concept of scale encompasses this maxim in a way that corresponds to how some non-military geographers visualize a sophisticated landscape-regional-global framework. Moreover, the over-mapping of these two similar frameworks can also provide a link between the ways in which environmental geopolitics and military geography explain why and how military forces act upon the environment, as well as the effects of these actions across scales as described by researchers in fields such as militarized landscape research and environmental history.

The tactical-operational-strategic concept of military scale has only come to be generally accepted by military thinkers within the past several decades (Zabecki, 2006 & 2018). In the 19th century, theorists of war such as Clausewitz and his contemporary, the Swiss-French military officer A.H. Jomini, identified two scales of war: *tactics* and *strategy* (Zabecki, 2006). However, both theorists had at least begun to work out a third level. Jomini identified an intermediate scale of war linking tactics and strategy, which he titled “Grand Tactics” (Howard, 1993). Clausewitz, by contrast, identified a superior scale of war, *policy* (as in his famous maxim that “war is a continuation of policy by other means”), the dictates of which the other two scales serve to achieve (Zabecki, 2006). However, as Zabecki (2006) argues, a closer reading of Clausewitz reveals that his concept of the *strategic* level of war corresponds to the modern *operational* level, and that Clausewitz’s discussions of *policy* corresponds to the modern definition of the *strategic*

scale. As such, the modern tactical-operational-strategic construct can be traced directly to Clausewitz's theories of war. Indeed, Clausewitz himself made a direct analogy between his abstract three-tiered theory of the levels of war and a three-tiered concept of space when he noted that "The concepts of time—war [strategic], campaign [operational], and battle [tactical]—are parallel to those of space—country [global], theater of operation [regional], and position [landscape]" (Clausewitz, 1993). Inherent in this quote is acknowledgement of the direct link between the tactical-operational-strategic conception of the levels of war and the landscape-regional-global construction of space. Having noted this, however, one must keep in mind that the two frameworks are inherently different. The tactical-operational-strategic frame is specifically formulated for analyzing military-political activity, thus making it in effect a specialized sub-type of the local-regional-global construct rather than a co-equal equivalent.

Clausewitz defines the *tactical* level of war as the scale at which *engagements* occur. The term *engagement* denotes individual battles of varying complexity that are confined to individual landscapes (Clausewitz, 1993, 146). Given that O'Lear and Diehl (2007) observe that the components of scale consist of "places, actors, and a relational dimension that links places and actors," a working definition of the landscape scale of military impacts on the environment should then incorporate actors (military forces), places (the local landscapes on which military forces operate), and a relational link between them (acts of direct violence that disrupt the landscape).

The *operational* level of war (Clausewitz's "strategy") Clausewitz defines as being the realm of campaigns. Campaigns consist of "the use of engagement for the purposes of the war" (Clausewitz 1993, 146). As Zabecki (2006) and others have noted, this definition positions the operational level of war as a relational link between the tactical and strategic levels (Prete, 2021).

Various engagements separated in space and time work together to form a campaign, the object of which is to achieve the political ends of the strategic level of war. Thus, the operational scale examines the relationship of one engagement to its effects elsewhere. A corresponding definition of the regional scale of the effects of military actions on the environment would then examine how the direct violence of a military disruption of a particular landscape (actor) causes related disruptions (relationship) on other landscapes that are distant in space and/or time from the place of the original disruption (place). This definition coincides with concepts of slow violence.

Finally, the *strategic* level of war (Clausewitz's "policy") denotes the political—or geopolitical—context in which violence occurs. Policy is the reason and justification for military violence, but political considerations also act as a moderating factor on the scale and types of violence employed in a conflict (Clausewitz, 1993, 84). The ultimate political aim of the belligerents in war is to alter this context from one state to another. The sum purpose of campaigns is to bring about this alteration. Similarly, the global construct of environmental scale tends to encompass effects that alter the status quo of the entire Earth environment, or at least a sizable portion of it (Dalby, 2022). As such, a definition of the global scale of the environmental effects of warfare should encompass the ways in which the accumulated direct and indirect disruptions caused by military actions (actor) alter the underlying context (relationship) of the global environment (place).

A disciplined application of the above framework will ensure this research avoids the third, and final, pitfall identified by O'Lear (2010): Assumptions that processes and effects remain the same across scales. Here, Clausewitz's (1993) discussion of the differences between *engagements* and *marches* in Book 2, Chapter 1 of *On War* is useful in highlighting the differences in processes that are relevant at the tactical (landscape) and operational (regional)

levels of war. According to Clausewitz, *engagements* are the realm of actual combat between the opposing forces. If, as Zabecki (2006) notes, combat is composed of the elements of fire and maneuver, then element of firepower dominates engagements at the tactical level of war. By contrast, Clausewitz describes *marches* as the movement of military forces from the location of one engagement to another (Clausewitz, 1993, 148). This relationship between separate engagements elevates this activity to the operational level of war. Here, the element of maneuver is dominant, as the object is simply to get forces to the location of the next engagement and not necessarily how those forces fight once there. Moving up to the strategic level of war, the ability of either side in a conflict to bring not just military, but also political, economic, and ideological power to bear to achieve policy aims comes to the fore, factors that can serve to deemphasize the importance of both firepower and maneuver (O’Lear, 2010).

Moreover, success in one level of war does not necessarily transfer to the other levels. As Zabecki (2006) observes, the United States military won every tactical engagement during the Vietnam War but failed to achieve strategic victory. Similarly, the German army’s performance at the tactical level in both world wars generally superior to their enemies but it proved hopelessly inferior at the operational and strategic levels.

However, the analogy between the tactical-operational-strategic framework of military operations and the landscape-regional-global framework for the study of environmental disruptions begins to break down at this point. Associating the two ideas of scale too closely with one another could mislead students of the war-environment relationship to conceive of local-regional-global environmental disruptions as simply shadows of the *types* of activities that military forces conduct on the various levels of war. While doing so might be useful in guiding researchers to focus on the types of disruptions that will usually occur at, for example, the

operational level, it will be less useful in studying the relationships that the disruptions themselves create across geographic and temporal scales.

Therefore, one way to define the landscape-regional-global concept of scale that also differentiates it from the military concept is to focus on the types of relationships for which this framework of scale was designed. The tactical-operational-strategic scale tries to account for the relationship of the fire-maneuver dynamic with the broader geopolitical context. Similarly, this study's landscape-regional-global framework seeks to understand the relationship between direct violence and slow violence and how these relationships alter the global environment.

2.4 Direct and Slow Violence

A key component of this research is an examination of the relationship between acts of war-related *direct violence* with resulting and related conditions of *slow violence* in landscapes. O'Lear (2018, 94), building upon Galtung (1969), defines direct violence as something that "occurs as a discernable event by a perpetrator who has purpose." As O'Lear (2018) notes, this form of violence can be easier to study as its effects are dramatic and easily quantifiable. Slow violence, in contrast, is harder to measure and define. It "unfolds slowly over time" and "operates at spatial and temporal scales that do not grab headlines" (O'Lear, 2018, 93). Quoting Galtung (1969), O'Lear (2018, 94) defines slow violence as "the difference between the potential and the actual, between what could have been and what is." A better understanding of the relationship between direct and slow violence is vital to analyzing how military activity damages landscapes. Moreover, better frameworks through which to understand this relationship suggest

the potential to enrich the field of military geography by showing how the actions and effects of past wars can alter the context and underlying logic of future military conflict.

This definition of slow violence is useful for studying the environmental disruptions of war in several ways. First, conceiving of slow violence as the difference between the actual and the potential state of the environment provides a baseline (what could have been) from which to measure environmental disruption. Put another way, the (admittedly nebulous) baseline from which this study measures environmental change is an imagined landscape in which disruptions of both the direct and slow violence of war did not occur. Second, this definition of slow violence highlights temporal and spatial scales of disruption that are less obvious in examinations of the impacts of direct violence, and how the mechanisms of disruption can change across different scales. Finally, concepts of slow violence, as outlined by researchers in fields such as environmental geopolitics and militarized landscape research, contrasts with the direct violence that is typically the focus of military geography research, creating the opportunity to study relationships that exist between these two types of violence. Specifically, this study seeks to better understand the relationship between forms of direct violence inherent in the preparation for and conduct of war and the slow violence that can occur as a result in all contexts.

As with Clausewitz's (1993) dictum that the study of war should begin at the lowest level of combat, the *engagement*, so this study assumes that the beginning point for the study of the relationships between direct and slow violence should be the initial disruption caused by acts of direct violence in the landscape. As noted by Machlis and Hanson (2008) and Bauer (2009), the scalar equivalent to the engagement in studies of direct violence in the environment is the empirical, scientific case study, such as those often produced by researchers in the field of

militarized landscapes studies. Such case studies represent a vital starting point for connecting direct violence with resulting slow violence, since they typically relate incidents of direct military violence on a landscape with environmental consequences that persist over time. However, what solitary case studies like these can often fail to address is the far-reaching environmental consequences wrought by processes of slow violence. In other words, they require a framework to help researchers assess how direct violence morphs into different types of slow violence across temporal and spatial scales. This is then the entry point for ecological theory and earth system science, with their focus on networked relationships across environmental spheres.

2.5 Ecology and Earth System Science

As pointed out by Machlis and Hanson (2008), the current challenge of war-environment research is to integrate Clausewitz's "grammar" of war with ecosystem science in a way that communicates the breadth and interconnectedness of war-related disruptions on the landscape. They note that ecological theory is well suited to studying this problem due to its focus on multi-scalar relationships among organisms and between organisms and the environment. Moreover, they argue that an ecological framework for war-environment studies should "treat biophysical and social economic systems as highly coupled systems" that require researchers to apply interdisciplinary approaches to achieve fuller understanding of war's impacts (Machlis & Hanson, 2008, 730).

Attempts to apply ecological theory to the environmental effects of war predate Machlis and Hanson (2008). The prolific Arthur Westing (1976) attempted an ecological analysis of the

Vietnam War in his *Ecological Consequences of the Second Indochina War*, while Lanier-Graham (1993) put forward an ecological framework of war's disruptions that classified violence as either "intentional direct destruction", "incidental direct destruction", or "induced...medium and long-term consequences attributable to war," which in some ways foreshadows the direct/slow violence construct. Even so, as Bauer (2009, 20) writes, "Systematic thinking about the environmental effects of war is rare to find in the literature," indicating that more work is necessary to highlight the ecological nature of war's environmental impacts.

All the above-mentioned war-environment researchers have wrestled with how to classify war-related disruptions; whether by the intentionality of the violence (Westing, 1976; Lanier-Graham, 1993), the original purpose of the violence (Machlis and Hanson, 2008), or the severity of the resulting disruption (Bauer, 2009). While each of these approaches possesses merits, this study applies a different approach, classifying disruption according to two factors: the Earth spheres (lithosphere, hydrosphere, atmosphere, biosphere) in which the initial act of direct violence occurs, and the mechanism of the disruption (mechanical, chemical, radiological, biological). This approach echoes that applied by Westing (1976) in his study of the ecological consequences of the Vietnam War and is in line with recent thinking about how to build interdisciplinarity into human-environment research more broadly (Martin & Johnson, 2012). Such an approach focuses on the relationships and interactions across spheres, and as such must be interdisciplinary to be effective. Moreover, this project assumes humans and their activities (sometimes called the anthroposphere) to be part of the biosphere, since arbitrarily defining "the environment" as non-human nature can obscure many of the direct and slow consequences of violence done to landscapes in which humans are present.

Neither Westing nor later researchers have systematically applied such a structure broadly to build a framework for classifying and studying the interconnected and multi-scalar environmental disruptions of war. The creation of such a framework, one that marries 1) a better understanding of why and how military forces act upon landscapes, 2) empirical scientific case studies of landscape disruptions, and 3) aspects of ecological theory and earth system science, will help to structure and situate research across fields and disciplines.

3. Scope

Again, the purpose of this research is to create a heuristic tool to help structure studies of how the direct violence inherent in the application of military power creates conditions of slow violence in the environment at various scales and in different contexts. Concepts of social power help to narrow the scope of this project, as it focuses on the kinds of violence caused by military power. However, concepts of context broaden the scope to include activities associated with preparation for war and postwar contexts. Finally, the relationship between direct and slow violence represents the key focus which is reflected in the resulting heuristic tool. Focusing on these relationships allows for a disciplined application of concepts of scale that can reveal how environmental disruptions change as they transition between scales and across spheres.

The major contributions of this research to the field of war-environment research include (1) its improved integration of military geography perspectives, (2) a more disciplined and detailed application of concepts of scale in terms of the relationship between military violence and ecological consequences, and (3) a more nuanced understanding of context that brings to

bear concepts of social power and violence to highlight the far-reaching breadth of war-related activities and disruptions.

4. Structure

This dissertation follows the structure outlined below:

Chapter 2: Bibliometric Analysis as Literature Review

This study aims to build a structure for interdisciplinary research into the war-environment relationship. As such, it draws upon literature from numerous disciplines and sub-disciplines that have engaged with this problem. To better understand the focus, key themes, and relationships between the various approaches to war-environment research, this literature review takes the form of a bibliometric analysis of online database queries. The search terms that reflect the major approaches to war-environment research, including military geography, environmental geopolitics, militarized landscapes, environmental history of war, and warfare ecology. The chapter's meta-analysis of the query presents the geographic distribution and key journals of ongoing academic publishing trends, as well as temporal and disciplinary trends. This chapter has been submitted to the *Journal of Military History* for publication.

Chapters 3-4: Military Cartography as a Window into Military Geography

A key contribution of this research is to better integrate military geography into research examining the war-environment relationship. Modern military organizations are prolific

mapmaking entities, and their maps represent a useful window for understanding how military forces perceive and act upon landscapes. Moreover, World War I saw the birth of modern military cartography and research into maps produced by this war's belligerents is both an exciting and underexplored topic within the history of cartography research. Original archival research and analysis was conducted to study the practice of tactical mapmaking within the American Expeditionary Force (AEF) during World War I. This research resulted in two papers, one describing the types and purpose of the various maps produced by the AEF, and the second outlining a historical geographic information system (HGIS) database and approach for studying these types of maps. The first of these papers, "Map Rooms and Cartographic Sections: The Tactical Cartography of the AEF in the Great War", has been accepted for publication by the *International Journal of Cartography*. The second paper is complete and has also been submitted to the *International Journal of Cartography*.

Chapter 5: A Taxonomy of War-related Environmental Disruptions

This chapter develops a taxonomy of war-related environmental disruptions by combining concepts of scale and context from warfare ecology and military geography with a grounded theory-based investigation of empirical scientific studies. The coding phase of this investigation resulted in the above-described two-part classification of disruptions, which combines the framework of earth spheres with concepts about mechanisms of disruption. This chapter provides a grammar and foundation for a topology of war-environment disruptions and will be combined with Chapter 5 to produce a publishable paper describing and justifying the heuristic tool.

Chapter 6: A Warfare Ecology Heuristic Tool

This chapter develops the heuristic tool itself, which assumes the structure of a three-dimensional framework with axes devoted to context, scale, and severity of disruption. The tool is a layered composite model, with each layer representing impacts in one of the earth spheres. This structure allows the examination of relationships between direct and slow violence in at least two ways. First, it can reveal “gradients” of impact within earth spheres across scales and contexts. Second, it can reveal relationships between disruptions that occur or persist in different earth spheres. Together with the previous chapter, this will form a forthcoming journal article outlining the heuristic tool and its uses.

Chapter 7-9: Case Studies

In the next three chapters, the heuristic tool will be used to analyze the environmental disruptions of three historical conflicts that all occurred in vulnerable high-latitude environments: The Falklands War of 1982, the Aleutian Islands campaign of 1942-43, and the Norwegian theater of the Second World War from 1940-45. These conflicts were selected due to the similarity of the environments in which they occurred, namely littoral areas on the Arctic, sub-Arctic, and sub-Antarctic regions of the world. These case studies also cover a diverse range of operational and temporal scales, allowing for better validation of the heuristic tool’s usefulness across the range of scales at which wars occur.

Most of the research for these case studies relies upon secondary literature, including military histories and military geography studies of these conflicts, as well empirical scientific studies of their associated environmental disruptions. However, a key focus for future research for both the Norwegian and Aleutian case studies will be the training area that the US established for the 10th Mountain Division at Camp Hale, Colorado. Troops destined for both Norway and the Aleutians trained at this location, which remains environmentally degraded to this day. This future study will combine archival and field research on location at Camp Hale along with discourse analysis from stakeholders in the future of the Camp Hale landscape to show the complexities of the creation and remediation of environmental disruptions associated with the preparation and post-war contexts of warfare ecology.

Chapter 10: Conclusion

The concluding chapter of the dissertation will assess the potential impact of the proposed war ecology heuristic and provide closing thoughts on ways forward for better integrating military geography and other disciplines into a more interdisciplinary approach to war-environment research. It will further comment upon the potential for this sort of research to exert influence on policy, such as forms of arms control or international bans on weapons use, or in fostering forms of ideological power that can act as brakes upon forms of military violence.

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Chapter 2 - Literature Review & Bibliometric Analysis

Abstract

Explorations of the relationships between warfare and the environment are a growing field of inquiry among researchers globally. Several approaches to examining these relationships have evolved in the past fifty years, including the fields of military geography, environmental histories of war, militarized landscape studies, environmental geopolitics, and warfare ecology. Unfortunately, the research engaging with these approaches remains fragmented and lacks a unifying framework and taxonomy. This paper employs a meta-analysis of scholarly database queries to examine this fragmentation in terms of geographic origin, discipline, and publishing venue, and suggests an initial framework to encourage interdisciplinary research into warfare-environment problems. The results of this meta-analysis indicate that warfare-environment research occurs overwhelmingly within anglophone countries and is published largely by anglophone journals. However, across the major approaches to this topic, significant variation exists with respect to the origin of published work outside of the US, UK, or Canada. Furthermore, these approaches display notable variation in publishing venue, both in terms of publishing journals and overall disciplinary focus. Published reviews of literature have identified the concept of spatial scale (i.e., landscape/regional/global), as well as the context or place along the continuum of violence in which a which conflict occurs, as starting points to suggest frameworks for a unified taxonomy for warfare-environment research. This paper builds upon these reviews to suggest ways in which a common taxonomy of scale and context can help bridge interdisciplinary gaps within this field.

1. Introduction

The relationship between war and the environment has long been a focus of academic research, and the literature examining this relationship appears to be increasing in both volume and diversity (Pearson, 2012; Woodward, 2005 & 2019; Francis, 2014). Recent scholarship has increasingly focused on the impacts that warfare exerts upon the environment, as opposed to earlier trends in which the environment served as a variable for explaining the causes and conduct of warfare (Closmann, 2009; Francis, 2014; Lawrence et al, 2015). This is a timely transition for the field, as global awareness of the environmental dangers posed by conflict continues to grow across the international community and even in the awareness and actions of military forces themselves (Francis & Krishnamurthy, 2014; Davies & Riddell 2017; UNEP, 2009a, 2009b, 2020). Moreover, the traditional approaches to this field are gaining renewed relevance due to the anticipated impacts of climate change upon the causes and conduct of warfare (Palka & Galgano, 2012; Burnett & Mach 2021). However, despite a significant increase in warfare-environment research over the past two decades, the literature examining this topic remains fragmented along disciplinary lines and lacks theoretical depth, prompting calls for further inquiry into this topic, as well several suggested conceptual frameworks to unify research (Palka & Galgano, 2005, 2011, 2012; Woodward, 2004; Bauer, 2009; Machlis & Hanson, 2008, 2011; Lesko, 2020). To assist in unifying warfare-environment research, this paper explores the geographic origins, temporal trends, and disciplinary focus of warfare environment publications since 2000 by conducting a meta-analysis of peer-reviewed publications that were compiled using targeted queries of a bibliographic database.

Numerous reviews of warfare-environment scholarship have revealed at least five major approaches adopted by scholars in their research. These approaches fall generally into the categories of military geography, militarized landscape studies, environmental histories of war, environmental geopolitics, and warfare ecology (Woodward, 2005, 2014; Machlis & Hanson, 2008; Hupy, 2008; McNeill, 2010; Pearson, 2012; Francis, 2014; O’Lear, 2018). According to several published reviews of literature that examine this topic, each of these terms represents a distinct conceptual framework of warfare-environment studies that differ in terms of focus, scale, directionality, and inclusiveness (Woodward, 2005; McNeill, 2010; Pearson, 2012; Francis, 2014). The term environmental security was also considered but ultimately rejected due to Woodward’s (2014) concerns about conflating the broader arena of security and securitization with those more narrowly focused on the impacts of militarism and militarization. Though debates exist over the propriety of these and other terms (see for example Woodward, 2005 & 2014; Marler, 2013; Hanson & Machlis, 2014), for practical purposes they provide a reasonably comprehensive coverage of the various geographic approaches to examining the warfare-environment relationship.

Military geography research has generally focused on understanding impacts that environmental factors exert upon military operations at the landscape scale, while militarized landscape studies tend to reverse this directionality to examine how warfare and its related activities reshape local environments (O’Sullivan, 1991; Winters, 1998; Doyle & Bennett 2002; Caldwell et al, 2004; Woodward, 2014; Rech et al 2015; Lohman & Fuhrman, 2019).

Environmental history attempts to view warfare and the environment as being in a relationship in which nature is both an actor upon and influenced by human activity and tends to examine these relationships at regional scales (Tucker & Russell 2004; Closmann, 2009; McNeill, 2010).

Environmental geopolitics examines how states employ environmental themes and realities to generate geopolitical power and tends towards the regional and global scale (O’Lear, 2018). Finally, the warfare ecology framework attempts to integrate aspects of the four previous approaches to provide a more holistic understanding of the warfare environment relationship by leveraging ecological theory (Machlis & Hanson, 2008). This study uses these five labels—which have been highlighted by other scholars in their reviews of war-environment literature—as search terms to provide a series of cross sections of current research into the warfare environment relationship. While including other or modified terms might return different or even broader results, for the sake of manageability this study has limited itself to those identified in geographical reviews of this subject.

2. Methods

To understand the nature and volume of ongoing warfare environment research in scholarly publications, this study conducted a non-statistical meta-analysis of research published from 2000 to 2022 that contained the terms “military geography,” “militarized landscape,” “environmental history of war,” “environmental geopolitics,” or “warfare ecology” in the keywords, abstract, or title of the manuscript. While this method necessarily excludes foundational publications from before 2000 that have shaped thinking this topic, such as Lacoste (1973) and Westing (1980), the purpose of this paper is to examine the recent trends in war-environment research, justifying the temporal bounding of the searches.

Queries in the Web of Science Core Collection database (published by Thomson Reuters) returned results for each term as separate exports. The Web of Science Core Collection database

covers the physical sciences, social sciences, and humanities, and focuses on more impactful publications, making it advantageous for analyzing trends across and between sub-disciplines relating to warfare-environment research within the broader academic community, which is why this database was selected for this study. Other options included the SCOPUS database, which also covers a diverse range of journal articles covering physical sciences, life sciences, health sciences, social sciences, and humanities subject areas, as well as the GreenFILE database, which is a smaller database due to its limited subject area but retrieves publications that specifically address human-environment interaction studies that may be overlooked in larger databases. Initial queries in SCOPUS gave results nearly identical to those obtained from Web of Science, indicating that a duplicate study of SCOPUS results would not be likely to change the conclusion of this study. Initial queries in the GreenFILE database returned too few results for satisfactory analysis. A limitation of this study, or any relying on most current databases for bibliographic analysis, is that it excludes unpublished dissertations and theses.

3. Results and Discussion

The following section presents results of the meta-analysis with accompanying discussion and is summarized by (1) number of publications, (2) disciplinary contributions, (3) the country of origin of warfare-environment publications, and (4) journal relevance and influence within this subject area.

3.1 Numbers of Publications on the Warfare-Environment Relationship

The numbers of publications examining the warfare-environment relationship has increased steadily over the last two decades, with the military geography, environmental history, and environmental geopolitics approaches showing similar patterns of growth, while research using the militarized landscape and warfare ecology approaches appears to have remained relatively stagnant (Figure 2.1). One likely explanation for this result is that these latter two terms have simply fallen out of use with researchers. The number of entries published in 2021 for each query term was 95 for military geography, 4 for militarized landscape, 136 for environmental history of war, 99 for environmental geopolitics, and 19 for warfare ecology. Some overlap likely exists between the five queries. Further, these queries returned largely anglophone research, certainly skewing the geographic distribution of the results. The sparse number of results for warfare ecology likely reflects its relative newness (Machlis & Hanson, 2008) in comparison to the other approaches that trace their roots to the 1970s or, in the case of military geography, to the nineteenth century (Westing, 1980; Lohman & Fuhriman, 2019).

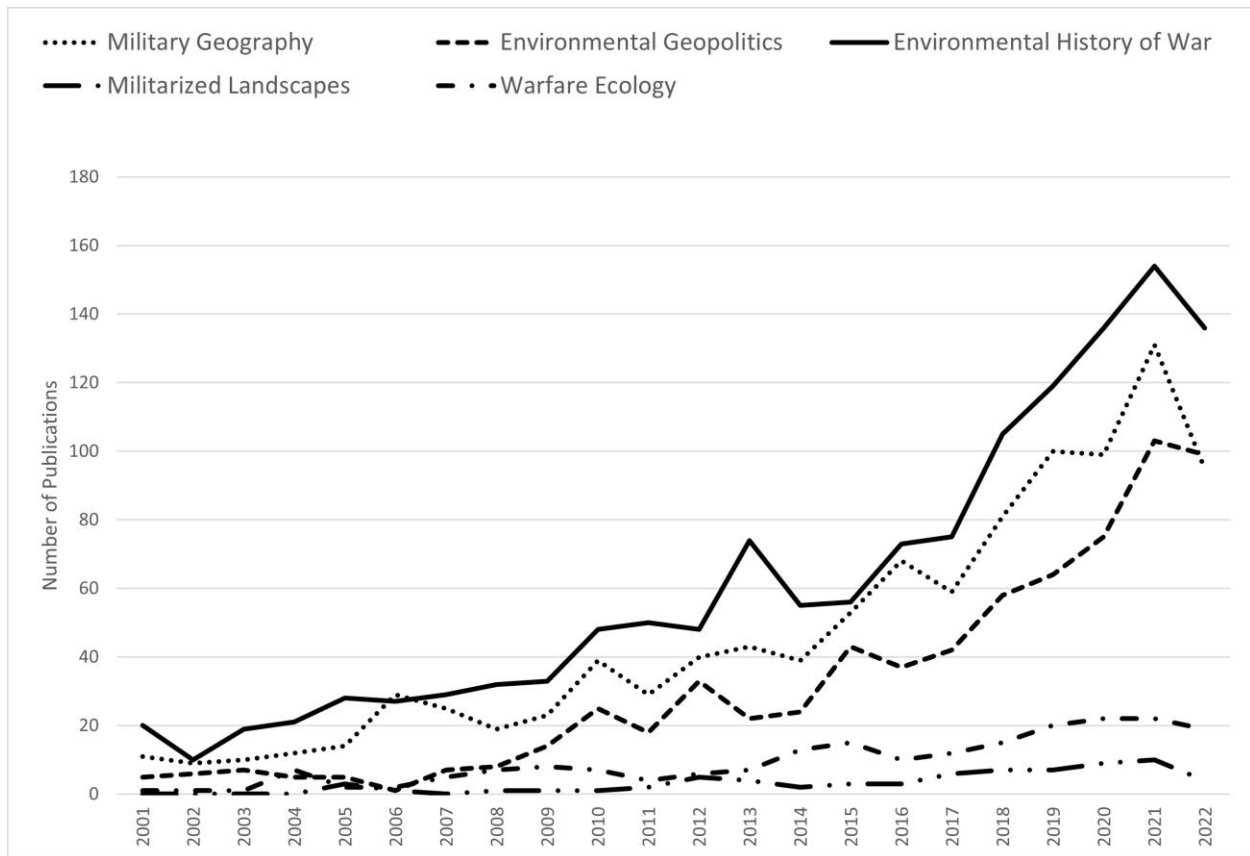


Figure 2.1 Number of articles published each year containing the term the “military geography”, “environmental geopolitics”, “environmental history”, “militarized landscape”, and “warfare ecology” in the title, keywords, or abstract of publications indexed in the Web of Science database.

It is possible that the rapid growth of research into the warfare-environment relationship has been spurred by a growing understanding within the international community of the need to account for environmental change and environmental considerations when planning for future operations and infrastructure, as well as an increased focus from the UN on the linkages between conflict and environmental security (Pearson, 2012; UNEP, 2009a, 2009b, 2020). Similarly, an increasing awareness within the defense community of the importance of understanding the interaction between environmental factors—especially climate change—and security issues may have prompted increased research, particularly within the military geography approach, given

this sub-discipline's close ties to the defense establishment (Woodward, 2005; Foley, 2012; Burnett & Mach 2021).

3.2 Disciplinary Contributions to Warfare-Environment Research

An analysis of warfare-environment publications by research area as distinguished by the Web of Science database reveals significant differences between approaches in terms of the disciplinary focus with which they engage (Figure 2.2). The Web of Science database assigns a subject category or categories to each query result based on the subject category that the database assigns to the publishing journal or book. According to this analysis, geography is the dominant discipline conducting research within the military geography and environmental geopolitics approaches, while history and various kinds of environmental studies dominate the environmental history approach. This result is perhaps not surprising, given that “geo,” “history,” and “environment” were explicit components of the database search terms, likely skewing the search results towards these disciplines. However, this division is borne out in an examination of the publishing venues for these approaches (see below). Militarized landscape research largely splits between the geographical and environmental studies discipline, with lesser engagement with history, political science, and area studies. Warfare ecology research trends towards a focus on other social sciences, particularly anthropology, though the relatively small number of publications returned by this query makes drawing conclusions about its disciplinary distribution premature.

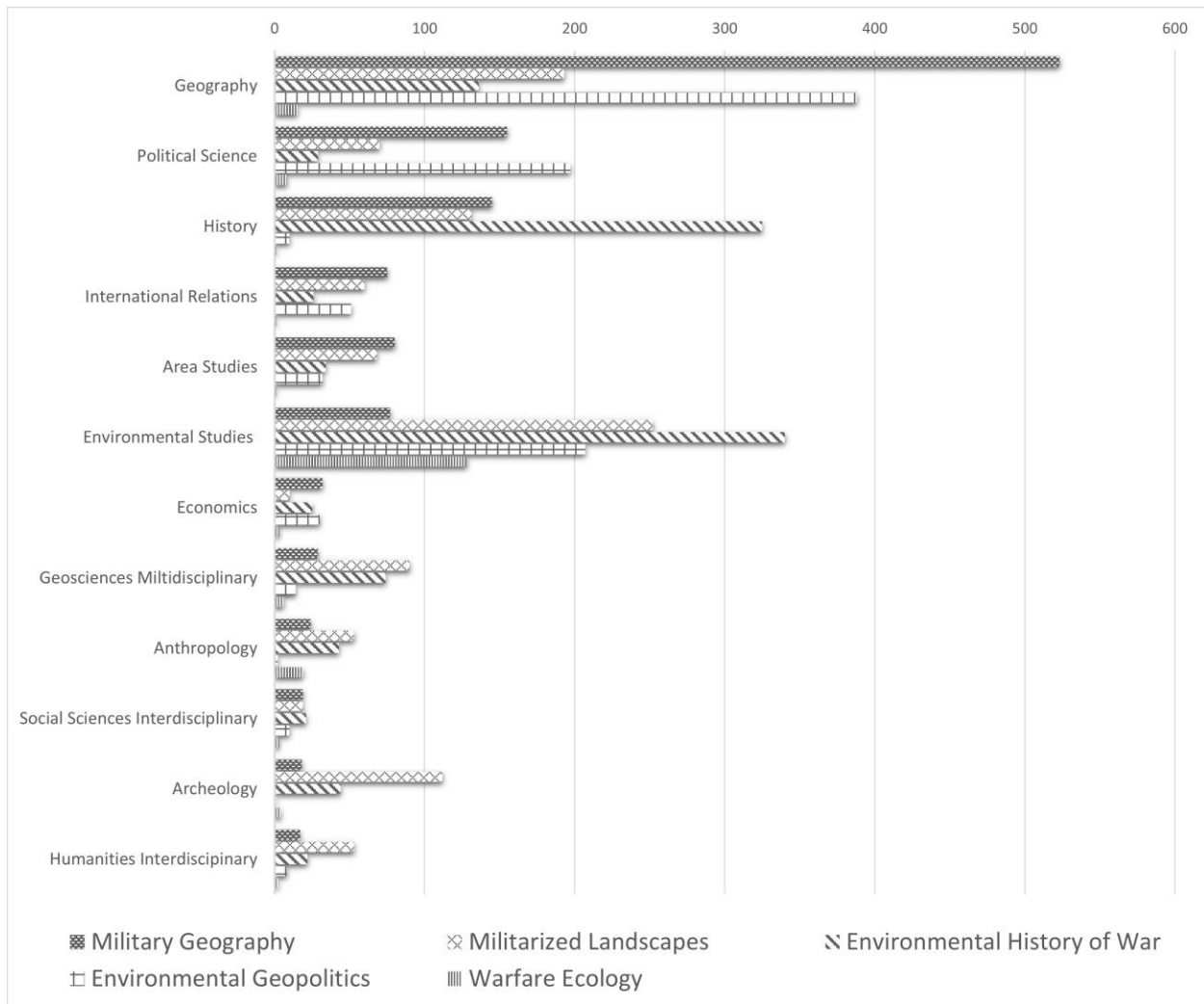


Figure 2.2 Total number of publications (2000–2022) per Web of Science-defined subject category citing the term “military geography,” “militarized landscapes,” environmental history of war,” “environmental geopolitics,” or “warfare ecology” in the title, keywords, or abstract from the database Web of Science.

This analysis indicates notable fragmentation in warfare-environment literature, which more broadly reflects the challenges inherent in multidisciplinary and interdisciplinary research. These can include fundamental differences in epistemologies, methods, research question formulation, and communication (Bracken & Oughton 2006). Indeed, scholars within several of these approaches have grappled with the barriers that different taxonomies and terminologies create between disciplines and communities examining this topic, with several suggesting and

contesting ways to use a common language to encourage collaboration and broader distribution of research (Palka & Galgano, 2005, 2012; Woodward, 2005, 2019; Marler, 2013; Hanson & Machlis, 2014).

Furthermore, scholars may be building additional artificial barriers to research based on biases related to research funding or concerns about the end use of warfare-environment research. For example, as Woodward (2005), Palka and Galgano (2005, 2012), Pearson (2012), and Farish (2015) have observed, military geography—at least in the US—has long been largely a domain of the defense and security communities, funded by and providing research for US government agencies in pursuit of US national interests. In the broader academic community, this has created some reluctance towards collaboration or even engagement with many of the topics that fall traditionally within this approach, though some of this reluctance towards collaboration seems to have eased in the past two decades (Pearson, 2012; Palka & Galgano, 2012; Woodward, 2014; Lohman & Fuhrman, 2019).

Finally, another factor driving the disciplinary fragmentation within warfare-environment research may be the scale at which scholars conduct their studies. Environmental geopolitics studies generally remain at global scale, while environmental history studies generally adopt a regional framework. By contrast, military geography and militarized landscape research focuses mostly on individual landscapes (McNeill, 2010; Pearson, 2010; Woodward, 2014). This is perhaps an area where Machlis and Hanson's (2008) and Palka and Galgano's (2012) attempts to define taxonomies for warfare environment research may prove to be most useful in encouraging collaboration, as both suggested frameworks provide a similar approach to understanding scale and context in relation to warfare-related subjects (Figures 2.3 and 2.4). Indeed, both frameworks offer a similar interpretation of scale as it relates to warfare, as Palka and Galgano tie their

tactical/operational/strategic conception of scale to one that bears an explicit resemblance to Machlis and Hanson's landscape/regional/global framework (Palka & Galgano, 2012).

These two models are also similar in they both envisage different, often overlapping "contexts" or "stages" of warfare. In this case the term "context" refers to the idea that military conflict can be divided into discrete stages (i.e., pre-war vs. post-war or insurgency vs. large-scale combat). Palka and Galgano's (2012) conception of warfare relies upon (now somewhat-outdated) US-military doctrine about the context in which military forces may operate, progressing along a continuum of increasing violence from peacetime through stability and support operations (SASO) to wartime. This framework lacks an explicit lens through which to study pre- and post-war activities, though these could be encompassed in the peacetime and SASO categories. Moreover, few military geography studies focus on the pre- and post-conflict phases of warfare, leaving gaps that other approaches to warfare-environment research are attempting to fill. Machlis and Hanson's (2008) ecological framework uses an approach like Palka and Galgano's, employing a triune understanding of context, but it differs in that their model views conflict activities and effects on a temporal continuum, dividing them into the categories of "preparation", "war", and "post-war" activities.

The similarity of these two approaches suggests the possibility of at least two methods for unifying the way warfare-environment researchers communicate, both by scale and by context. While the two interpretations of context appear at first to be very different, in effect Palka and Galgano's "peacetime" category is analogous to Machlis and Hanson's "preparation," while the "SASO" covers many of the activities that Machlis and Hanson consider to be part of the "post-war" phase. Still, the ongoing discussions surrounding fundamental terms and concepts in

warfare-environment research can create a confusing environment, obscuring which terminology or research approach might be most appropriate and effective.

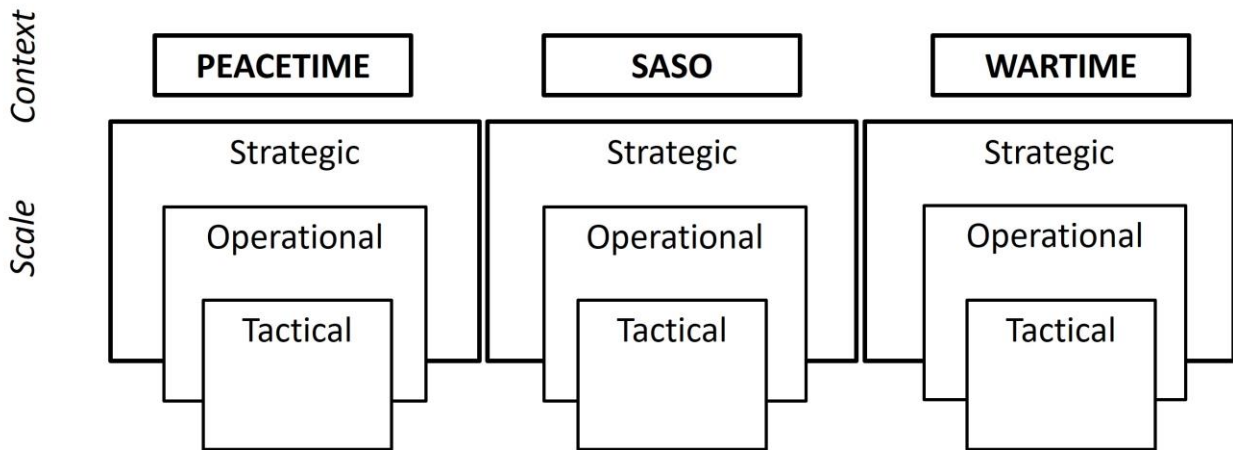


Figure 2.3 Palka and Galgano’s suggested framework for conceptualizing military geography as an academic discipline with scale divided between “tactical,” “operational,” and “strategic” (after Palka and Galgano, 2005).

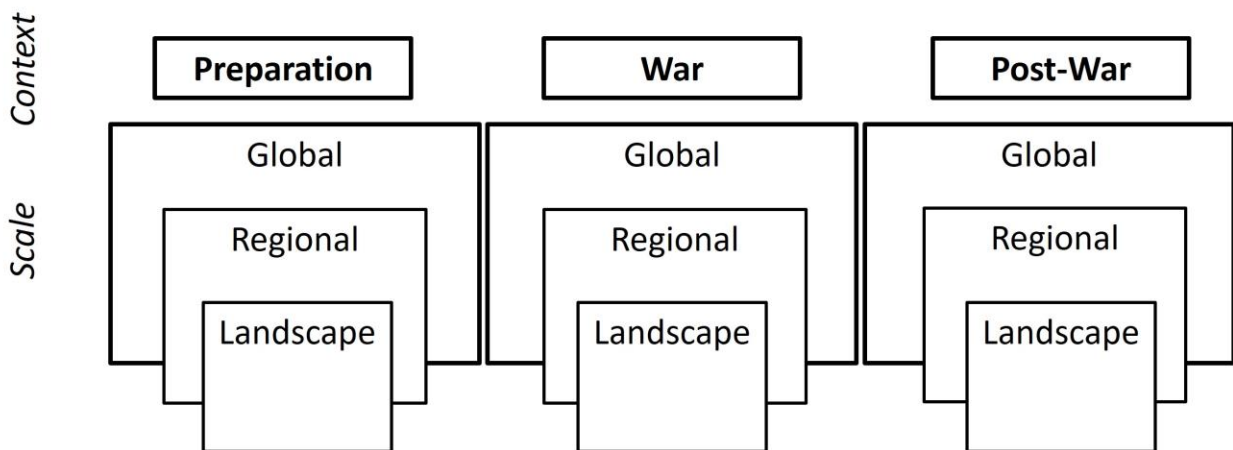


Figure 2.4 Machlis and Hanson’s (2008) suggested framework for warfare ecology with scale divided between “Landscape,” “Regional,” and “Global.” Note the similarities of the conceptions of scale and context to Palka and Galgano’s frameworks for these attributes. In both frameworks, the different scales and contexts often overlap (after Machlis and Hanson, 2008).

3.3 Contributions by Country

Anglophone research dominates the literature in all five approaches, with this bias being especially pronounced within the militarized landscape approach, where English-speaking countries account for nearly 73% of the scientific production. Among the other four approaches, anglophone countries consistently account for more than half of all publications. This result also reflects the fact that the queries were conducted in English, as well as the greater resources generally available to research institutions in the global north. However, significant variation in non-anglophone national contributions exists within the remainder of the scientific production across terms.

This variation reflects the internal historiography and focus of the dominant disciplines that engage with each approach and reflects some confluence between academic research with the national interests of certain countries and regions. Within the military geography approach, most non-US/UK/Canadian research originates from northern and eastern Europe, with a secondary locus of research in the Pacific Rim countries of China and Australia (Figure 2.5), a distribution that reflects recent regional tensions and conflicts. The long-running NATO military involvement in Afghanistan encouraged this trend as it has in other areas of academic inquiry, while the return of great power politics and increased military tensions in both Europe and east Asia have certainly reinforced it (Flint, 2004; Browning, 2018; Straughn et al, 2019; Pearson, 2018). Russia, Turkey, and China are, respectively, the next three most prolific producers of military geography research. Russian scholars have written extensively within the military geography approach, reflecting that country's post-Cold War concerns with its Near Abroad that has manifested itself most obviously in the ongoing Russo-Ukrainian War (Zakharenko, 2001;

Olesik, 2006). Furthermore, given military geography’s applied nature, the long-running involvement of both the Russian and Turkish militaries in the Syrian civil war has spurred research in this area, while China’s rising military power and its tensions with Taiwan help explain its moderately large contribution (Selby et al, 2017; Pearson, 2018; Moran & Turner, 2022).

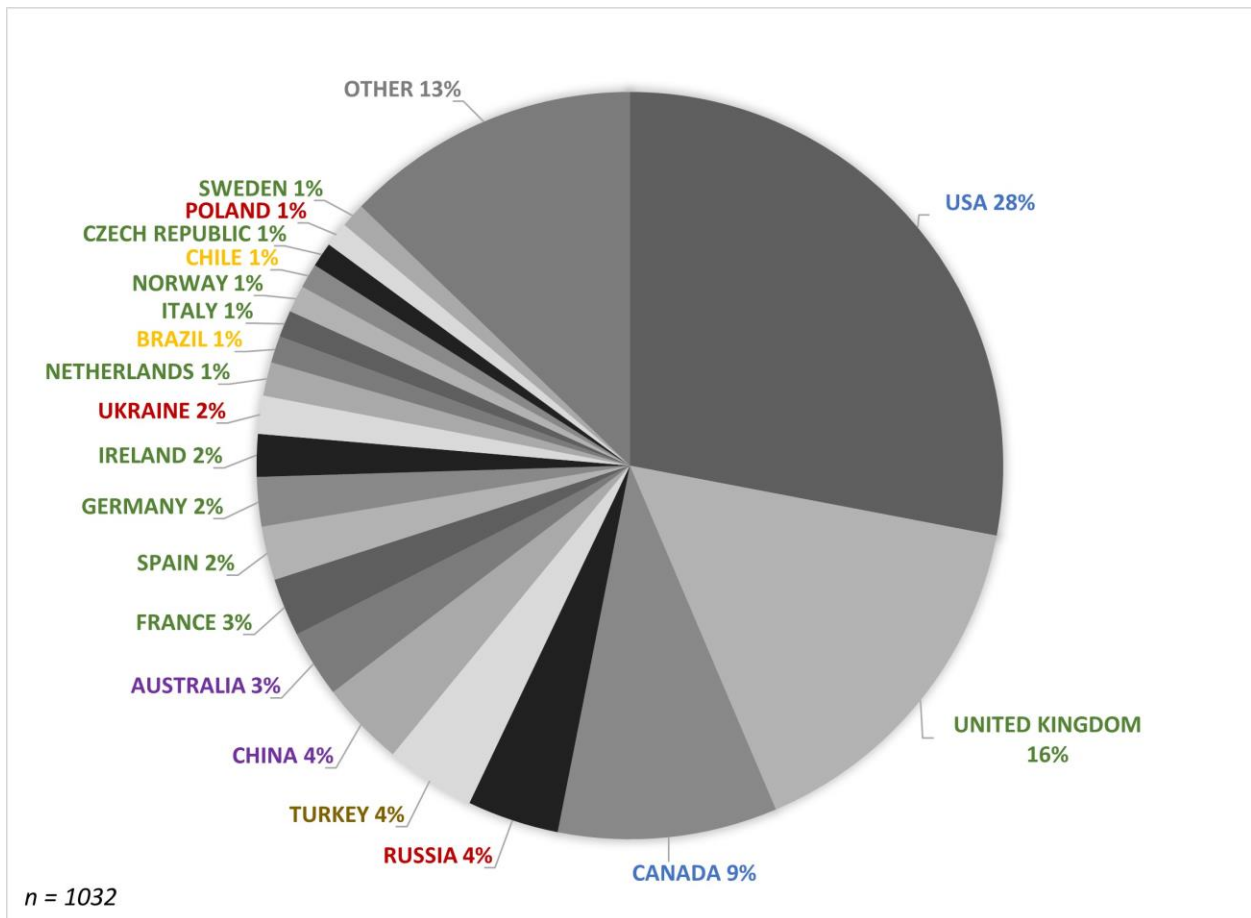


Figure 2.5 Proportion of publications (2000–2022) per country citing the term “military geography” in the title, keywords, or abstract from the database Web of Science. Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

The dominance of anglophone research within the militarized landscape approach reflects this sub-discipline's roots in the post-Vietnam War era in the US (Figure 2.6). Yves Lacoste and Arthur Westing pioneered this approach from the 1970s onward, with research examining the environmental toll of the Vietnam War and the environmental threat posed by a potential conflict between nuclear-armed powers during the Cold War (Lacoste, 1973; Westing, 1977, 1980), and this approach gained further relevance through examinations of the environmental costs of the Gulf War (see for example Sadiq & McCain, 1993). Much militarized landscape research imitates Westing's style (Pearson, 2012). However, this approach appears to have stagnated in terms of new research since the 1990s, possibly because the end of the Cold War removed the threat of nuclear conflict from the forefront of public and academic consciousness (McNeill & Unger, 2010). Another explanation is that many of the major conflicts since 2000, including the wars in Iraq, Afghanistan, and Syria, have occurred in areas that are inaccessible for academic research due to poor security conditions, preventing scholars from travelling to and scientifically assessing the environmental impacts of these conflicts (Weir et al, 2019; Abdullateef et al, 2020).

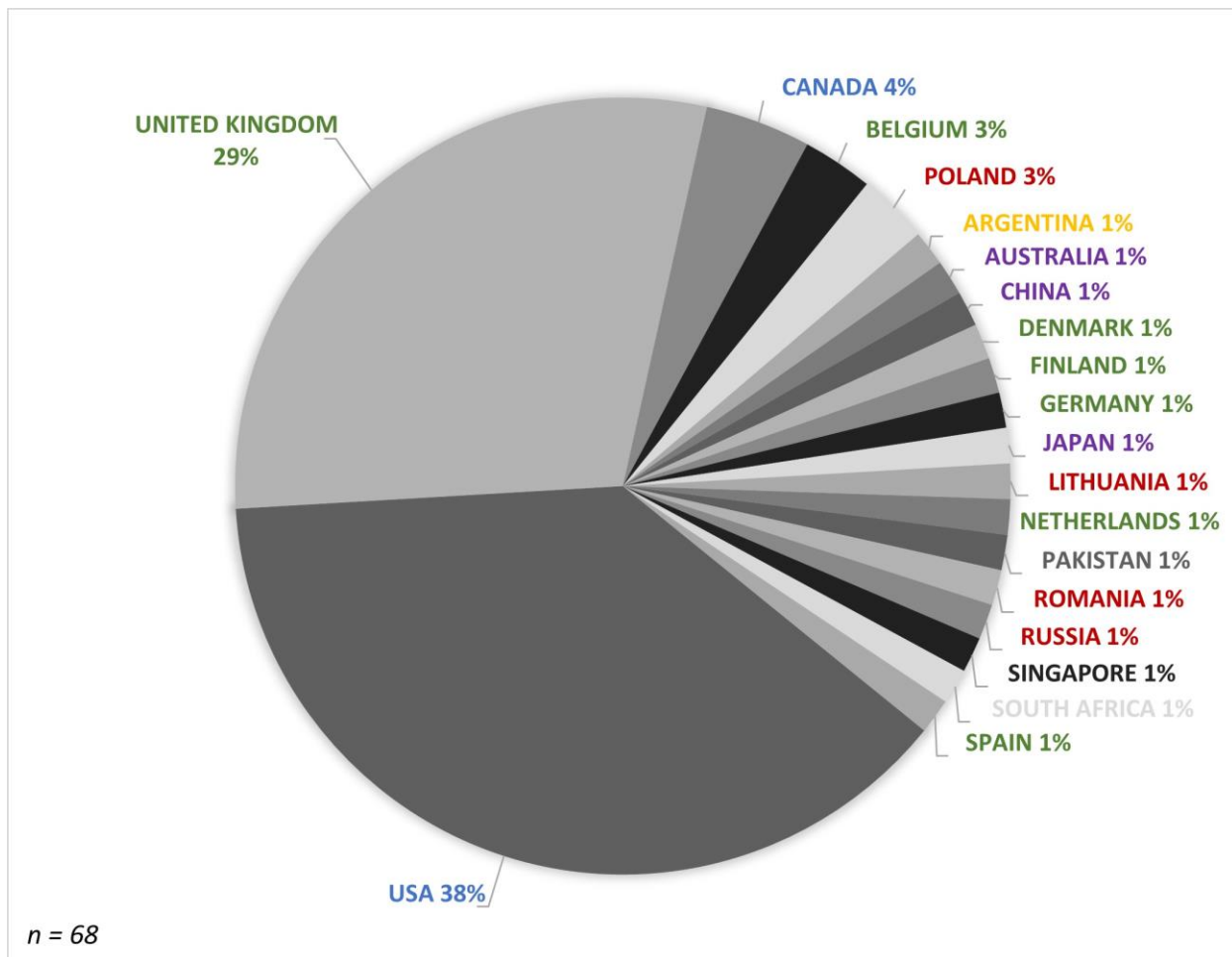


Figure 2.5 Proportion of publications (2000–2022) per country citing the term “military geography” in the title, keywords, or abstract from the database Web of Science. Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

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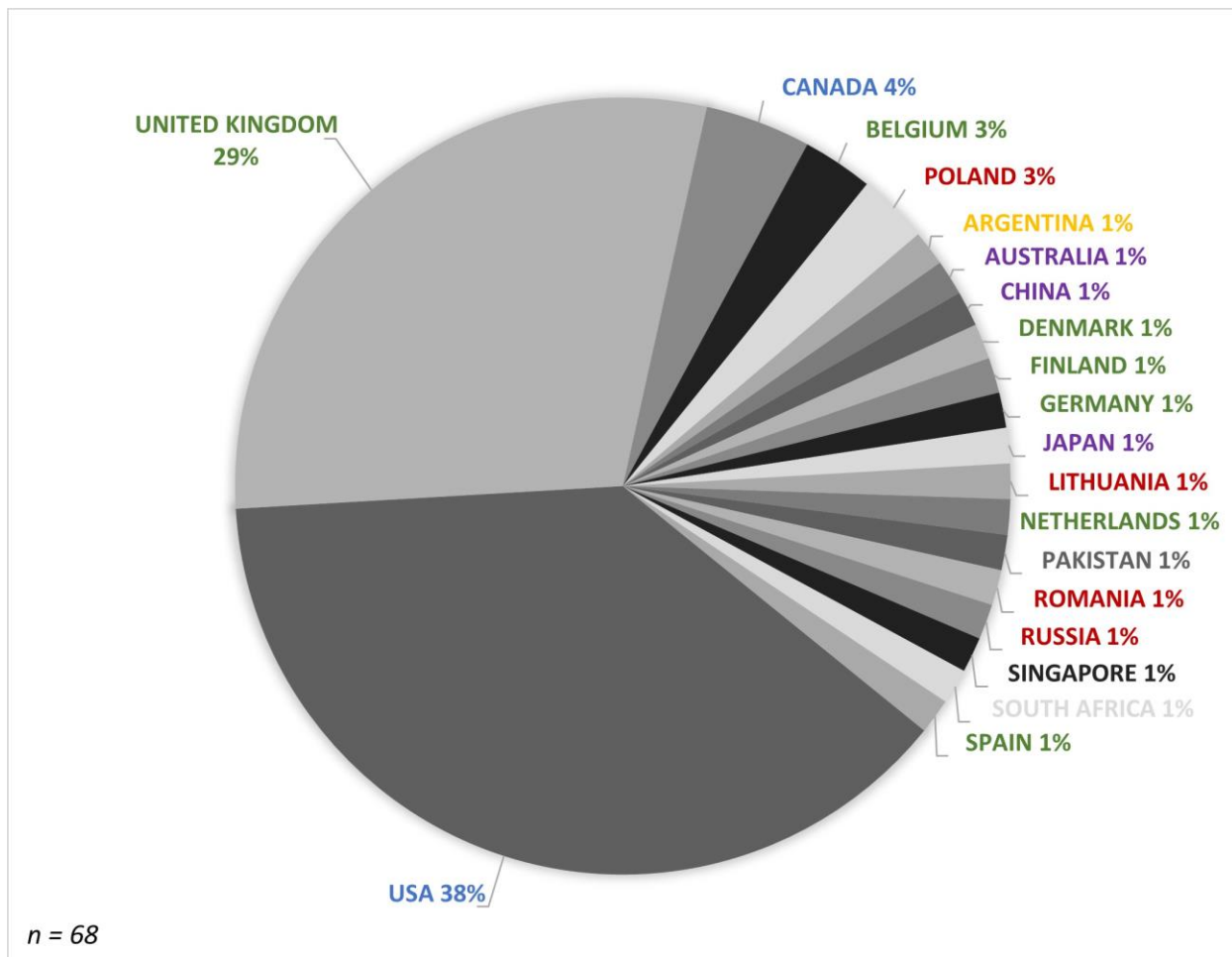


Figure 2.6 Proportion of publications (2000–2022) per country citing the term “militarized landscape” in the title, keywords, or abstract from the database Web of Science. Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

Environmental history of war is a growing subdiscipline within historical research with significant cross-pollination from cultural and physical geography, as illustrated by the mix of journals publishing research within this approach (McNeill, 2010). The geographic pattern of scientific production within this field mirrors that of military geography, with northern and eastern Europe being the largest contributors after the anglophone countries (Figure 2.7). This likely reflects a renewed interest in the environmental degradation of past wars as concern has

grown about contemporary military tensions on the European continent, borne out tragically with the Russian invasion of Ukraine in 2022.

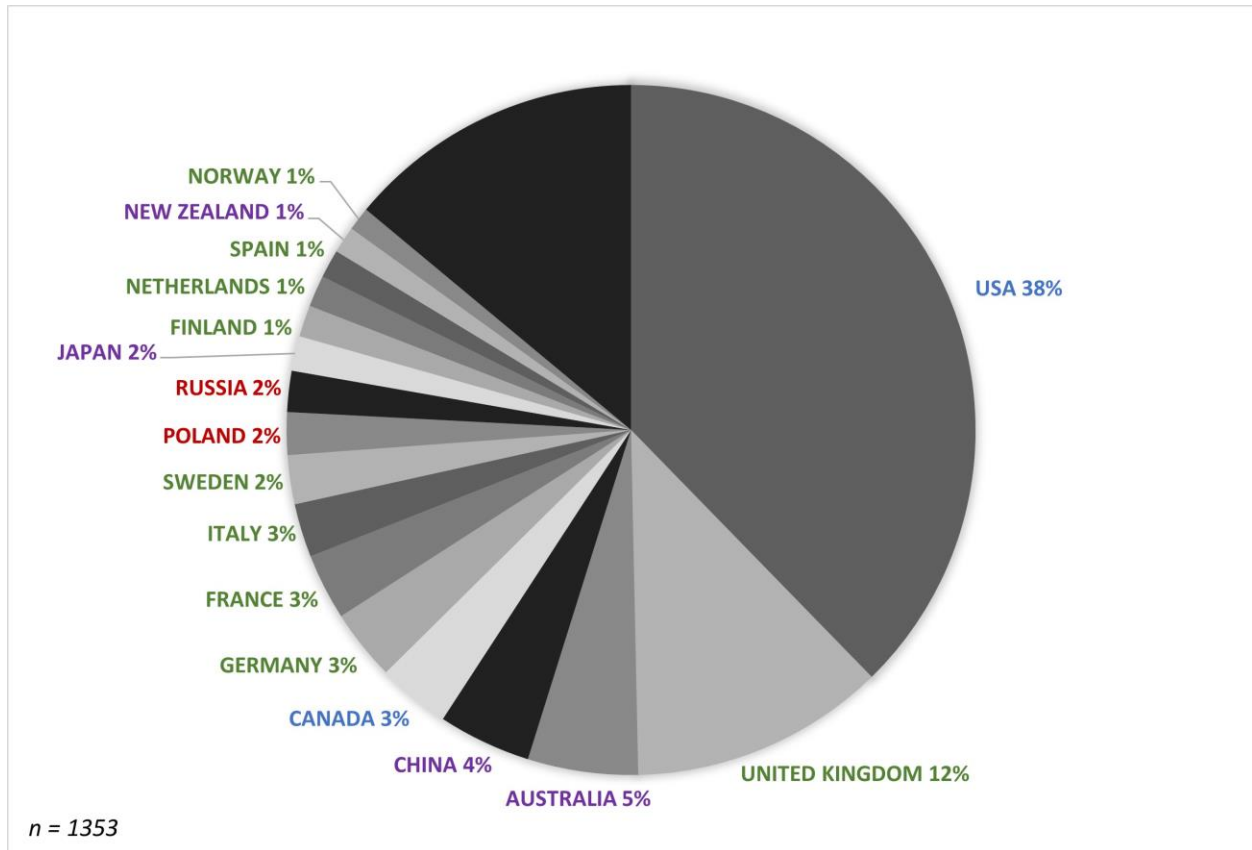


Figure 2.7 Proportion of publications (2000–2022) per country citing the term “environmental history of war” in the title, keywords, or abstract from the database Web of Science. Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

Environmental geopolitics is the only approach in where the US is not the leading contributor of research. In this case the UK is the main locus for research following this approach, reflecting a traditional British and Western European interest in geopolitics in general (Figure 2.8) (O’Lear, 2018, 10-11). Outside of the anglophone countries, this subfield contains

the greatest proportion of contributions from the Asia-Pacific region, with significant production by China, Australia, Singapore, New Zealand, and India, again reflecting concern about the growth of great power competition in this part of the globe (Pearson, 2018).

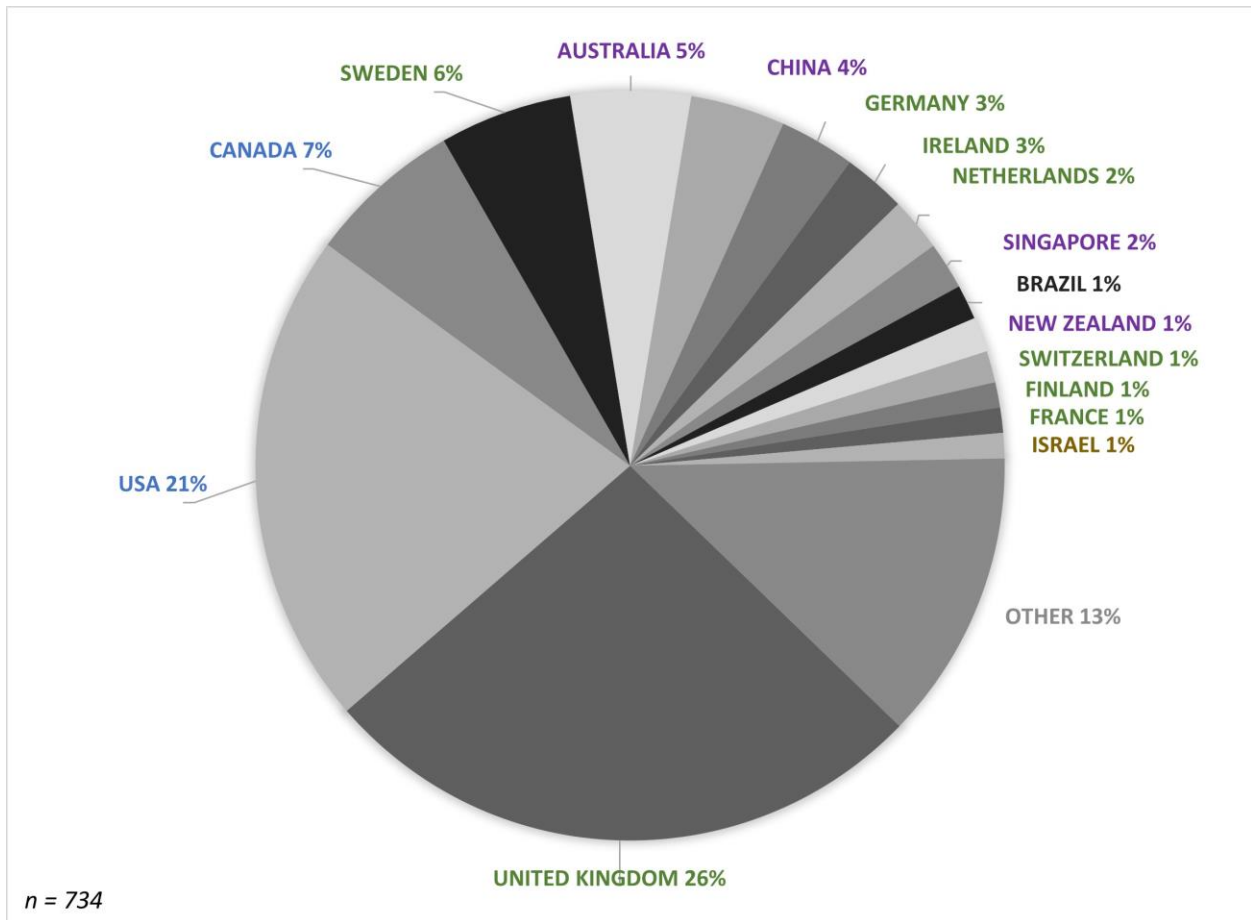


Figure 2.8 Proportion of publications (2000–2022) per country citing the term “environmental geopolitics” in the title, keywords, or abstract from the database Web of Science (n = 734). Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

Finally, the warfare ecology approach is the most dominated by US-based research (Figure 2.9). This fact reflects the approach’s recent origins in the US, as well as global operations conducted by US military forces during the study period, which has prompted

numerous US-based studies examining the interactions of military operations outside of actual conflict with the local environments and ecologies in which these forces operate (Marler, 2013). Furthermore, this field’s engagement with ecological theory has yielded a pattern of collaboration with biological sciences and anthropology, as opposed to the geographical and historical focus of the other four approaches, which is reflected in the mix of journals that publish warfare ecology research (see below).

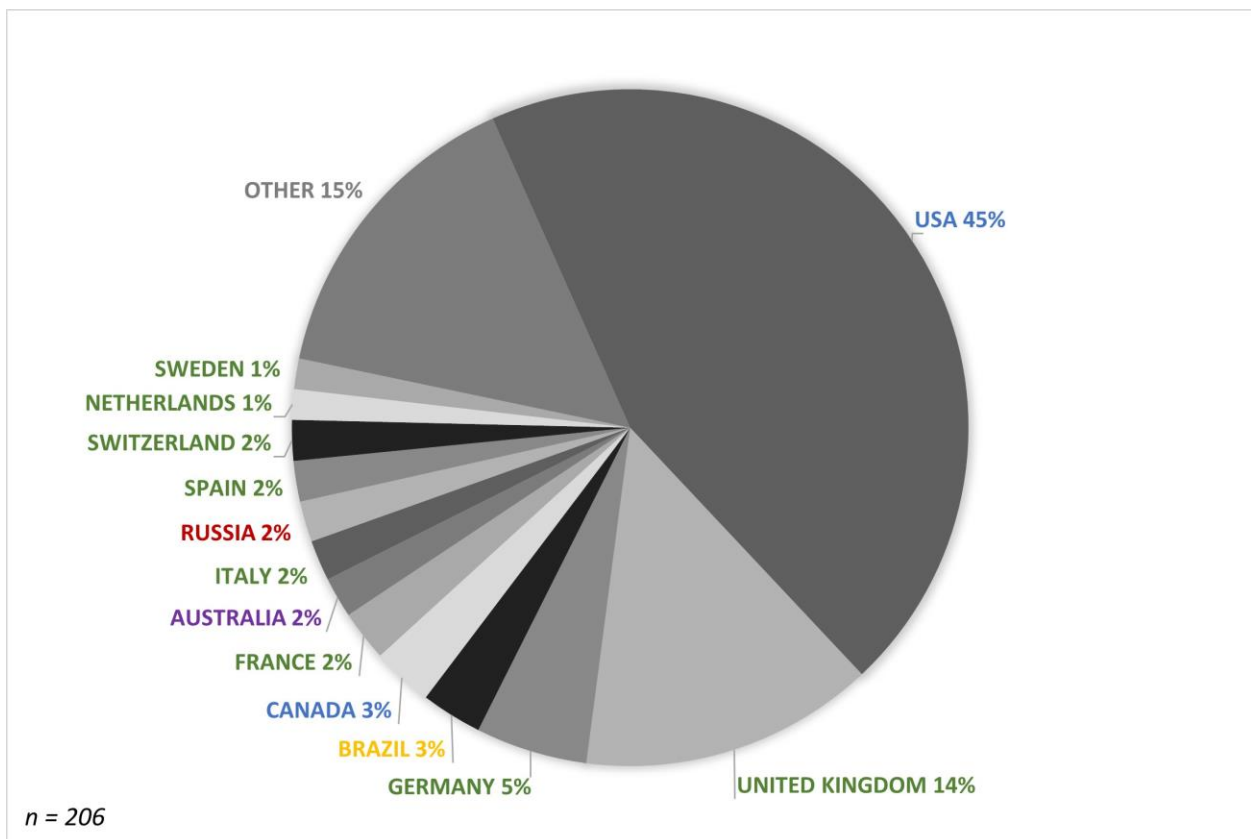


Figure 2.9. Proportion of publications (2000–2022) per country citing the term “warfare ecology” in the title, keywords, or abstract from the database Web of Science. Regionally, North American countries are highlighted in blue, South America in gold, Northern and Western Europe in green, Eastern Europe in red, Asia/Pacific in purple, and Southwest Asia in brown. Countries representing less than 1% of publication volume are merged into the category “OTHER.”

3.4. Journal Relevance and Influence

In terms of publication outlets, warfare-environment research shows a clear division between one grouping of military geography and environmental geopolitics on one hand, and another of environmental history and militarized landscape research on the other (Table 2.1). For the former, geography journals tend to dominate in publishing research for these approaches, with journals such as *Geopolitics*, *Political Geography*, and the *Annals of the Association of American Geographers* being common within the top ten journals of both approaches. Nearly all the other top journals publishing research according to these approaches are explicitly geographical, indicating a dominant focus on the spatial component of the warfare-environment relationship. One journal, *Political Geography*, is among the top publishers common to all five approaches, likely indicating the inherently political nature of warfare-related research.

In the case of environmental history and militarized landscape research grouping, historical journals are more prominent, with *Environmental History* and *Environment and History* being top forums for publishing research within both approaches. This trend likely reflects the backwards looking analytical focus of militarized landscape research and environmental history, as opposed to military geography and environmental geopolitics, which can tend to show a more applied and contemporary focus (Lohman & Fuhrman, 2019). Furthermore, environmental history also tends to engage with biomedicine studies that seek to understand the human health impacts of conflict. Both approaches also include geographical journals in their lists of top publishers, indicating more cross-disciplinary collaboration within this grouping than exists within communities conducting military geography and environmental geopolitics research.

	Military Geography	Environmental Geopolitics	Environmental History of War	Militarized Landscapes	Warfare Ecology
1	POLITICAL GEOGRAPHY	GEOPOLITICS	ENVIRONMENTAL HISTORY	ENVIRONMENTAL HISTORY	JOURNAL OF EXPERIMENTAL MARINE BIOLOGY
2	JOURNAL OF HISTORICAL GEOGRAPHY	POLITICAL GEOGRAPHY	ENVIRONMENT AND HISTORY	ENVIRONMENT AND HISTORY	HUMAN ECOLOGY
3	ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS	GEOFORUM	AVIATION, SPACE, AND ENVIRONMENTAL MEDICINE	ENVIRONMENT AND PLANNING A: ECONOMY AND SPACE	MARINE ECOLOGY PROGRESS SERIES
4	EURASIAN GEOGRAPHY AND ECONOMICS	TRANSACTION OF THE INSTITUTE OF BRITISH GEOGRAPHERS	JOURNAL OF HISTORICAL GEOGRAPHY	EUROPEAN JOURNAL OF ARCHEOLOGY	EVOLUTION AND HUMAN BEHAVIOR
5	APPLIED GEOGRAPHY	ENVIRONMENT AND PLANNING D: SOCIETY AND SPACE	AGRICULTURAL HISTORY	GENDER, PLACE, AND CULTURE	JOURNAL OF CHEMICAL ECOLOGY
6	PROFESSIONAL GEOGRAPHER	PROGRESS IN HUMAN GEOGRAPHY	JOURNAL OF URBAN HISTORY	JOURNAL OF BORDERLAND STUDIES	THE JOURNAL OF THE ROYAL ANTHROPOLOGICAL INSTITUTE
7	ANTIPODE	ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS	POLITICAL GEOGRAPHY	JOURNAL OF EASTERN AFRICAN STUDIES	POLITICAL GEOGRAPHY
8	GEOFORUM	GEOGRAPHICAL JOURNAL	JOURNAL OF AMERICAN HISTORY	LANDSCAPE RESEARCH	PROCEEDINGS OF THE ROYAL SOCIETY B: BIOLOGICAL SCIENCES
9	GEOPOLITICS	EURASIAN GEOGRAPHY AND ECONOMICS	SCIENCE OF THE TOTAL ENVIRONMENT	POLITICAL GEOGRAPHY	ANNUAL REVIEW OF ANTHROPOLOGY
10	TRANSACTION OF THE INSTITUTE OF BRITISH GEOGRAPHERS	SUSTAINABILITY	ENVIRONMENTAL HEALTH PERSPECTIVES	WAR IN HISTORY	BEHAVIORAL ECOLOGY

Geography
History
Anthropology
Health/Biomedicine
Bioscience
Interdisciplinary

Table 2.1 Rankings of publications volume (2000–2022) by journal citing the term “military geography,” “militarized landscapes,” “environmental history of war,” “environmental geopolitics,” or “warfare ecology” in the title, keywords, or abstract from the database Web of Science.

The warfare ecology approach, as mentioned above, shows a markedly different publication pattern than the other four approaches. Bioscience journals (particularly marine biology-focused ones) feature prominently in this approach, reflecting an active and collaborative group of scholars who have been examining the environmental dangers posed by historical military shipwrecks and current naval operations in the Pacific related to geopolitical tensions around the Pacific Rim (Monfils, 2005; Marler, 2013). Anthropology journals also feature prominently among the top publishers in this approach, as do explicitly interdisciplinary journals, which may reflect a perspective inherent in the ecological approach. However, warfare ecology’s lack of significant engagement with the major geographical or historical journals indicates that Machlis and Hanson’s (2008) framework, despite receiving attention from several

of the prominent scholars conducting warfare-environment research, may have so far failed to significantly engage broader thinking in these communities. To date, much of the literature applying ecological theory to understanding the environmental impacts of conflict generally examines the ecologies of the local environments in which the conflict occurred, rather than treating the conflict's belligerents and their supporting economies as a holistic ecology to better understand the interaction between environment and war at different scales, as Machlis and Hanson (2004) originally suggested.

4. Conclusions

This meta-analysis of warfare environment research conducted over the past two decades suggests that the volume of published research on this topic has increased steadily since 2000 and will likely continue to grow in the coming years. Specifically, the military geography, environmental history, and environmental geopolitics approaches have added significant amounts of new research in the past two decades, while the militarized landscape and warfare ecology approaches have stagnated in terms of adding new publications. Overall, warfare-environment research tends to originate in anglophone countries, particularly the US, UK, and Canada, with northern and eastern Europe and China being other loci of scientific production. Geography journals tend to be the venues for the publications of military geography and environmental geopolitics research, while militarized landscape and environmental history research generally publishes in historical journals. Warfare ecology research shows a strong relationship with biological science journals.

The analysis also indicates that warfare-environment research remains fragmented by discipline, approach, geographic origin, and publishing venues. Much of this fragmentation reflects regional concerns about potential and actual conflict arising from renewed great power competition in both Europe and Asia, but much also reflects a failure to establish a common theoretical framework and a common language to communicate results within this topic. Machlis and Hanson's (2008) ecological approach to studying warfare-environment interactions shows the most promise for providing a cohesive theoretical framework going forward because it is less confined to the discrete and parochial conception of the military continuum of violence than is Palka and Galgano's (2012) framework. Furthermore, the warfare ecology approach continues to shape ongoing efforts to understand the environmental costs of war in ways that other frameworks do not (see for example Francis, 2011; Francis & Krishnamurthy, 2014; Nasirian et al, 2015; Hanson, 2018; Belcher et al, 2019). Moreover, an explicitly ecological approach encourages researchers to reach across disciplinary boundaries, which can afford them the opportunity to access data sources being discovered or generated outside of their field. This is important, as Francis and Krishnamurthy (2014) have identified a lack of data as one of the key constraints holding back warfare-environment research.

In engaging with this framework, researchers across disciplines should begin their projects with an awareness of the taxonomy into which their research falls in terms of scale and context. Table 2.2 indicates broadly how the focus of each of the four major warfare-environment approaches is situated within Machlis and Hanson's warfare ecology framework. This is not to say that scholars should remain straightjacketed by the normal context and scale of their chosen approach. Rather, researchers can view the warfare ecology framework as a matrix that connects their studies to those of other approaches and disciplines. For example, a military

geography researcher wishing to conduct a study of a wartime military campaign at the regional (operational) scale should be aware that they may find a greater breadth of literature by engaging with environmental historians than remaining strictly within the confines of military geography. Similarly, an environmental historian seeking to understand the local postwar impacts of a particular conflict may engage more with the work of militarized landscape researchers rather than that of other environmental historians. Such awareness will not only promote more cross-disciplinary research by helping scholars look outside their discipline’s body of literature but may also expand the boundaries of scale and context with which these approaches traditionally engage.

Scale	Context		
	Preparation (Pre-War)	War	Postwar activities
Landscape (Tactical)	Militarized Landscapes	Military Geography	Militarized Landscapes
Regional (Operational)	Environmental History	Environmental History	Environmental History
Global (Strategic)	Environmental Geopolitics	Environmental Geopolitics	Environmental Geopolitics

Table 2.2 The dominant situation of the various approaches to warfare-environment research according to scale and context within Machlis and Hanson’s (2008) warfare ecology framework. This framework ties the military-specific context of the tactical/operational/strategic levels of war to the landscape/regional/global conceptions of space in the way suggested by Palk and Galgano (2012).

Regardless, warfare-environment research maintains a persistent need for small-, mid-, and large-scale studies of the discrete aspects and impacts of military conflict, and also broader

sources of data to underpin these studies. A more holistic, ecological approach that takes into consideration multiple scales and contexts will illuminate relationships between conflict and the environment that have been previously overlooked or under-studied, just as greater engagement between researchers across disciplines, approaches, regions, and publishing venues will do much enhance and enrich these studies with broader perspectives and sources of data.

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Chapter 3 - Map Rooms and Cartographic Sections: The Tactical Mapmaking of the American Expeditionary Force in the Great War

Abstract

The Great War of 1914-1918 marked important developments in the evolution of military cartography. While much recent research has examined these developments in the context of the European belligerent armies, including those of the British, Italians, and Germans, little research has explored the mapmaking efforts of the American forces that participated in the closing months of the conflict. This paper examines how the Army- and Corps-level headquarters of the American Expeditionary Force (AEF) in France used tactical maps to visualize spatial information and control the operations of subordinate forces on the battlefield to better understand how these novel mapmaking processes developed. The research draws upon archival records—including the AEF’s maps and official documents—to understand how the AEF acted as a cartographic system that collected, transmitted, mapped, and distributed spatial information. The research indicates that the AEF mapmakers learned from the cartographic techniques of the other allied armies to develop a form and language of cartography that was distinct to the American army in France. These results reinforce the conclusions of other scholars that have argued that the Great War marks an important point in the evolution of military cartography.

1. Introduction

The Great War of 1914-1918 showcased major advancements in the lethality, scale, and technology of warfare. One manifestation of this process was evident in the evolution of military cartography during the conflict (Collier, 2015a). Much recent research has examined the military mapmaking of the European armies during this conflict, including those of the British, Italians, Austro-Hungarians, and Germans (Radunzel, 2016 & 2019; Demhardt, 2018; Chasseuad, 2018; Espenhorst, 2018; Prá et al, 2022). However, comparatively little research has explored the mapmaking efforts of the American forces that fought in 1917-1918 (Apkin, 2017; Moore, 2018). Over a relatively short period of time, the American Expeditionary Force (AEF) in France produced an enormous number of daily and periodical tactical maps to visualize their environment and control the operations of subordinate forces. Given how American military culture has increasingly shaped that of militaries around the world since the Great War, these documents present an intriguing avenue through which to examine the evolution of military cartography, the ways in which the AEF headquarters processed information, and the evolving nature of modern warfare more broadly (Bjerga & Haaland, 2010). Drawing upon archival sources including tactical maps and other documents produced by AEF headquarters and units, which are held at the US National Archives at College Park, Maryland, this paper outlines many of the types of maps that the AEF produced during the St. Mihiel and Meuse-Argonne offensives of September-November 1918 and argues that these maps, along with the tactical maps produced by the other Great War belligerents, represent an important development in the evolution of modern military cartography.

1.1 Types of Maps: Terrain versus Tactical

Regarding military maps specifically, historians of cartography have tended to pay more attention to the scientific techniques or technical means that Great War military surveyors used to produce ever more large-scale, accurate, and intricately detailed base maps for the armies in the field, as opposed to studying the tactical uses to which military formations put these maps (see for example Collier, 2018 and Chasseaud, 2018). The driving motivation for the creation of these base maps was the emerging dominance of indirect artillery fire on the battlefield, which drove a requirement for maps of sufficient scale, detail, accuracy, and precision, for artillery observers to direct long-range fire onto precise targets (Chasseaud, 2018). Indeed, prior to the outbreak of the Great War the French plans directeurs had mapped their country's frontier and fortress areas at scales of 1:10,000, 1:20,000, and 1:50,000 in anticipation of possible war with Germany (Arnaud, 2022). Other spurs to advancement included the use of aircraft and photography to produce maps (Coller, 2015a).

Researchers have paid less attention to how the armies used these maps. Before the Great War, military staff officers typically treated maps as static documents for planning purposes or to understand the terrain over which their forces would operate (Collier 2015a). During the titanic struggle of 1914-1918, however, advances in reconnaissance (aircraft and automobiles), communications (telephone and radio), and printing (lithographs and powered printers) allowed armies for the first time to map the actions of their forces and the enemy almost continuously, and to mass produce and distribute the resulting maps as a means of information sharing and control (Keegan, 2003; Radunzel, 2016; Demhardt, 2018; Chasseaud, 2018). As Radunzel (2016) and Prà et al (2022) have argued, this ability to conduct continuous mapping of a changing battlefield marked an important development in the practice of military cartography, ranking alongside other developments such as the widespread use of machineguns and aircraft, or the

introduction of tanks and poison gas, as markers of the changing face of modern warfare. As such, this paper focuses on the subset of AEF tactical maps that attempted such continuous or iterative coverage of battlefield events as a novel military mapmaking process that saw its coming of age in the Great War.

This paper defines a tactical map as the general type of map on which staff mapmakers overprinted tactical information onto pre-printed editions of already-surveyed base maps (Prà et al, 2022). This definition contrasts with the base or terrain maps that surveyors produced to show the locations of physical and cultural geographic features on the earth's surface. While the AEF did conduct some surveying to produce their own terrain maps in France, usually the American forces simply reprinted existing French maps for use as base maps (Moore, 2018). The American tactical maps, by contrast, represented the work of staff officers and mapmakers within the AEF's tactical headquarters who were struggling to develop coherent and intuitive ways to understand and control the massive and destructive forces they were facing and employing. As such, tactical maps provide a unique window into the processes and evolution of American military mapmaking during the Great War, as well as the development of warfare during the conflict more broadly.

1.2 Methods

Most of the tactical maps that the AEF produced during the Great War are located at the US National Archives facility in College Park, Maryland, in the Strategic Operations Map Series of Records Group 120. For this project, hundreds of these maps were digitally photographed over a week-long period in the summer of 2022 using archival methods outlined by Keeling and

Sandlos (2011). The digital images of the maps were then georectified in ArcGIS Pro 3.1.1 using terrain features such as road intersections and bridges as control points between the satellite imagery of present-day terrain features and the contemporary landscape portrayed on the AEF's base maps. Pairing historical military maps with GIS software is a useful method for analyzing this type of document, as exemplified by Knowles (2008) and Prà et al (2022). Georectification allowed comparison between the various series of tactical maps and the map editions within the series, facilitating the analysis described below.

1.3 AEF Background and Organization

The United States joined the war against Germany in April 1917 (US Senate, 1917, April 6). The first American troops began to arrive in France in June of that year (Woodward, 2014). However, only by August 1918 could the American army concentrate sufficient numbers to justify the formation of the AEF's first field army. By the beginning of September 1918, the AEF fielded more than a million troops under the command General John "Blackjack" Pershing and was prepared to execute its first major operation under entirely American control: the assault against the St. Mihiel salient east of Verdun (Hallas, 1995; Carter, 2018).

The basic tactical unit of the AEF was the division (Grotelueschen, 2007; Kretchik, 2011). The next higher echelon was the corps. A corps headquarters could control the operations of anywhere from two to as many as six divisions. Above the corps echelon of command sat the field army. The AEF eventually consisted of two field armies (First and Second). These controlled, by the end of the war, six American (I, III, IV, V, VI, and VII) and three French (2nd Colonial, XVII, and XXXIII) corps (US Army, 1988). Finally, after the US Second Army

formed in October 1918, the AEF headquarters became an army group-echelon command controlling multiple field armies. Corps echelon headquarters and above possessed the necessary equipment—specifically powered printers and trained cartographers—to iteratively produce tactical maps (Moore, 2018; Chasseaud, 2018). While lower-echelon headquarters also produced maps, their capability to conduct continuous tactical mapmaking was far less developed (Chasseaud, 1918).

1.4 AEF Staff Organization

The AEF in France benefitted from the reforms that the US Army had instituted following the Spanish-American War under the guidance of Secretary of War Elihu Root (Koistinen, 1997; Woodward, 2014). These reforms laid the groundwork for the American forces in the Great War to generate the professional staff organizations that could control and resource the massive and complex operations in which the AEF would participate. However, the American staff systems also benefitted from the experience of their new allies, who had been fighting in France for nearly three years by the time the AEF began to form. The AEF's General Order 8 (1917) laid out how the army's division, corps, and field army headquarters should organize themselves (US Army, 1992). Leaning explicitly upon French and British staff organizations, this document divided the American staff system into Administrative, Intelligence, Operations, Training, and Coordination sections, with a separate "Administrative and Technical" staff section encompassing various unique specialties such as aerial and gas warfare.

By early 1918, however, the American forces in France had gained enough experience for General Pershing to issue General Order 31 (1918) revising the AEF's staff structure to accommodate his vision for how American forces could differentiate themselves from their allies in terms of organization and tactics (US Army, 1992). This new order applied a numbering system to the various staff sections (G1 for Administration, G2 for Intelligence, G3 for Operations, etc.) and expanded several specialized staff organizations, including the artillery and air service staffs, into full-fledged and independent staff sections within the headquarters (Figure 3.1). Moreover, these general orders directed that American headquarters at all echelons conform to this system. These general orders also contained specific instructions concerning the types of tactical maps various sections were responsible for producing, though the actual processes of the AEF headquarters do not appear to have adhered too closely to these cartographic instructions.

ORGANIZATION OF GENERAL
HEADQUARTERS AMERICAN EXPEDITIONARY FORCES,
(G. H. Q. A. E. F.)
TABLE I.

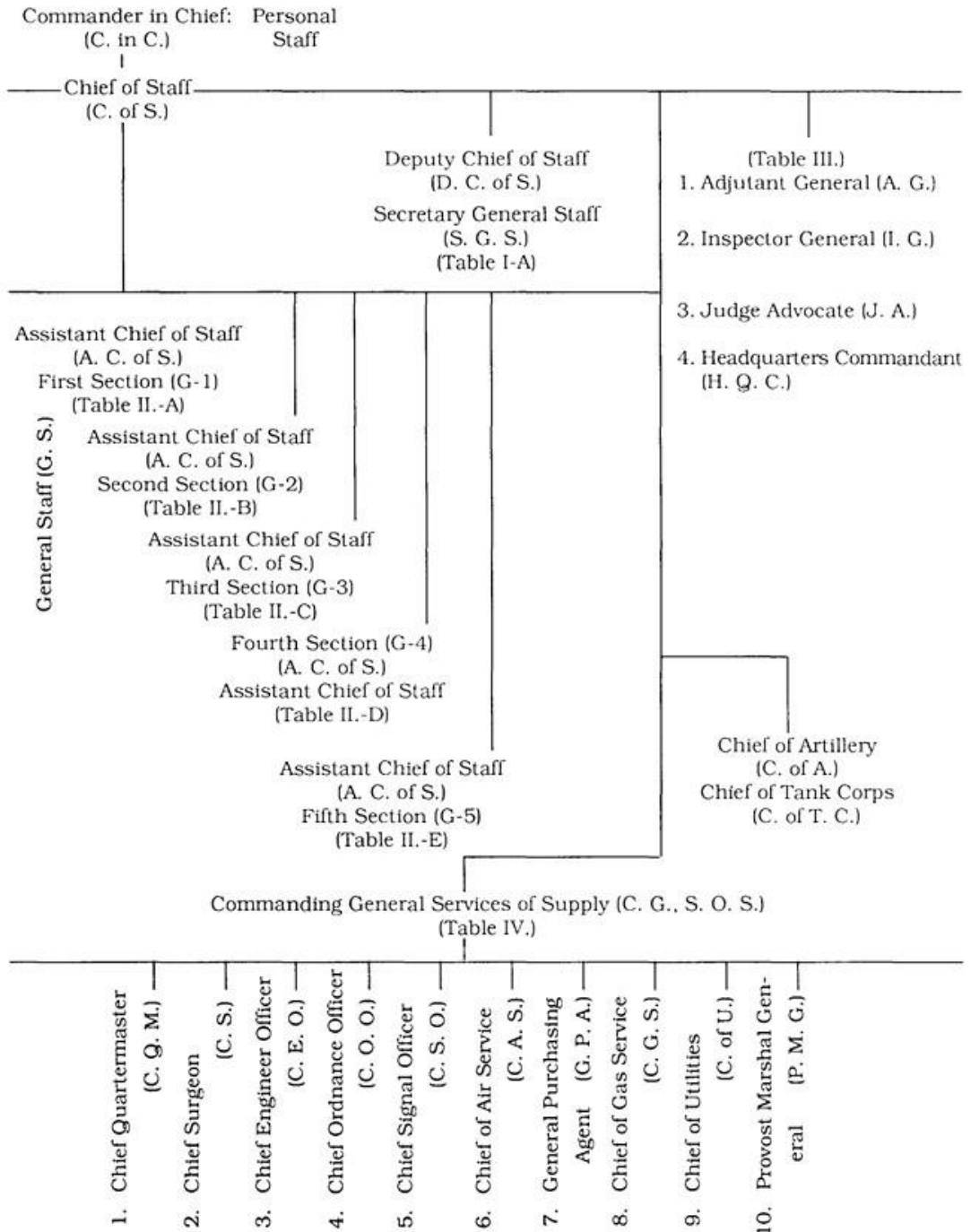


Figure 3.1 Organization of the GHQ staff sections of the AEF as directed by General Order 31 (1918) (US Army, 1992, pp. 217).

2. Major AEF Operations

The first major American-led offensive was the set-piece attack on an appendage of the German front northeast of Verdun known as the St. Mihiel Salient. This attack began on 4 September 1918 and, aided by the fact that the Germans had already begun withdrawing from the salient, concluded successfully four days later (Carter, 2018). Even before the St. Mihiel offensive had commenced, the AEF staff led by Colonel George Marshall began planning for a subsequent offensive to break through the German Hindenburg Line at an area dozens of miles to the west of St. Mihiel (Hallas, 1995).

By late September 1918, the AEF began its second major offensive operation, this time attacking northwards between the rugged Argonne Forest and the Meuse River (Woodward, 2014). Suffering heavy losses, the American army ground haltingly forward through September and October 1918 before reaching the main fortifications of the Hindenburg Line (Zabecki, 2018). Subsequently, American divisions breached this fortification belt after further heavy fighting. By the signing of the Armistice on 11 November 1918, American forces were advancing rapidly northward towards the key railroad junction at Sedan.

The tactical mapmaking efforts of the American headquarters during these two major offensives demonstrate both increasing levels of standardization and sophistication, as well as examples of improvisation as the staff officers grappled with the scale and complexity of the battles their formations were fighting. The St. Mihiel offensive involved nearly 500,000 US and French troops as well as thousands of artillery pieces and hundreds of aircraft, while the Meuse-Argonne offensive was even larger, launching more than a million US and French troops against 450,000 dug in German defenders on a front of more than forty kilometers (Hallas, 1995; Lengel, 2008).

The American mapmakers incorporated both British and French tactical mapmaking techniques into their own maps. They also incorporated efforts at standardization that were emerging within the broader allied command establishment, as demonstrated by General Orders 60 and 65, which directed American cartographers to align their cartographic processes with those of their allied counterparts (US Army, 1992). However, many of the mapmaking techniques used by the Americans also appear to have been improvised and novel, such as attempts to create new tactical map languages and efforts to show change over time on single map sheets, indicating a unique tactical map culture that was developing within the AEF.

3. The AEF's Tactical Maps

Nearly every staff section in the headquarters of AEF units at the corps echelon and above produced tactical maps. The AEF headquarters and each army-level headquarters were each authorized one battalion of engineer troops to conduct map surveying and printing, though in reality the army-level headquarters only ever received at most a company of these cartographic troops due to shortages in trained personnel (US Army, 1991, 59). Each corps-level headquarters was authorized to have one engineer officer and twenty-three troops for map production. The personnel for these staff organizations were provided by the 29th Engineer Battalion, who ran the AEF's Base Printing Plant at Langres, where the vast majority of base maps were printed (US Army 1991, 56). In broad terms, the tactical maps they produced fell into two categories; some were for compiling and centralizing information within the headquarters to allow the various staffs and commanders to maintain situational awareness of the ongoing operation, while the purpose of others was to disseminate information and orders from the

headquarters back to subordinate units (US Army, 1992). The headquarters mapmakers typically produced the former map types on a regular—sometimes daily—schedule, while the latter types were more periodical and usually accompanied written orders to lower echelons such as field orders at the beginning of a discrete operation.

Among the various staff sections that constituted the AEF's headquarters, three stand out as prolific mapmaking entities. First, the Intelligence or G2 sections were responsible for compiling information about the enemy's strength, dispositions, and activities on the battlefield (Gilbert, 2012). Second, the Operations or G3 sections mapped the positions of friendly forces within the AEF's areas of responsibility and issued maps directing future movements and objectives (US Army, 1992). Finally, the staff Artillery sections worked with the G2 sections to map enemy artillery activities and battery locations and with the G3 sections to issue orders directing the deployment and firing objectives of friendly artillery batteries. Other staff sections also produced a significant number of periodical maps—particularly the G1 (administration) and G6 (signal) sections—that typically directed the activities of correspondingly specialized elements within the AEF's units. However, the intelligence, operations, and artillery sections were apparently the only ones that produced tactical map series with daily editions.

4. Maps of the G2 Intelligence Sections

American corps- and field army-echelon G2 sections contained a sub-section, the G2 Cartographic Section or G2C, whose members were responsible for the sections' mapmaking efforts (Moore, 2018). These produced at least two daily tactical map series during the AEF's operations. The Enemy Order of Battle (EOOB) map series sought to track the location and

strength of enemy units opposing the AEF. The Graphical Summary of Enemy Activities (GSEA) series mapped what the enemy was doing on the battlefield. Other maps that the intelligence section produced only periodically included radio intercept sketches that attempted to pinpoint the locations of enemy radio transmitters and headquarters, circulation maps that tried to discern the traffic patterns of support elements behind the enemy's lines, and trench or fortification maps that charted the shape and extent of enemy trench systems and fortress complexes. Taken together, the mapping efforts of the G2 sections attempted to compile for the headquarters a comprehensive picture of the enemy's situation and activities each day.

4.1 Enemy Order of Battle Maps

The first of the two daily map series that the G2 Intelligence sections of the AEF prepared daily was the Enemy Order of Battle (EOOB) Map. The purpose of these maps was to maintain a running tally of the identity and location of enemy units that were opposing the AEF on a given day (Figure 3.2). Also, the EOOB maps communicated a rough estimate of these units' strength, condition, and movements in the form of annotations and arrow symbols adjacent to the block symbols that denoted individual regiments. Additionally, these maps templated the locations of enemy headquarters at the division, corps, and field army echelons of command, and gave an assessment of where the enemy drew their administrative boundaries between their divisions and corps fighting on the front line. Additionally, the map language provided a visual cue to indicate when new enemy units appeared at the front, changing the texture of the box symbols to indicate whether a unit was newly identified since the last map edition.

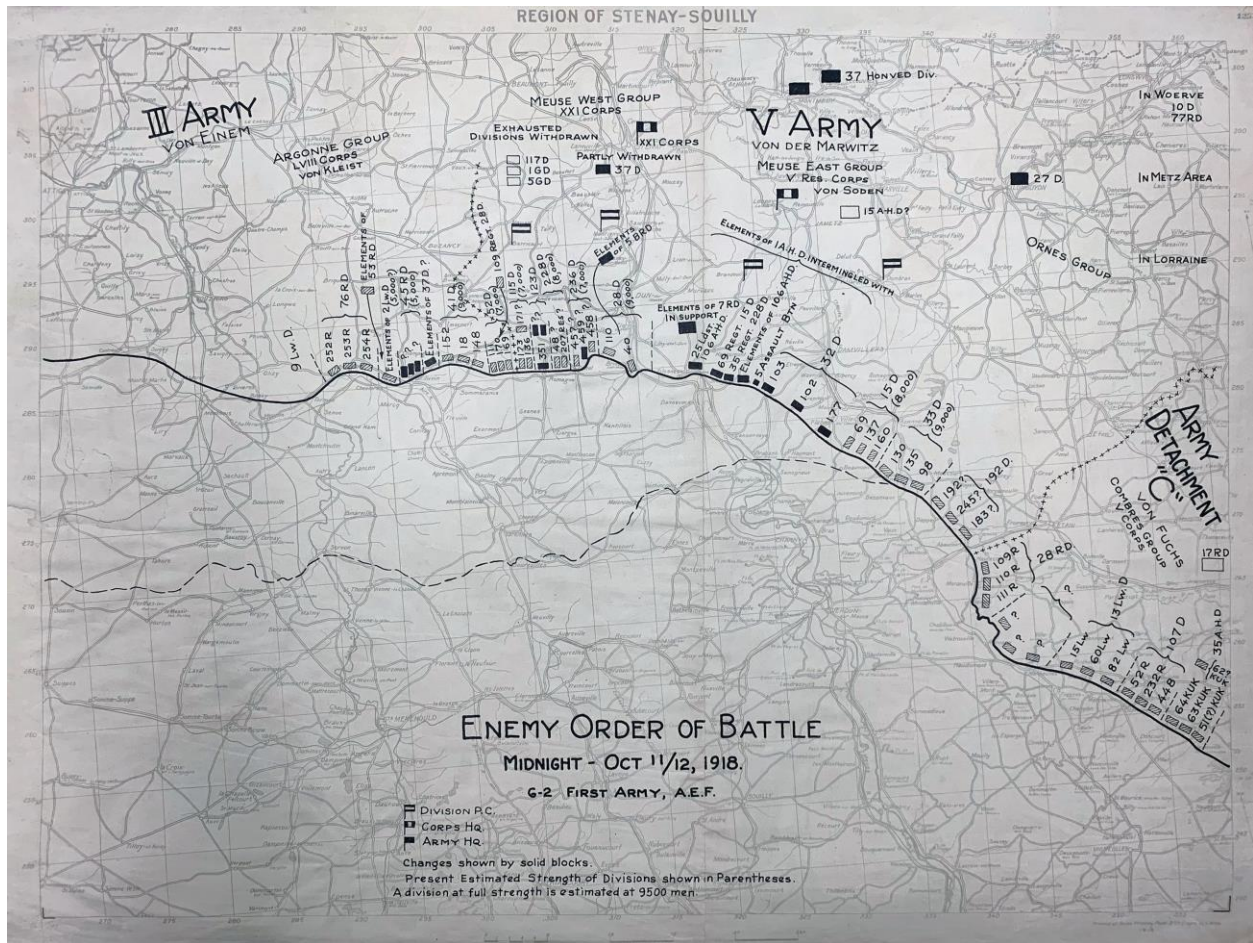


Figure 3.2 Facsimile of Enemy Order of Battle, Midnight – Oct. 11/12, 1918 (G2, First Army, AEF, 1918 October 11-12).

AEF units began to print EOOB maps as early as mid-July 1918 at the corps echelon, while the army-echelon AEF headquarters began producing a daily edition of this series on 3 September 1918—just before the start of the St. Mihiel offensive—and continued to issue an edition daily without interruption until the armistice, overprinting the maps’ tactical information onto base maps printed by the 29th Engineer at Langres (US Army 1991). AEF staff officers appear to have compiled the army-echelon version of these maps from those of subordinate units along with the written intelligence summaries provided to the headquarters (see for example G2, First Army, AEF, 1918, September 5). The base map for this series was initially a 1:200,000

scale custom chart of the area encompassing the St. Mihiel salient. As the battle moved northwest during the Meuse-Argonne offensive and the AEF took responsibility for an increasingly long stretch of the allied frontline, the mapmakers transitioned to using standard French 1:200,00 scale charts covering the Stenay-Souilly area for the western half of the American sector and the Metz area in the eastern half (Lengel, 2008). These base maps were of appropriate extent to cover the terrain far into the enemy rear area, allowing the mapmakers to chart enemy units arriving and departing, as well as enemy units resting or in reserve.

The G2 mapmakers used a map language for the EOOB maps that bears resemblance to that employed by British Army mapmakers in other theaters of the war, reflecting the decision by American intelligence officers to intentionally model their activities after British intelligence (Gilbert, 2012; Chasseaud, 2014; Collier, 2015a; Radunzel, 2016). They symbolized enemy units with discrete block symbols, using the blocks' texture to indicate whether a unit in the line had changed from the previous day's map. Flag symbols denoted the location of enemy command posts, with different patterns on the banner portion of the symbol denoting whether the headquarters was of division or corps echelon (Figure 3.2). A heavy line on each edition of the map indicated the mapmakers' assessment of the location of the front line on that day, while thinner lines or lines composed of small cross symbols indicated where the intelligence officers assessed the enemy had assigned administrative boundaries between their units. The annotating text indicated quantitative and qualitative information about the units that the maps portrayed, including their identification, strength, superior headquarters, and the identity of corps- and field army-echelon commanders.

4.2 Graphic Summary of Enemy Activity Maps

The second type of daily map series that the AEF intelligence sections produced was the *Graphic Summary of Enemy Activity* (GSEA), which the US Second Army staff also titled *Graphic Summary of Intelligence* maps. The purpose of these maps was to summarize events and enemy actions that observers reported over a twenty-four-hour period, such as areas shelled by enemy artillery and movement behind enemy lines, observations of which were reported in the daily intelligence and operations summaries submitted by subordinate headquarters (G2, 1918, September 5). Taken together with the EOOB maps, the GSEA maps provided a concise picture of the Americans' understanding of the enemy situation on a given day. This allowed the G2 sections to work with the Artillery staff to assist the latter in their counterbattery and interdiction fire planning against enemy positions (Grotelueschen, 2001; Gilbert, 2012). Indeed, a great deal of overlap existed between what types of information the intelligence staff cartographers mapped and what their artillery compatriots chose to portray, indicating a close habitual relationship between these two staff sections.

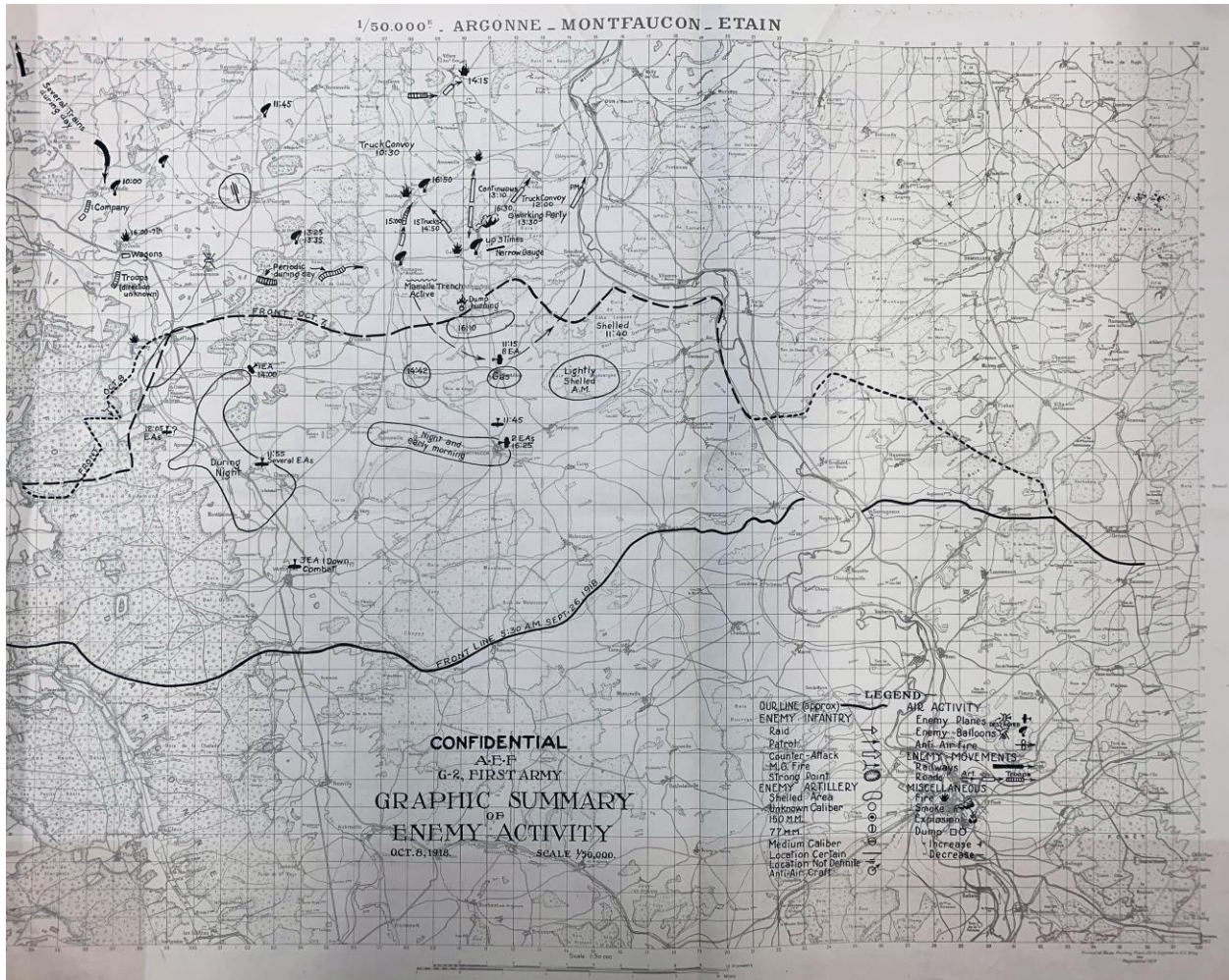


Figure 3.3 Facsimile of Graphic Summary of Enemy Activities Map Oct. 9, 1918 (G2, First Army, AEF, 1918, October 9).

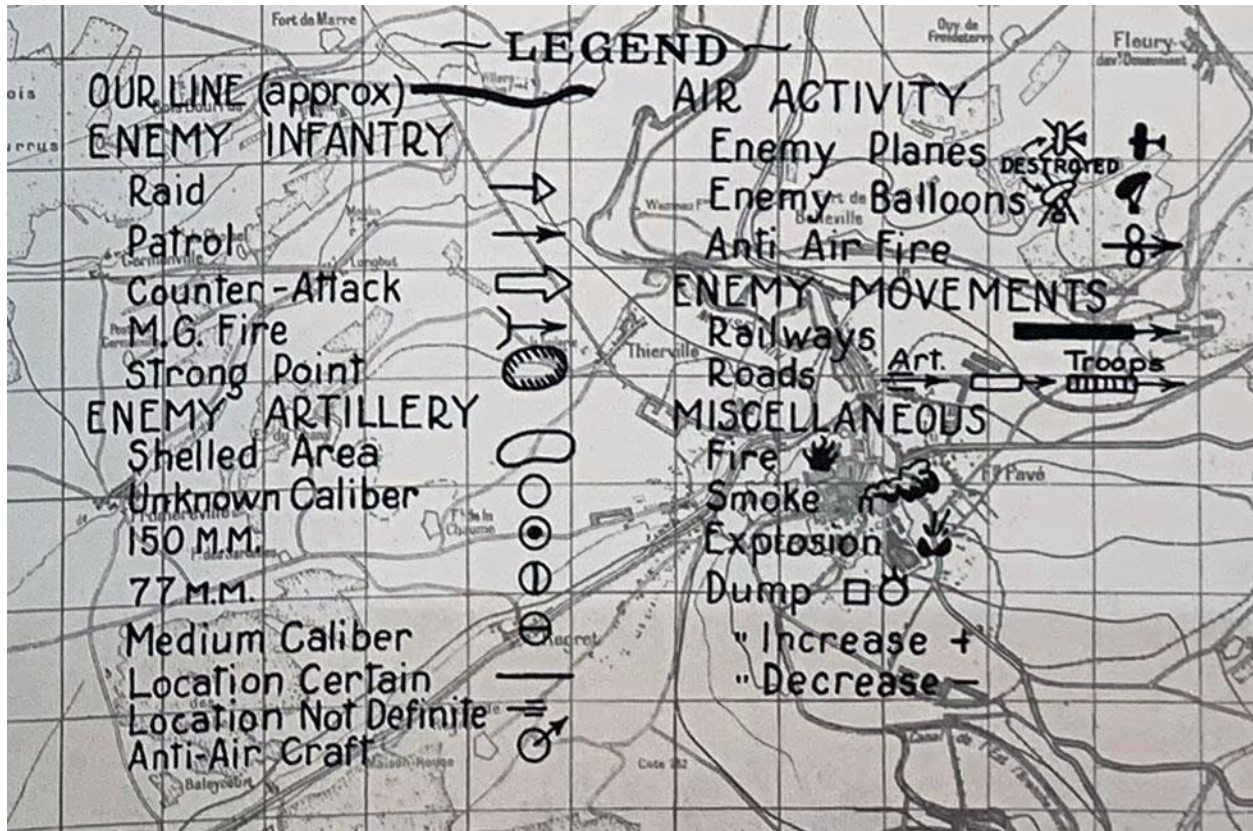


Figure 3.4 Legend of the AEF's GSEA maps showing the pictographic map language employed by the mapmakers (G2, First Army, AEF, 1918, October 9).

The AEF headquarters produced a first rudimentary edition of the GSEA series on 1 October 1918, upon the conclusion of the St. Mihiel offensive and after the commencement of the Meuse-Argonne offensive (Hallas, 1995). Thereafter the series developed rapidly into a standard form that the field army-echelon intelligence sections produced daily until 11 November. The late emergence of this map series indicates that the AEF headquarters staff had assessed a need for the type of information that these maps showed, an impression reinforced by the ad hoc nature of the pictographic map language that the cartographers employed in this series (Figure 3.4).

The G2 mapmakers overprinted the GSEA information onto base maps of much larger scale than the EOOB maps, 1:50,000 for US First Army and 1:100,000 for the US Second Army,

as opposed to the standard 1:200,000 scale of the EOOB maps. The difference in scale indicates that the mapmakers valued precision as they charted where enemy activity was occurring that was less necessary in the running tally format of the EOOB maps. The base maps for the US First Army series consisted of reprints of several different French map sheets, centered consecutively farther north as the American offensive progressed, while the Second Army overprinted all maps of their series onto a special edition map centered on St. Mihiel. Regardless, the extent of all these base maps was sufficient to cover only western half of the sector of front for which the AEF was responsible. This focus indicated a fixation by the intelligence staff on the area of the AEF's front in which the American forces were conducting active offensive operations at the expense of initially more static sections of the frontline farther east. This fixation could reflect the American command's obsession with offensive action (Grotelueschen, 2001 & 2007; Kretchik, 2011; Woodward, 2014).

The mapmakers in both US field armies and several of the subordinate corps employed composite map languages throughout the run of the GSEA map series that reflected its ad hoc nature. On the one hand, they used standard symbols to designate the location and caliber of enemy artillery common across the Entente armies by mid-1918 (Chasseaud, 2014; Pra et al, 2022). Like the EOOB maps, the GSEA maps used a heavy black line to indicate the location of the frontline on a given day. However, the pictographic symbols that the G2C cartographers used to portray other events, such as the downing of enemy observation balloons or explosions behind enemy lines, appear unique to this map series (Figure 3.4). Moreover, this map language did not remain consistent at lower echelons as some corps within the AEF used their own unique symbology on their versions of these maps (G2, I Corps, 1918, October 9).

Several sources informed the GSEA maps. Information such as shelled areas and areas that had received enemy machinegun fire appears to have originated from the daily operations reports that each corps submitted to their superior field army daily, as well as less formal reports that the lower-echelon staffs and liaison officers provided via telephone and telegraph (HQ III Corps, 1918, October 16). Here the Americans leaned explicitly upon British experience, as exemplified by the *Notes on the Interpretation of Aeroplane Photographs* published by the AEF's Air Corps, which was simply a reprint of a British War Office publication (War Department, ND). Information about enemy air and balloon activity, as well as observations about enemy activity behind the lines, originated from daily reports by the AEF's Air Service, which sent out patrols and lofted observation balloons of their own for this purpose (HQ, Air Service, AEF, 1918, October 9; Hudson, 1968; Gilbert, 2012). Interestingly, the Air Service also frequently conducted patrols to locate the front lines of friendly units, reflecting the fact that communication between the frontline infantry to their higher headquarters was often less than sure (Ferrell, 2005; Clodfelter 2007).

4.3 Other G2 maps

Other than those map series described above, the G2 sections at all echelons of the AEF produced numerous other kinds of maps on a periodic or as-needed basis. One early form of intelligence map that appears in the archival records are radio intelligence sketches (Figure 3.5) (G2, A6, First Army, 1918, July 14). These maps templated the locations and identification of enemy radio transmitters and the architecture of enemy radio networks. Later, the Second Army G2 radio intelligence section also produced a short series of more formal maps titled "German

Radio Stations.” These maps, in addition to showing the geographic locations and relational networks of enemy transmitters, also contained graphs that analyzed the volume of enemy communications traffic over time (Figure 3.6). Other types of periodically produced G2C maps included maps of enemy fortifications (Figure 3.7), maps summarizing prisoner interrogations, maps that showed the circulation of traffic behind enemy lines, and maps showing the location of key civil and military infrastructure around the area of operations.

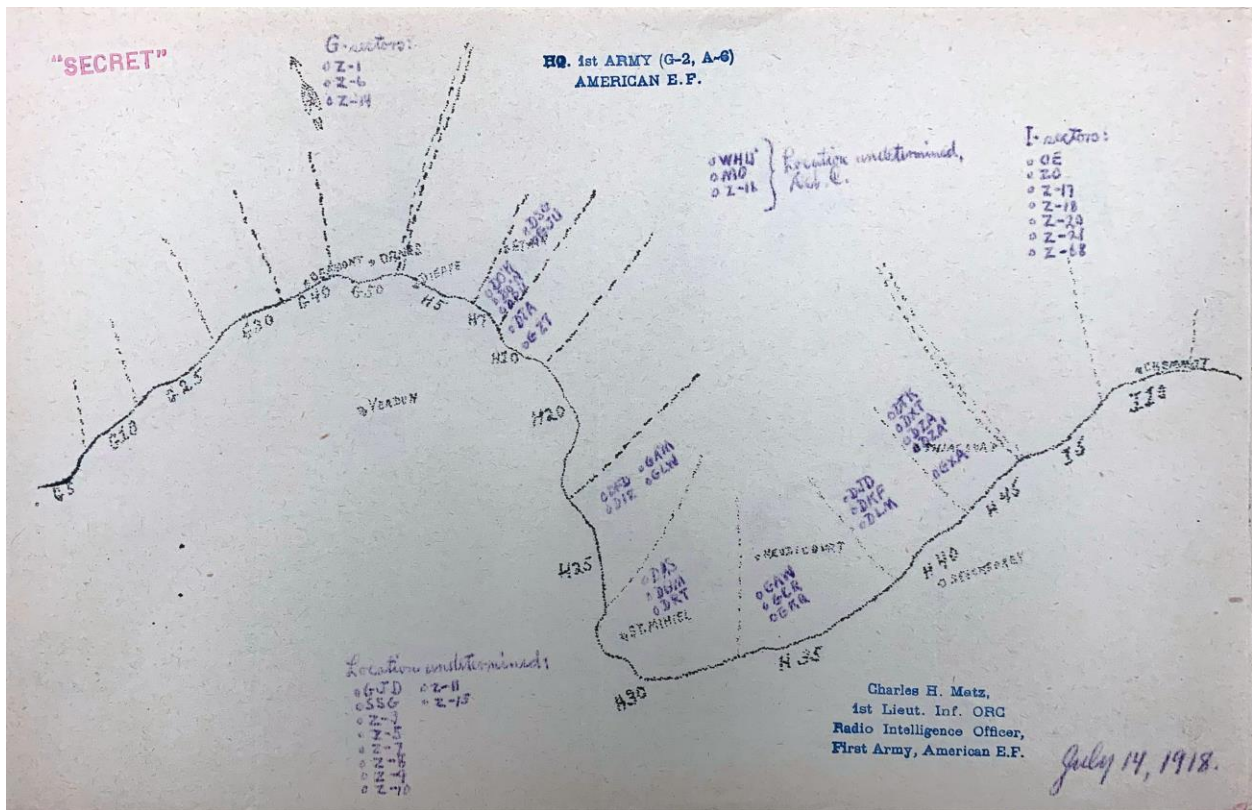


Figure 3.5 Facsimile of *Radio Intelligence Sketch 14 July 1918* (G2, First Army, AEF, 14 July 1918).

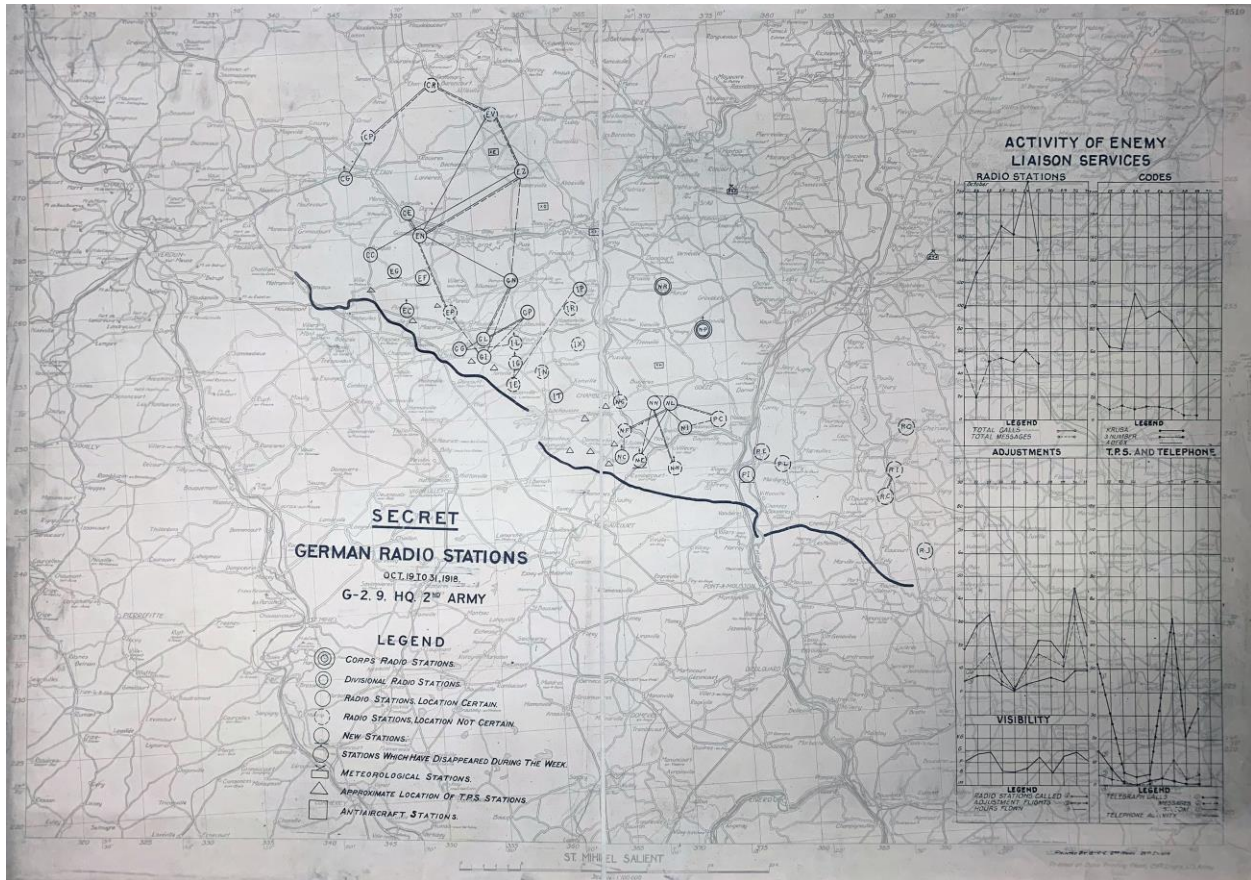


Figure 3.6 Facsimile of a G2C, Second Army map showing the templated locations of enemy radio stations. Note the graphs on the right side of the map presenting pattern analysis of emissions over time (G2C, Second Army, 1918, October 19-31).

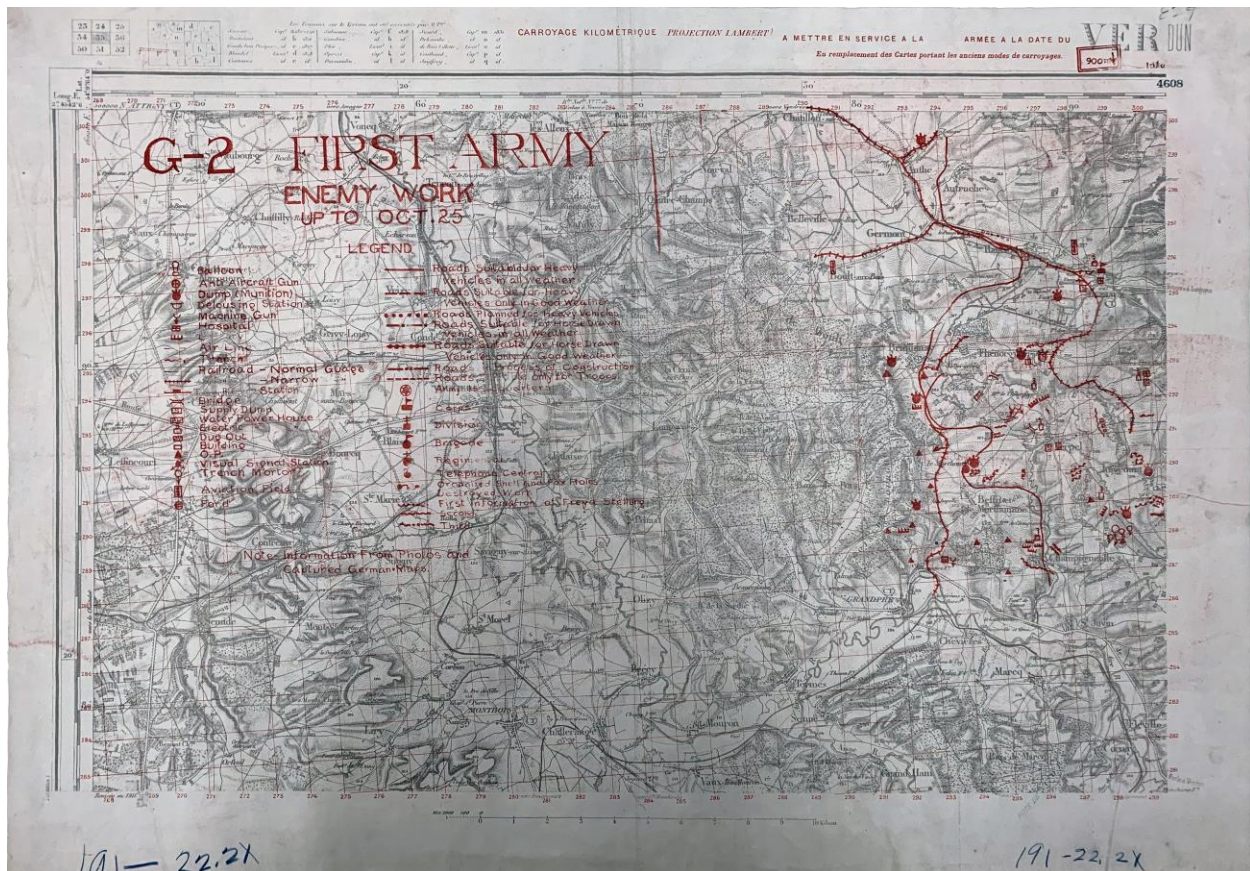


Figure 3.7. Facsimile of *Enemy Works Map Oct. 25, 1918* (G2, First Army, AEF, 1918, October 25).

Looking at the G2 maps holistically, the mapmakers appear to have leaned upon their allies, especially the British, for inspiration in their map language as demonstrated by the symbology of the EOOB maps. However, they also developed their own unique ways of communicating spatial information, as shown by the composite map language of the GSEA maps and the Enemy Works maps. The volume of mapmaking activity conducted by the intelligence sections show a voracious appetite for information about the enemy, and a recognition of maps as key tools for rationalizing and contextualizing the raw data that was passing through the various headquarters each day (Gilbert 2012).

5. Maps of the G3 Operations Sections

Like the G2 staff, all the AEF's G3 operations staff sections contained a sub-element whose responsibility was the preparation of the sections' tactical maps. These subsections bore the name of *G3 Map Room*. Though less prolific than their G2 counterparts, the operations sections' mapmakers still produced a large volume of tactical maps, including two daily map series and several other types of periodic or special-use maps. The G3 Map Rooms' focus was on the location and administration of friendly units. One of the daily map series, the *Front Line Map*, was simple in form but challenging in creation, and vital to the conduct of offensive operations. The other daily series, the *Situation Map*, presented a picture of the deployment of friendly divisions and command posts across the battlefield each day. The G3 Map Rooms also produced maps to direct the actions and maneuvers of subordinate units, typically titled *Operations Maps*. Together, these maps aided the operations section in maintaining a comprehensive picture of the deployment of their subordinate formations and helped commanders direct the maneuver of their forces.

5.1 *Front Line Maps*

The Front Line Map was perhaps the simplest form of tactical map produced by the AEF. The First Army headquarters began producing Front Line Maps starting on 26 September 1918, after the end of the St. Mihiel operation and before the commencement of the Meuse-Argonne offensive. Subsequently, the First Army headquarters produced an updated edition of this map each day until the Armistice on 11 November 1918.

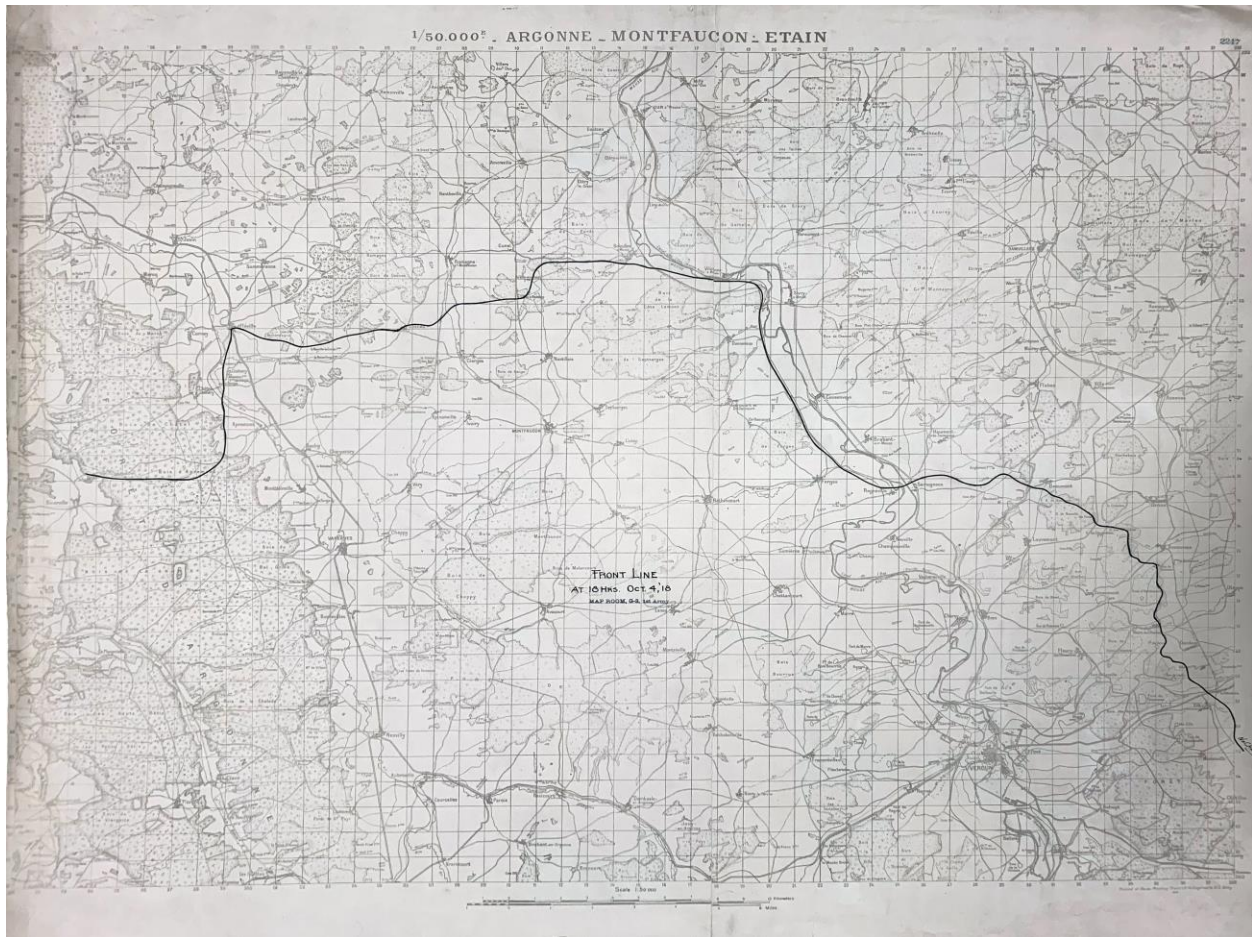


Figure 3.8 Facsimile of the First Army Frontline map for 9 October (G3, First Army, AEF, 1918, October 9).

This form of map consisted of a base map sheet onto which the G3 Map Room mapmakers drew a black line that indicated the forwardmost positions, or “front line,” of all friendly units (Figure 3.8). This series' base was a custom 1:50,000 scale map centered on the Montfaucou-d'Argonne, an area of prominent high ground that dominated the center of the Meuse-Argonne battlefield. As the operation proceeded and the American forces advanced off the northern edge of this map in November 1918, the mapmakers appended—actually pasted—strips of the northwardly adjacent map sheets onto this base to allow the mapmakers to keep pace

with the changing situation. The mapmakers based their assessment of the front line's location each day on the operations reports that subordinate units submitted daily.

The purpose of these maps appears to have been at least twofold. First, they provided a quick visual guide to the progress of American forces over time. More importantly, the location of the front line was vital information for the AEF's artillery. American artillery was often hesitant to fire in support of friendly units when the location of the front line was uncertain (Grotelueschen, 2001 & 2007). Alternately, an inaccurate understanding of the front line's location could yield tragic results, as when the famed "Lost Battalion" of the 77th Division was shelled by friendly batteries while they were trapped forward of US lines in the Argonne Forest (Clodfelter, 2007). The cartographic idea of the frontline map has persisted in present-day US and NATO doctrine, which specifies a "Coordinating Fire Line" (CFL) that marks the forward trace of friendly troops and beyond which artillery can fire without coordination (US Army, 2020). As such, the AEF's frontline maps prefigured artillery concepts that remain in use more than a century later.

5.2 Situation Maps

A second and more complicated form of daily tactical map produced by the AEF was the "Situation Map." This series, produced and distributed daily by the G3 Map Rooms of the AEF field army-level and at least weekly by the corps-level headquarters, sought to show the general positions of the headquarters' subordinate units and command posts, as well as administrative boundaries. The First Army G3 Map Room produced a daily edition of this map continuously from at least before the commencement of the St. Mihiel offensive on 26 August 1918 through the armistice, making this the longest-running series produced by the operations section of the

AEF staff. Corps staffs also produced situation maps and forwarded their maps to their higher headquarters for compilation.

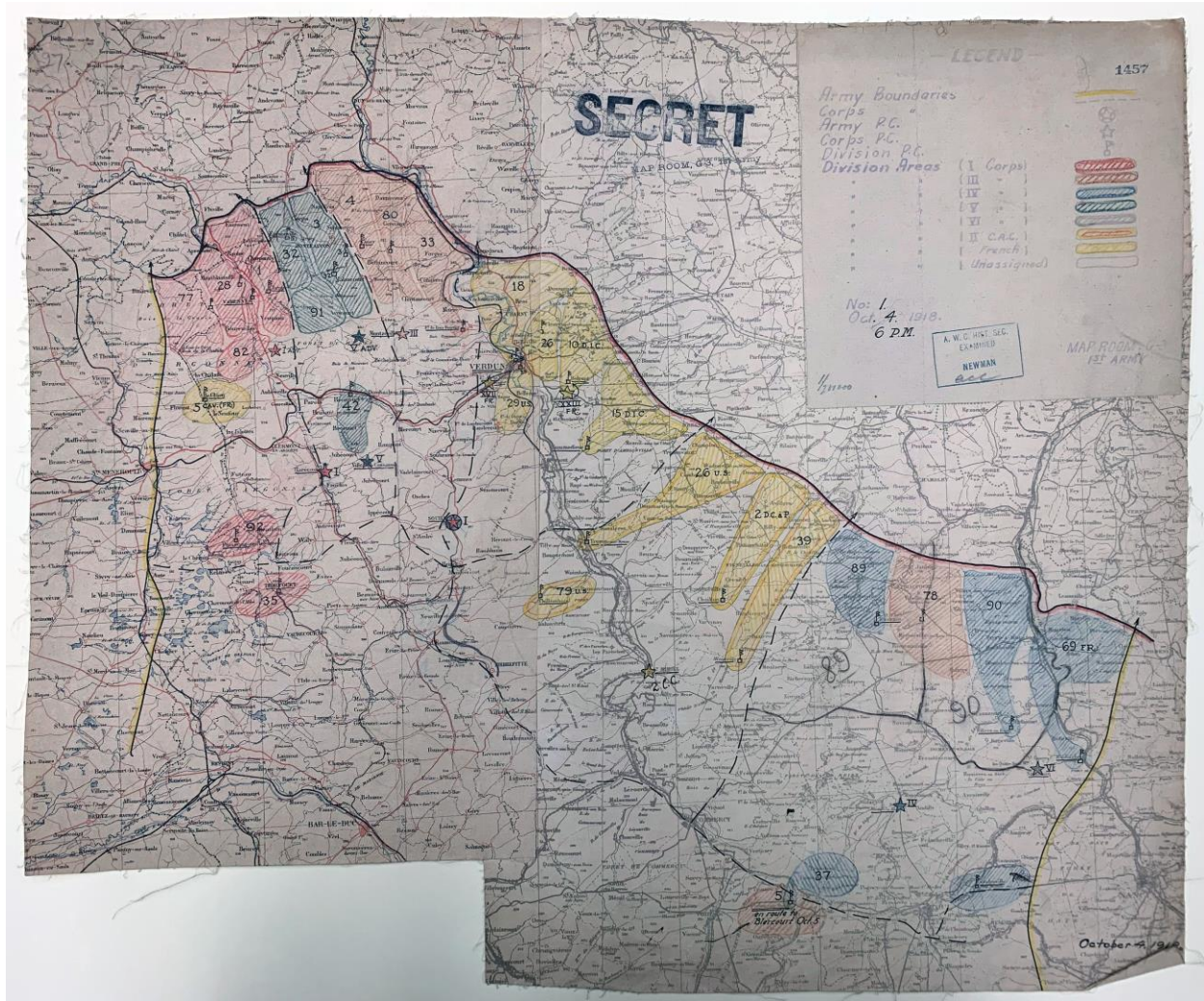


Figure 3.9 Facsimile of the First Army Situation map of 4 October. Note the legend in the top right differentiating the units of the various corps according to color. (G3, First Army, AEF, 1918, October 4).

The base sheet for this map type at the field army echelon was the French 1:200,000 scale battle map series. The extent of this base map was sufficient to encompass the AEF's entire area of operations, including its rear areas, allowing the mapmakers to show the rotation of divisions from the front and the approach of newly forming or reserve units. Corps echelon mapmakers

used larger-scale maps of smaller extent, usually 1:10,000 or 1:20:000, which allowed them to focus on their sector of the front.

The maps showed the divisions (at the field army echelon) and regiments (at the corps echelon) for which the headquarters was responsible as amorphous polygons, indicating the area that the division occupied on a given day (Figure 3.9). The mapmakers color-coded these polygons according to a division's superior corps or division headquarters. The maps represented divisional command post locations as small boxes with attached flags, while corps and army command post locations were designated by a star symbol. Finally, dashed lines indicated the administrative boundaries between corps while solid, yellow-highlighted lines showed army-level administrative boundaries and the frontline. Staff officers at each echelon compiled the situation maps and operations summaries from their subordinate units into a single draft product that they then forwarded daily to their higher headquarters along with their written operations summaries (HQ, III Corps, 1918, October 15-16). The map language of the American situation maps was identical to situation maps produced by the French and Italian armies during this same time, indicating an emerging level of standardization across the *Entente* that prefigures the standardization of doctrine that exists between NATO partners today (Pra *et al*, 2022; NATO, 2011).

5.3 Operations Maps

Another important type of map that the operations sections' map rooms produced periodically was the operations map. These accompanied field orders that directed offensive actions or defensive preparations and typically showed objective lines that units should reach or

defend by a certain time, as well as the projected boundaries between units and the AEF's the current front line (HQ, First Army, 1918, September 22). Initial drafts of operations maps assigned generic corps and division requirements to sections of the frontline. Later, finalized versions of these maps then allocated specific units against these requirements. Thus, the operations maps appear to have served two purposes, first as planning aids within the headquarters and then as a media to distribute the results of the planning to the units that would carry out the operation.

6. Maps of the Artillery Staff Section

The third major tactical mapmaking entity within the AEF were the artillery staff sections, which directed the actions of the armies' big guns, which could range in caliber from 75-millimeter and 155-millimeter howitzers at the divisional level of organization up to massive 14-inch naval guns mounted on railroad chassis (Marble, 2016). At the army and corps echelons, artillery staff officers used maps to aid their targeting process and to give directions to friendly artillery units (Groteluschen, 2001). As such, the artillery staff straddled the worlds of the intelligence and operations sections. They collaborated most closely with the G2 sections to discern patterns of enemy movement and deployment and to develop observation plans to direct artillery fire, and also with the G3 sections to coordinate areas where the batteries could deploy and barrage patterns to support the advance of infantry (Grotelueschen, 2007). The artillery staff produced one daily map series, the *Artillery Graphic Activity* map (AGAM), to compile information for analysis within the headquarters, and several types of periodic maps that disseminated information to subordinate units. Thus, in many ways the artillery section acted as a

bridge between intelligence and operations, drawing from and coordinating the activities of both to support the overall effort.

6.1 Artillery Graphic Activity Maps

The artillery staff coordinated closely with the intelligence staff at the field army echelon to produce a graphic representation of enemy actions that resembled closely the G2's GSEA map. The *Artillery Graphic Activity Map* (AGAM) drew upon the style and language of the GSEA maps in attempting to show enemy actions and events in a twenty-four-hour period (Figure 3.10). Indeed, the Artillery mapmakers often plotted their information directly onto an already-printed GSEA map from the G2. However, significant differences between the two map types existed, which reflected the differing responsibilities and perspectives of the originating staff sections.

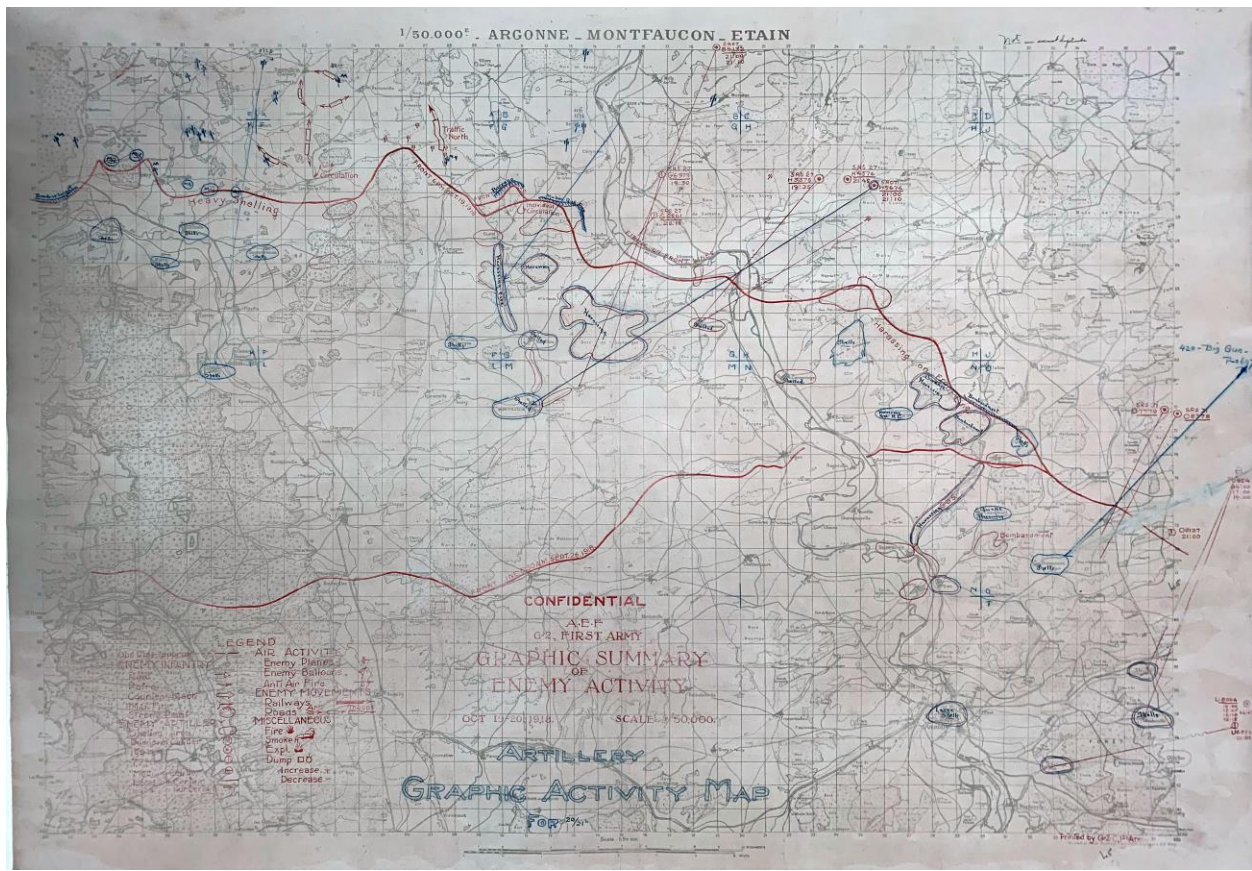


Figure 3.10 Facsimile of the First Army Artillery Graphic Activity Map for 20 October. Note that this map is overprinted atop a GS GSEA map, with the artillery information plotted in blue (AIS, First Army, 1918, October 20).

A noticeable difference between the G2 and artillery map series was the fidelity with which they represented the events of each day. While the G2 mapmakers appear to have exercised some discretion in choosing which enemy activity to plot on the GSEA maps, the artillery section mapmakers do not appear to have exercised the same discretion, opting instead to map every report of enemy activity. The result of this difference is that while every event portrayed on the G2 maps appears on the artillery maps, the reverse is not true, meaning that the AGAM series presents enemy activity with a higher degree of detail. This divergence is most noticeable in the portrayal of areas shelled by enemy artillery. This more fine-grained attention to detail by the artillery staff reflects their sections' dual responsibilities for both consolidating

information about enemy activities and translating this data into action in the form of counterbattery and interdicting artillery fire by friendly guns.

Another difference between the GSEA and AGAM series is their layering of information over time. Each GSEA map invariably portrayed the goings on over a single day. By contrast, many—though not all—of the AGAMs overlaid several days of information onto a single map sheet, using color to differentiate between different days' events. This technique allowed the artillery cartographers to represent patterns of enemy activity more effectively than the GSEA maps did, aiding their efforts to target enemy concentrations with friendly artillery fire. This sort of pattern analysis and close coordination between intelligence and artillery foreshadowed the “targeting process” of present-day American and NATO doctrine (US Army, 2023).

6.2 Artillery Objectives Maps

The artillery staff also used maps to translate their analysis of enemy concentrations into targets for friendly guns. These documents, known as Artillery Objectives Maps, used a simple map language to give directions to subordinate artillery headquarters and their firing batteries. Cross-hatched polygons designated areas that artillery batteries should target “for destruction,” while point symbols designated individual targets for interdiction or harassing fire. Maps at the field army echelon often contained text or legends directing the rate or number of shells that a target should receive. These typically accompanied directive and explanatory written orders from the artillery staff to their subordinate counterparts.

7. Maps of Other Staff Sections

While other staff sections within the AEF's headquarters were less prolific in their mapmaking, all still produced maps at least periodically, usually to direct the specialized support of friendly forces in conjunction with the field orders issued by the operations sections. While an exhaustive catalogue of these maps is beyond the scope of this examination, two of these map types bear mentioning because they illustrate how pervasive maps had become within the higher echelons of the AEF as a tool to efficiently communicate information. These included *Circulation Maps* produced by the Administrative G1 section of the AEF headquarters to direct the flow of traffic in the AEF's rear areas, and radio and telephone network diagrams produced by the G6 (Signal) section.

8. Conclusions

Taken together, the constellation of AEF tactical maps represents a mapmaking system that was distinct from those employed by the French or British armies, reflecting both the tendency of the AEF's senior leadership to discount the experience and techniques of their allies and, alternatively, the pragmatism of lower echelon organizations in adopting them (Grotelueschen, 2001 & 2007). The American mapmakers certainly leaned on their allies' experience for inspiration in some of their mapmaking techniques. And yet, many of the AEF tactical maps contain examples of improvisation by the mapmakers, such as the composite symbology of the G2's Graphic Summaries of Enemy Activity and the Artillery Section's Graphic Artillery Activity Maps.

The AEF's corps and field army echelon headquarters produced a remarkable volume of tactical maps during the approximately three months during which the AEF operated as a separate, American army on the battlefields of France. By combining previously developed tactical mapping techniques from their French and British allies with cartographic improvisation and innovation within their own organizations, they brought forth a tactical mapmaking system that attempted to control the complex offensive operations of forces with numbers exceeding a million soldiers. Some of the systems they developed, particularly the close targeting relationship between the intelligence and artillery sections of the staff, endure in American military doctrine to the present. As such, these maps represent an important milestone in the development of modern warfare, as well as in the development of military cartography more generally.

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Chapter 4 - Cartographic Data and the Great War: An HGIS for Tactical Cartography

Abstract

Historical military maps produced since the First World War (FWW), an underexplored class of archival document, present attractive targets for historical geographic information systems (HGIS) methods due to the large amount of data they contain and—because such maps were often produced in series—the opportunity to combine spatial and temporal analysis. HGIS has become a powerful analytical tool for exploring past events and reconstructing historical landscapes. However, a consistent theme in criticisms of HGIS methods is the high investment in terms of time and labor that researchers must devote to creating spatial databases. One method of overcoming this challenge is for researchers to employ effective design for the spatial databases into which they deposit the data they extract from map documents. This paper uses an exploration of the American Expeditionary Force's (AEF) maps from the Battle of the Meuse-Argonne in 1918 to showcase an enhanced entity relationship (EER) database structure for organizing the data coded into these battle maps. Moreover, this paper highlights three HGIS examples for analyzing the resultant data that demonstrate the value of the database structure for historical analysis.

1. Introduction

Historical geographic information systems (HGIS) allow researchers to compile digital databases of historical spatial information for analysis, making them powerful analytical tools within the fields of spatial history, historical geography, and others (Gregory & Healey, 2007;

Knowles, 2008; Lunen & Travis, 2013). In such inquiries, historical maps are valuable resources for reconstructing past landscapes and providing data about past events. However, historical *military* maps, thousands of which reside undigitized in archives around the world, remain under-explored and untapped sources of data (Apkin, 2017; Moore, 2018; Demhardt, 2018). Pairing these archival maps with HGIS provides opportunities to deepen the understanding of the history and development of military cartography, and to provide new perspectives on historical events. To assist and encourage further research along these lines, this paper demonstrates the creation of an HGIS as a spatial enhanced entity-relationship (EER) database to organize disparate types of data extracted from tactical military maps created by the American Expeditionary Force's (AEF) First Army during the First World War (FWW) and outlines several examples of how the HGIS to can be used to analyze the digitized data.

2. State of the Art

In recent decades, HGIS has matured as a method within the fields of spatial history and historical geography (Knowles, 2008). However, one of the challenges that continues to hamper HGIS is the high time and labor investment inherent in creating spatial databases (Lunen & Travis, 2013). Considering this fact, military maps—particularly those produced since the outbreak of the First World War—present attractive subjects for HGIS research. From the years leading up to the FWW and onwards, modern military forces have benefitted from highly accurate and detailed base maps onto which tactical information is plotted (Affek, 2013; Chasseaud, 2018; Ostafin *et al*, 2021). The accuracy and precision of these charts can streamline the georeferencing and vectorization of data contained within these documents when compared

with military maps of earlier periods (Ostafin *et al*, 2021). Moreover, as other research has demonstrated, technological improvements during the FFW gave armies the ability to map the situation on the battlefield on a nearly continuous basis (Keegan, 2003; Radunzel, 2016, 2019, & 2023; Demhardt, 2018; Chasseuad, 2018; Espenhorst, 2018; Prá *et al*, 2022). Such series maps represent an opportunity for researchers to create robust spatial databases to store the data these maps contain at a lower cost in effort than many other subjects of archival cartographic research. Furthermore, these maps present intriguing possibilities for temporal as well as spatial analysis, as many of the FWW map series contain daily editions that span periods of weeks to months.

Other researchers have already demonstrated the value of pairing GIS with historical military maps. Knowles (2008) paired maps produced during and after the Battle of Gettysburg with a digital elevation model-assisted viewshed analysis to explore what key commanders on the battlefield might have seen during the fighting. Wan *et al* (2020) compared GIS with georeferenced military maps produced by the Republic of China at the beginning of the twentieth century with military maps produced by the US military during the Second World War to estimate urbanization rates in pre-modern China. Kaim *et al* (2020) demonstrated the value of military maps in reconstructing historical landscapes by using pre-FWW Austro-Hungarian military survey maps to vectorize the historical road network for parts of the Hapsburg Empire. Finally, Prá *et al* (2022) used HGIS to explore FWW Italian army *tactical* maps, defining this map type as “maps that were continuously updated during battle, to show the evolution of frontline positions and activities” and arguing along with Collier (2015) and Radunzel (2016 & 2023) that *tactical* maps represent an important sub-class of military cartography.

Few if any researchers exploring historical military maps have described a deliberate design for HGIS database structure. Fortunately, examples of disciplined database design exist in

the broader HGIS field. Carrion *et al* (2016) demonstrated the utility of an extended entity-relationship (EER) data structure in their examination of the historical fiscal landscape of medieval Italy. Migliaccio *et al* (2019) used an entity-relationship diagram (ER) to structure their HGIS, which records data about the destructiveness of historical earthquakes. These and other studies demonstrate the utility of ER models to account for real-world entities and their relationships with one another. Augmented by EER concepts of hierarchy, specialization, and aggregation, this database structure is well-suited for organizing the kinds of data contained in tactical maps (Chen, 1976; Teorrey and others, 1986).

However, as many have noted, creating HGIS databases can be time-consuming and laborious, particularly given the large volume of documents that reside in many archival tactical map collections. To address this problem, this paper describes a broadly applicable model for a database design to organize the types of information contained in AEF tactical maps and provides some initial findings to demonstrate the value of creating an HGIS for tactical maps.

3. Overview of the AEF Tactical Maps and the Meuse-Argonne Offensive

This paper examines the tactical maps produced by the American Expeditionary Force in the during the Battle of the Meuse-Argonne in the FWW. Staff sections in the AEF headquarters produced five series of daily tactical map during the battle, including two series authored by the

G2 (intelligence) section, two by the G3 (operations) section, and one by the artillery staff¹ (Table 4.1) (Radunzel, 2023). The collective purpose of these map series was to provide the headquarters with a daily picture of the situation on the battlefield as understood by the mapmakers (Radunzel, 2023).

Staff section	G2 (Intelligence)	G3 (Operations)	Artillery
Map series produced	Enemy Order of Battle (EOOB) map Graphic Summary of Enemy Activity (GSEA) map	Situation Map Frontline Map	Artillery Graphic Activity (AGA) map

Table 4.1 Daily tactical map serials produced by the AEF First Army headquarters according to their authoring staff sections.

4. Data Collection

The AEF maps, which are stored at the US National Archives Research Facility in College Park, Maryland, were digitally photographed over a one-week period in August 2022. Adobe Photoshop was used to remove distortion created by camera angle and lighting. The digital map images were loaded into ArcGIS Pro 3.1.1 (Esri, Redlands, CA) as raster layers for georectification, vectorization, and analysis. To georectify the map images, map features from the digitized AEF base maps were matched with corresponding features in the ArcGIS World Topography base map layer. A total of 30-40 control points were used for each map, allowing a

¹ The Artillery staff produced five editions of a similar map series called *Artillery Activity Charts* that appear to have served the same function as the AGA maps. These two types of maps appear to have been folded into one another after October 10, 1918.

third-order polynomial transformation to warp the raster image to underlying features. This process proved successful in closely matching the features on the 1918 maps with the contemporary landscape (Table 4.2). The maps’ tactical data were then extracted by “heads-up” digitizing the hand-drawn symbols present on each map into separate geodatabase feature classes. Close study of the maps revealed numerous categories of data, as well as relationships between them, which guided the organization of the data into the database structure described below.

Map type	<i>Situation map (n=10)</i>	<i>Frontline map (n=10)</i>	<i>Enemy Order of Battle (EOOB) map (n=20)</i>	<i>Graphic Summary of Enemy Activity (GSEA) map (n=10)</i>	<i>Artillery Graphic Activity (AGA) map (n=10)</i>
Mean RMS	5.45	1.45	4.91	5.95	1.33

Table 4.2 Mean root mean square (RMS) error for each map series after georectification in ArcGIS Pro using a third-order polynomial transformation.

5. An EER Database Model for a Tactical Map HGIS

Entity-Relationship (ER) models are a class of descriptive logic that divides pieces of information or *objects* into the categories of *entities*, *attributes*, and *relationships* (Chen, 1976). Enhanced Entity-Relationship (EER) models elaborate upon this structure by incorporating additional constructs into the three fundamental ER objects, including hierarchies, aggregation, and categorization, each of which is advantageous when storing the hierarchical and aggregated data common to military maps (Teorrey *et al.*, 1986; Zhang *et al.*, 2016).

Analysis of the AEF tactical maps identified twenty-six types of entities, defined (after Carrion *et al.*, 2016) as “physical objects or abstract concepts that describe the real world.” Most of these entities are unique to only a single map series, such as the location of friendly division-

sized units (Table 4.3). However, a few, such as the information shared by the G2 and Artillery staff sections about enemy positions and events, spanned more than one map series. One type of abstract entity—the front line—was present on all five map types. The geometry of the symbology proved a useful attribute in helping to categorize the different types of data.

Information Type		<i>Friendly unit positions (Divisions)</i> <i>Friendly HQs (Divisions)</i> <i>Friendly HQs (Corps)</i> <i>Friendly HQs (Army)</i> <i>Friendly boundary (Corps)</i> <i>Friendly boundary (Army)</i> <i>Friendly planned unit movements</i> <i>Friendly planned HQ movement</i> <i>Friendly planned boundary changes</i> <i>Front line</i> <i>Enemy unit positions (Regiments)</i> <i>Enemy HQs (Divisions)</i> <i>Enemy HQs (Corps)</i> <i>Enemy HQs (Army)</i> <i>Enemy boundaries (Divisions)</i> <i>Enemy boundaries (Corps)</i> <i>Enemy boundaries (Army)</i> <i>Areas shelled (by enemy)</i> <i>Enemy artillery positions (77mm)</i> <i>Enemy artillery positions (medium)</i> <i>Enemy artillery positions (150mm)</i> <i>Machinegun fire (by enemy)</i> <i>Enemy strongpoint</i> <i>Enemy aircraft sighted</i> <i>Enemy aircraft destroyed</i> <i>Enemy balloon sighted</i> <i>Enemy balloon destroyed</i> <i>Enemy movement (troops)</i> <i>Enemy movement (vehicles)</i> <i>Enemy movement (train)</i>																														
Geometry		Polygon	Point	Point	Point	Line	Line	Text	Text	Text	Line	Polygon	Point	Point	Point	Line	Text	Line	Polygon	Point	Point	Point	Line	Polygon	Point	Point	Point	Point	Line	Line	Line	Line
Map Type	Situation Map	x	x	x	x	x	x	x	x	x	x																					
	OOB Map											x	x	x	x	x	x	x														
	GSEA Map											x							x	x	x	x	x	x	x	x	x	x	x	x	x	
	Frontline Map											x																				
	Artillery Activity Map											x							x	x	x	x	x	x	x	x	x	x	x	x	x	

Table 4.3 Types of entities that the AEF tactical maps included in their symbology

6. Entities: Headquarters, Units, Boundaries, and Events

Tactical maps symbolize entities that include physical objects and abstract concepts. This paper divides entities into four super-categories, two physical and two abstract (Figure 4.1).

Physical entities are defined as objects that physically exist or persist with a constant identity across map editions while abstract entities are either a one-time occurrence of a unique object or an object that does not physically exist. Physical entities include *headquarters* and *units*.

Headquarters consist of a commander and their staff, who control the actions of subordinate headquarters and, by extension, subordinate units. *Units* are hierarchical aggregations of

individuals and equipment that can be very complex. The “side” to which a headquarters or unit belongs (friendly or enemy) forms a subcategory of both entities, which are then further subcategorized according to their organizational strata. The AEF tactical maps typically represent units as entities with a single continuous geometry, usually at a scale two or three steps below the organizational hierarchy from the headquarters producing the map (Figures 4.2 & 4.3). Headquarters and units share many attributes, and at the strata at which the maps aggregate units they often exist as paired objects, which share the same primary key (i.e., the “1st Division” headquarters entity controls and shares the same primary key as the aggregated unit entity called the “1st Division”).

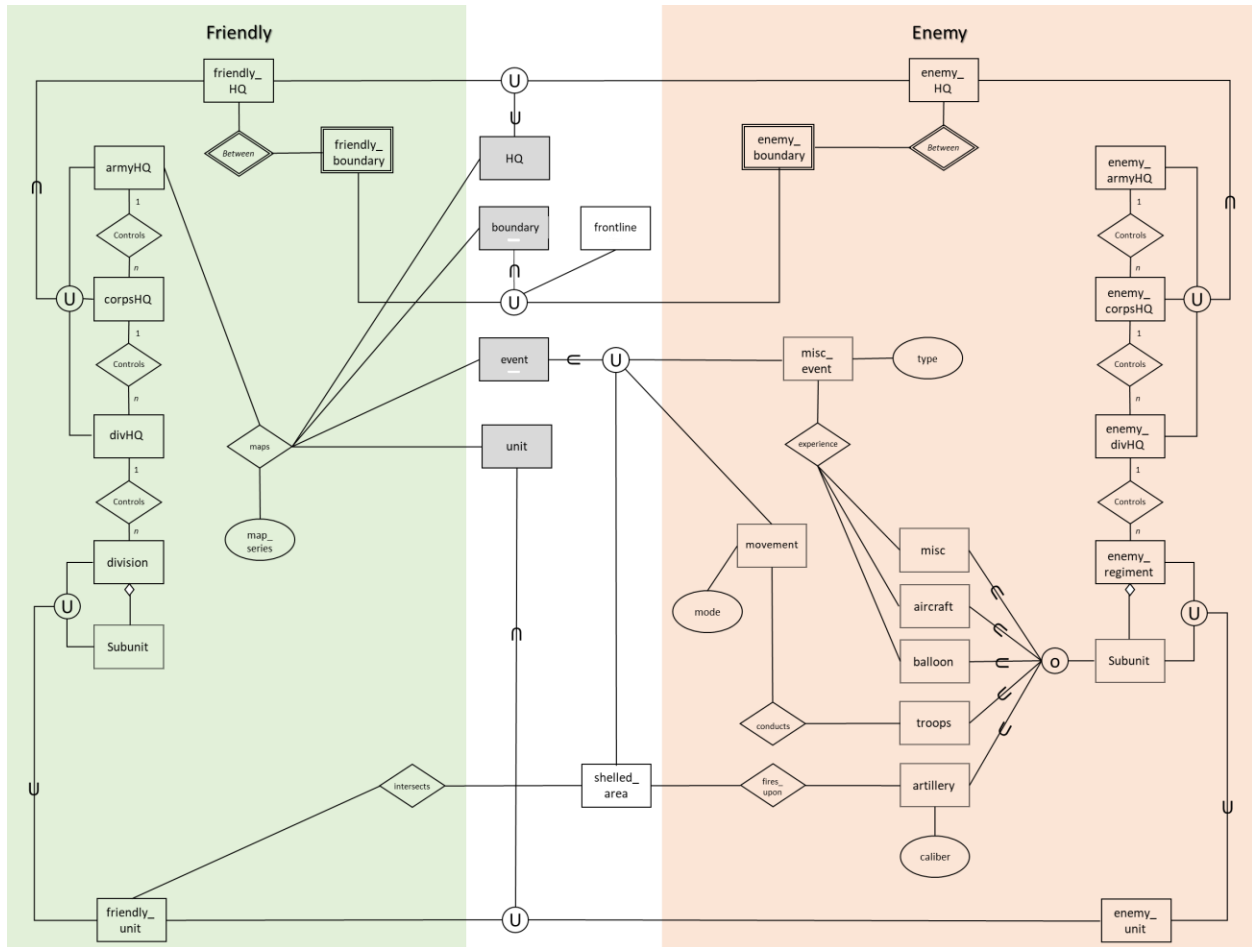


Figure 4.1 Entity relationship diagram (ERD) of the database model for examining AEF tactical maps. The four super-categories of data mapped by the AEF headquarters are marked in gray.

The two super-categories of abstract entities are *events* and *boundaries*. *Events* are the result of actions that are caused by or occur to physical entities (Figures 4.4 & 4.5). *Boundaries* were drawn on maps to delineate the geographic space in which headquarters controlled their units without the need for coordination with adjacent or higher headquarters (Figures 4.2 & 4.3). On the AEF maps, the front line formed a special boundary class indicating the forwardmost positions of friendly troops beyond which artillery could fire freely (Grotelueschen, 2007). AEF mapmakers typically differentiated the hierarchical strata associated with a boundary by using different styles of line symbols.

Headquarters are a categorization of entity that exist at different strata of hierarchical military organizations. A higher headquarters was generally necessary where two headquarters from the next lower strata of the hierarchy must operate together (i.e., a corps headquarters was necessary to control two subordinate division headquarters) (Woodward, 2014). The AEF maps used point geometry to show the locations of headquarters. Also, these maps typically ceased showing the location of headquarters below the hierarchical strata at which the map started to aggregate units. The unique name of the aggregated unit a headquarters controlled provides its primary key. Other attributes include the organizational strata, a composite attribute with data of the archival source map, other information such as higher headquarters and subordinate units, and location geometry (Figure 4.6). Other common attributes available from archival sources such as *Journals of Operation* or *War Diaries* can include the identities of the headquarters' commander and key staff.

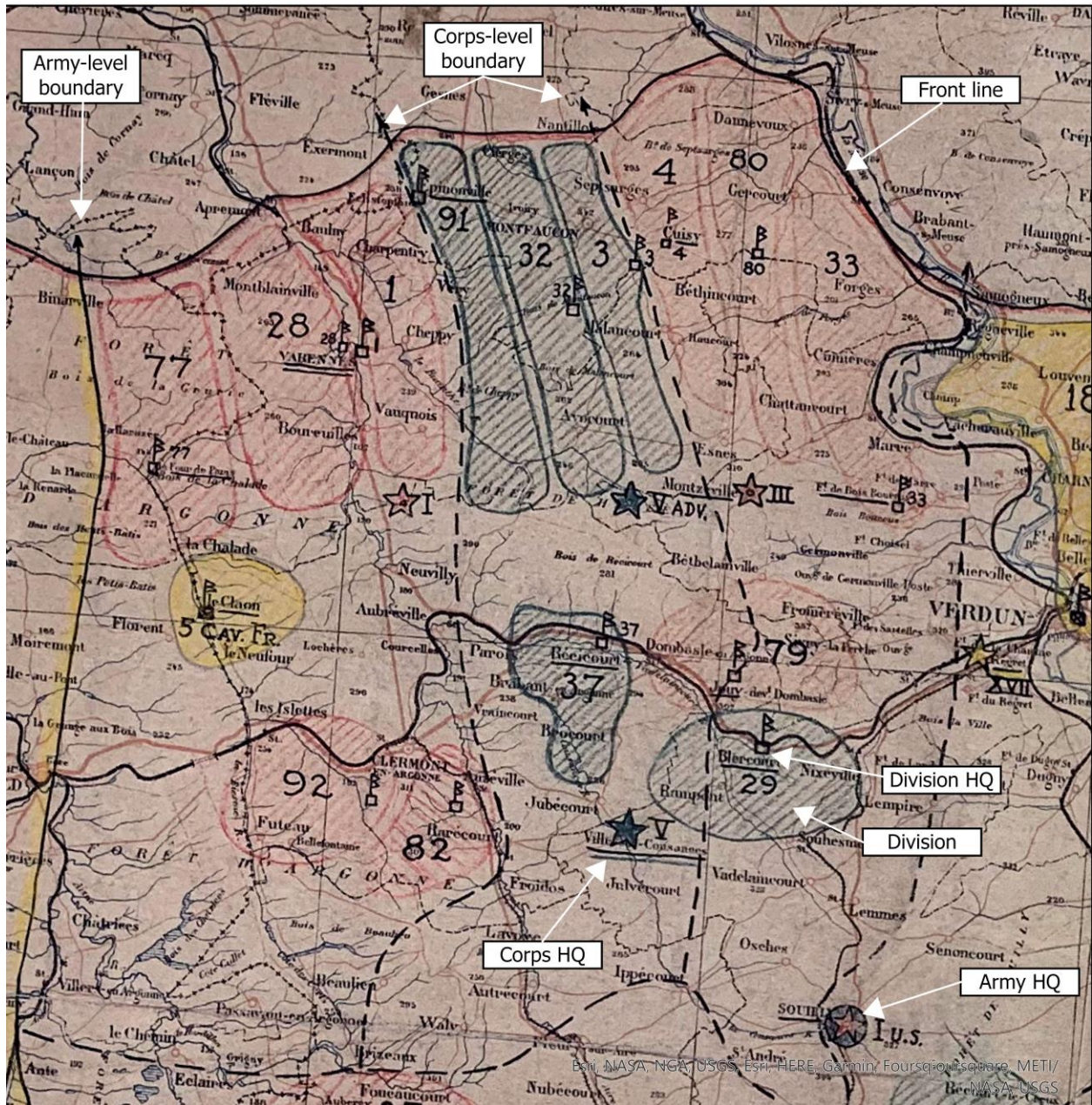


Figure 4.2 Extract of the October 9, 1918 edition of the AEF Situation Map series produced by the G3. This map series showed the location of friendly headquarters, units, and boundaries, as well as the front line (G3, 1st Army, AEF, 1918c).

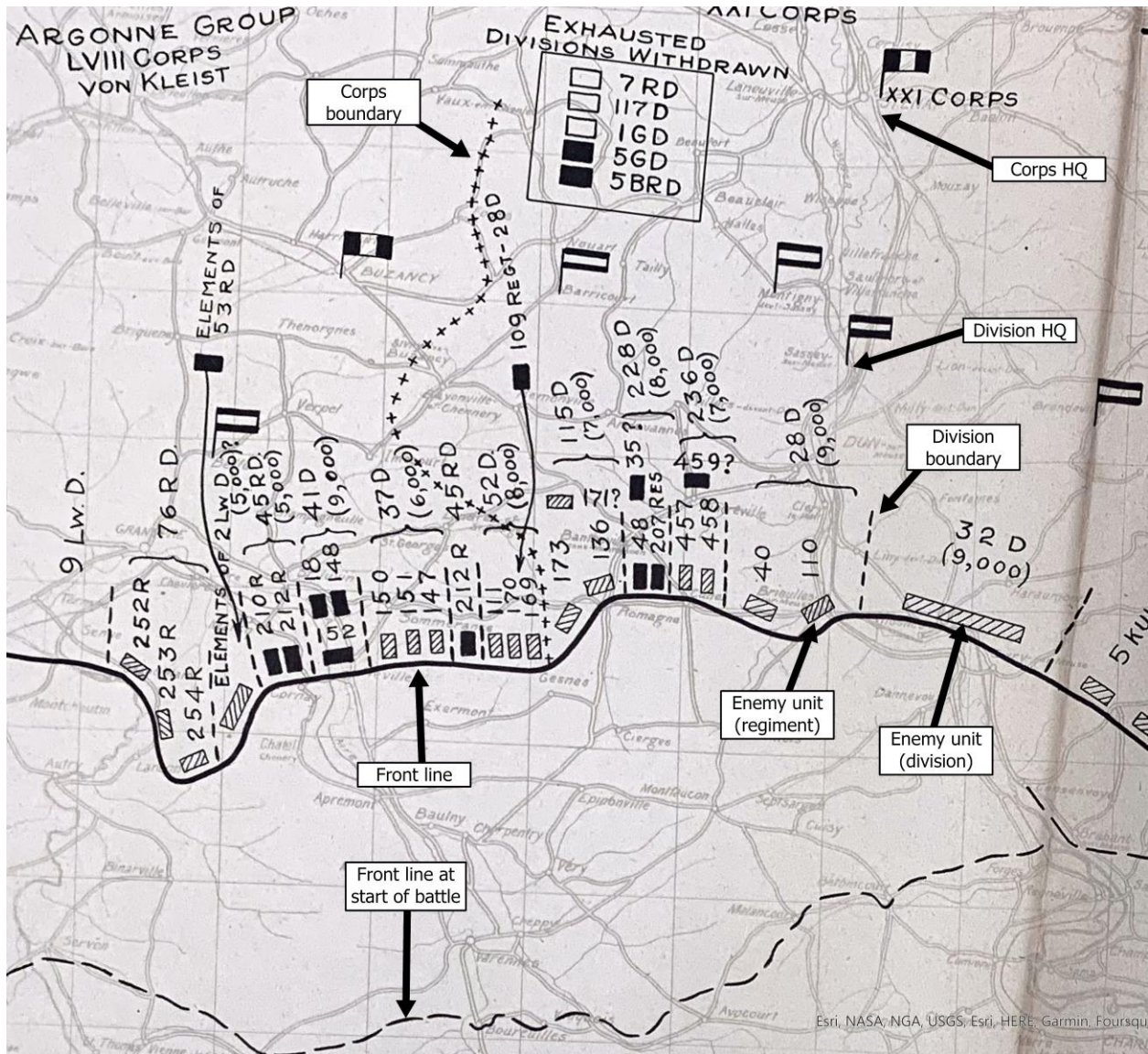


Figure 4.3 Extract of the October 9, 1918 edition of the AEF Enemy Order of Battle (EOOB) map series produced by the G2. This map series showed the assessed locations of enemy headquarters, units, and boundaries, as well as the front line (G2, 1st Army, AEF, 1918c).

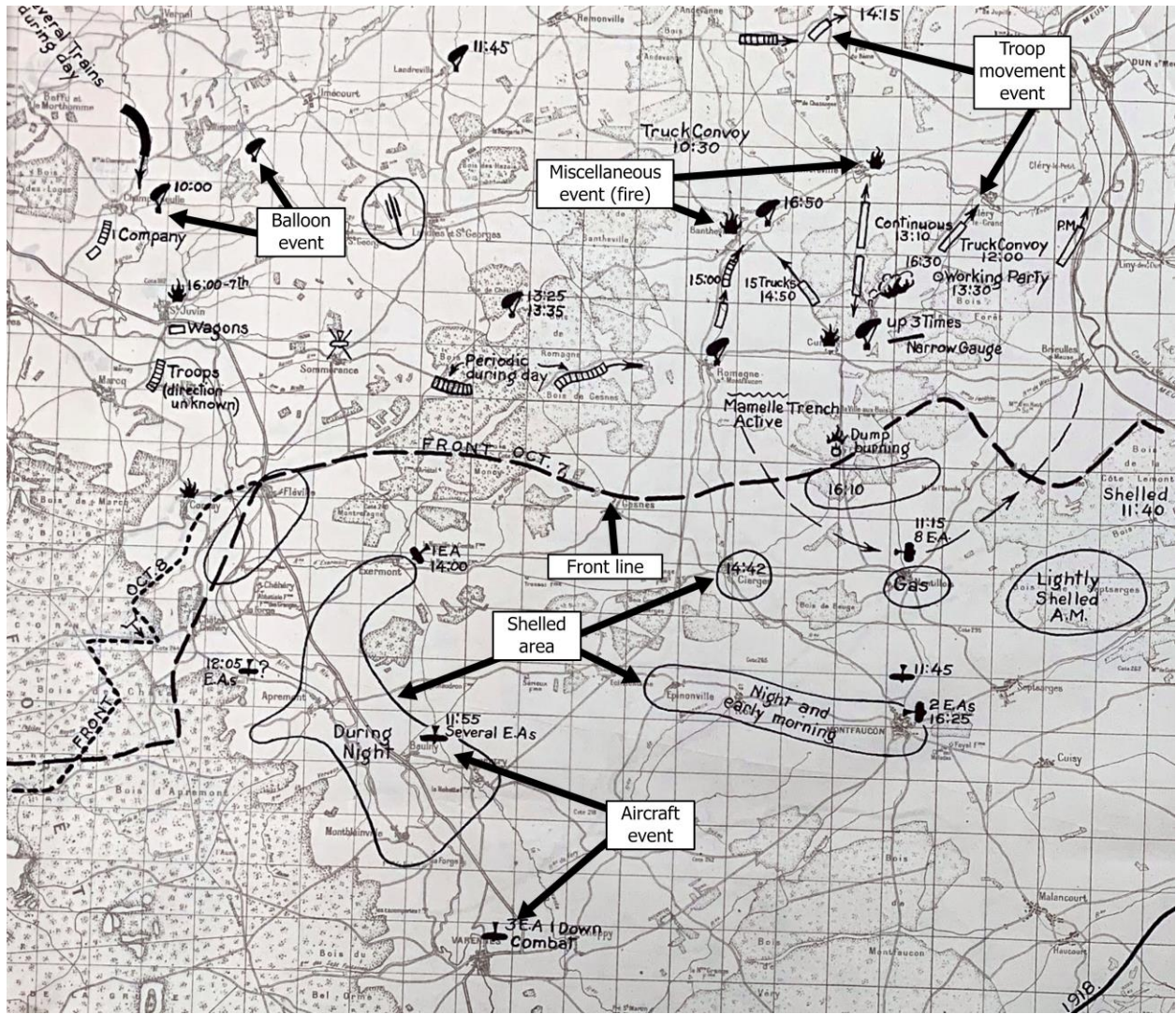


Figure 4.4 Extract of the October 9, 1918 editions of the AEF Graphic Summary of Enemy Activity (GSEA) map series produced by the G2. This map series showed the observed locations of events involving enemy subunits, including troops, artillery, aircraft, and observation balloons, as well as the front line (G2, 1st Army, AEF, 1918f).

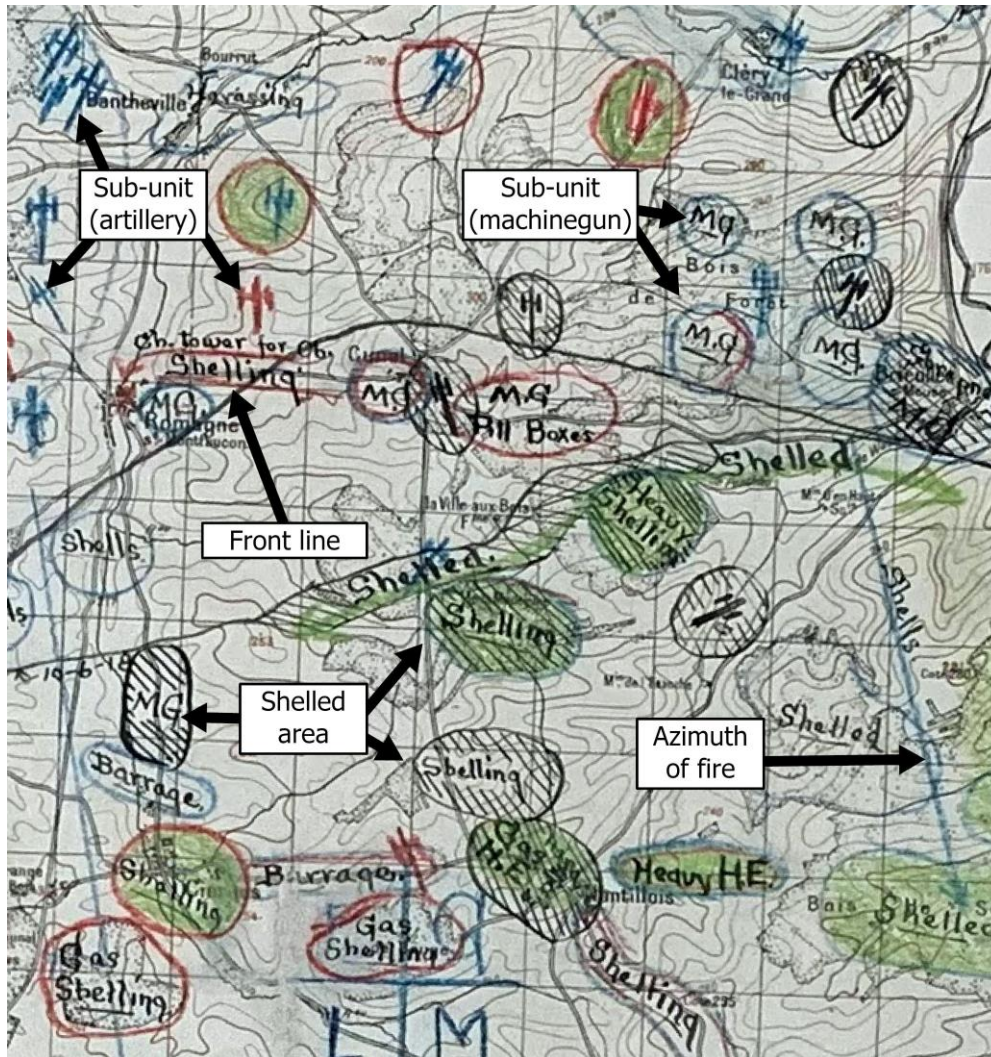


Figure 4.5 Extract of the October 9, 1918 edition of the AEF Artillery Graphic Activity map series produced by the Artillery Staff. This series showed the observed activity of enemy artillery and machinegun subunits, including the locations of enemy batteries, areas shelled by enemy guns, and azimuths of fire connecting them. This map also shows the location of the front line (AIS, 1st Army, AEF, 1918c).

Units as entities are aggregations of smaller subunits or individuals that follow the same general hierarchical structure as the headquarters. As such, the concept of a military unit is an aggregation that can mask significant complexity and variability, such as the types, strata, strength, and organization of its subunits. The aggregated nature of units as entities is reflected in the symbology used to portray them, namely amorphous polygons denoting the area in which the

mapmakers understood a unit to be present. Also, the mapmakers typically amalgamated headquarters and units into a single entity at strata below the level at which they choose to portray units. For example, the AEF situation maps do not show the location of brigade level headquarters because they map friendly units at the divisional level.

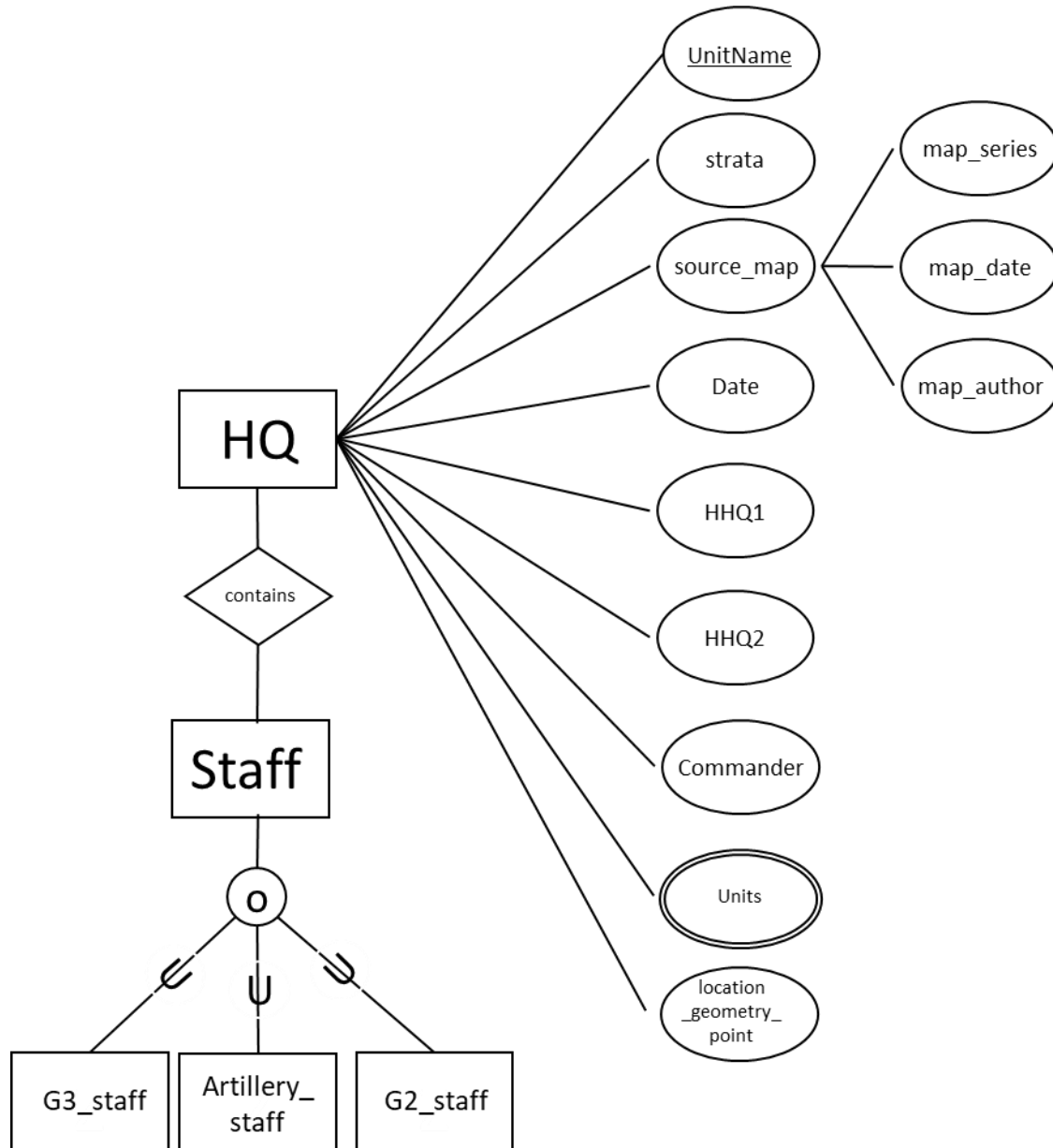


Figure 4.6 Data structure for the headquarters entity super-category.

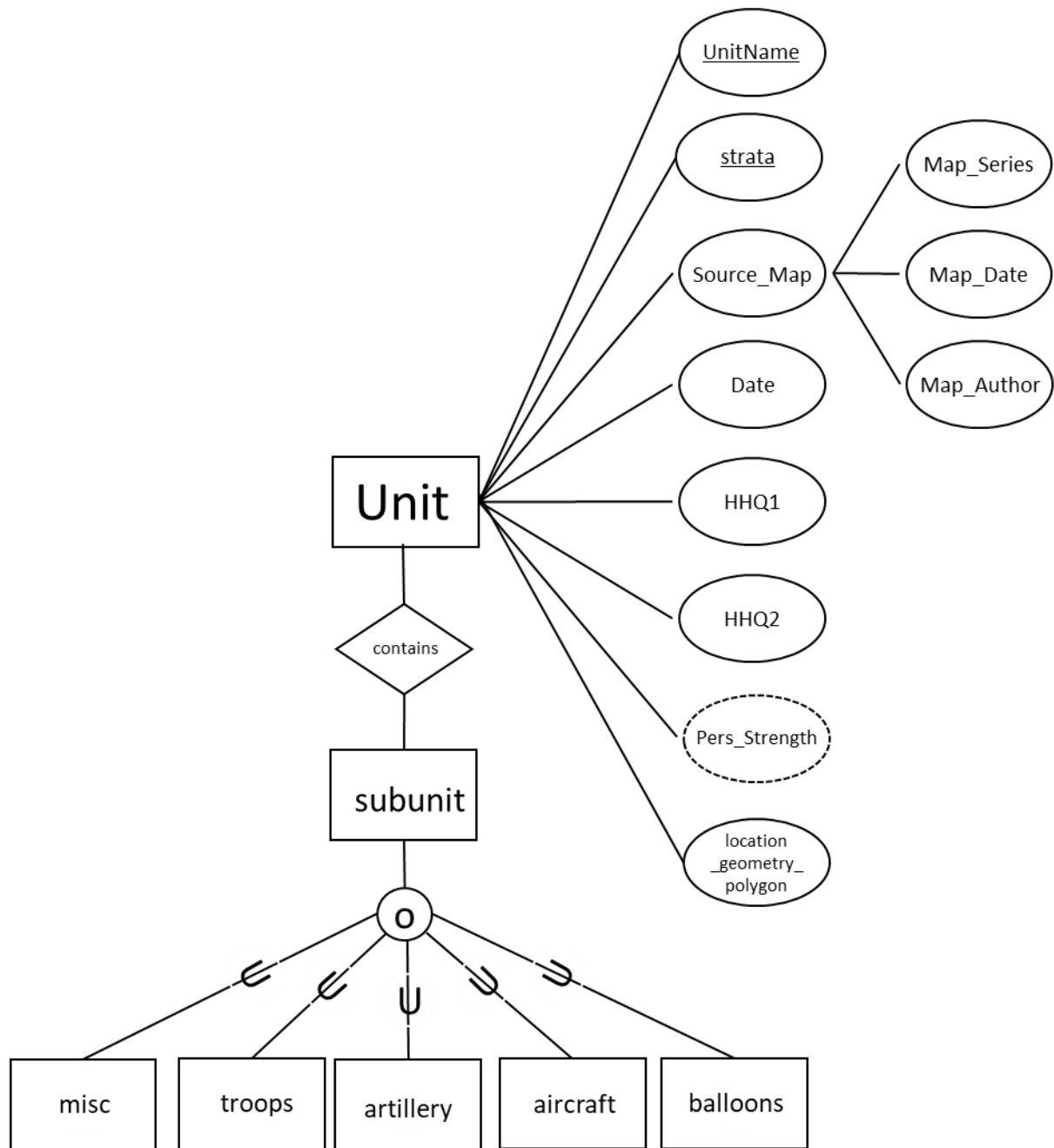


Figure 4.7 Data structure for the unit entity super-category.

The attributes for units in the database model are similar to those of headquarters (Figure 4.7). Units are identified by a unique name primary key, which they share with their associated headquarters. Attributes can include the personnel strength of a unit, which can be derived either

from a source that states this or from aggregating the strength of the subunits that compose the unit. Sub-units are represented as specialized variations of the broader unit category. Of note, an exception to the polygon geometry used to display units and to the headquarters-unit structure in general exists in the data contained in the G2 staff's GSEA maps and the Artillery staff's AGA maps (Figures 4.5 & 4.6). Some map editions display enemy subunits with point geometry symbols, thus necessitating a sub-category of unit.

Boundaries are abstract weak entities in that they derive their identification from the headquarters whose areas of responsibility they delineate. For example, the corps boundary between the I Corps and the V Corps on the AEF G3's October 9 Situation Map derives its identity from the primary keys of these two headquarters (Figure 4.8). The frontline boundary is an exception to this rule, as it existed as the forward trace of the entire force on a given day. Thus, the frontline entity's primary key is the source map from which it derives its geometry (Figure 4.9). As a rule, headquarters have at least as many boundaries as they possess neighboring units.

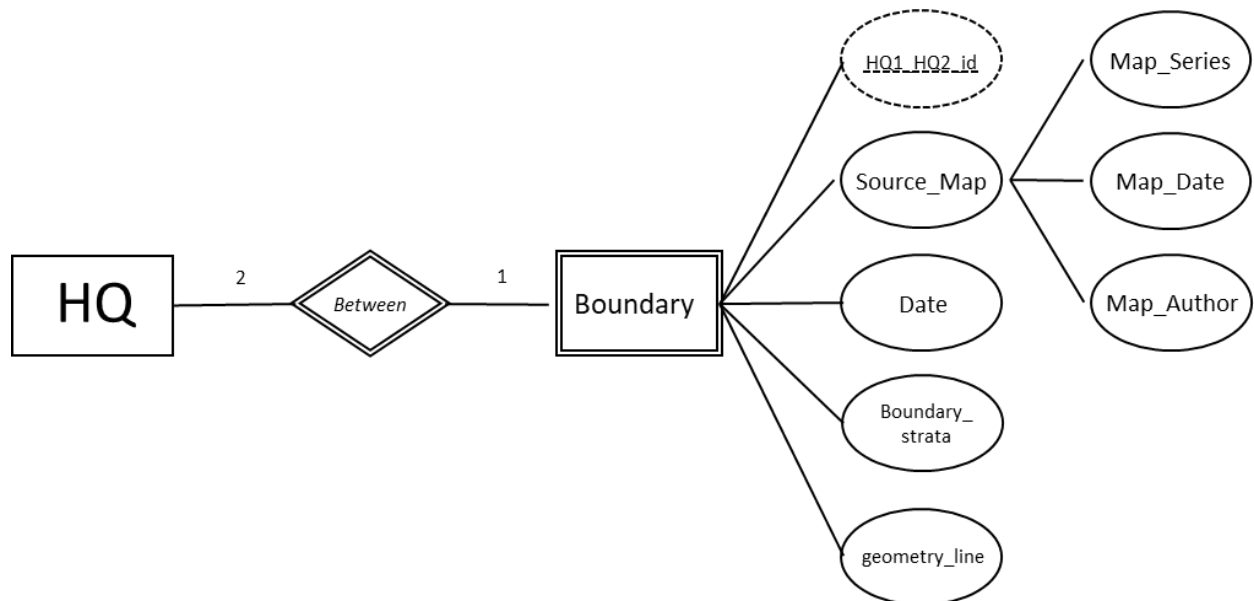


Figure 4.8 Data structure for the boundary entity super-category.

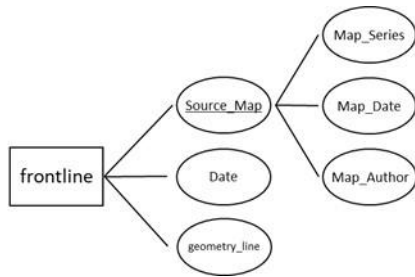


Figure 4.9 Data structure for the frontline entity.

Events are entities that occur and were recorded but do not necessarily persist as from one map edition to another. Physical entities cause events, such as artillery fire resulting in a “shelled area” entities. Events possess three sub-categories: shelled areas, movement, and miscellaneous (Figure 4.10). *Shelled area* entities are recorded on the GSEA and AGA maps as areas where weapons fire impacted. Common attributes of this entity include the specific time and intensity of the shelling event, as well as the types of ammunition employed. Another subcategory of events is *movement* by enemy units. The GSEA maps record these using linear map features to indicate the location and direction of movement (Figure 4.4). A distinguishing attribute of this entity is the mode of movement (i.e., marching, train, truck, or wagon). A third subcategory is miscellaneous observed events such as fires, smoke, and aircraft engagements.

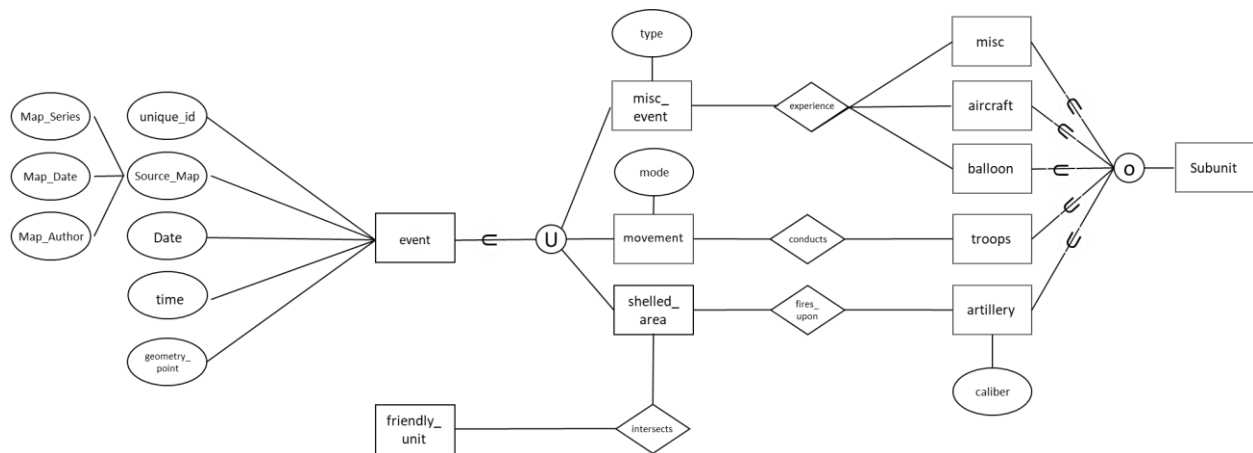


Figure 4.10 Data structure for the event entity super-category.

7. Attributes and Relationships

Information from other archival documents can augment an HGIS in the form of attributes that help to establish relationships between entities. Some examples of relevant attributes that supplementary documents can supply include the unit's strength or ammunition status. Attributes of headquarters can include the names of the commander and of key staff officers. Attributes of events can include the method by which the event was observed or the identity of the observer. Three types of relationships connect entities in this EER. *Entity-entity* relationships include the control exerted by headquarters over subordinate units. These relationships typically take the form of 1-to-*n*. *Entity-event* relationships connect a unit to an event that the unit caused, as when an artillery subunit on an AGA map is connected to a shelled area polygon by an azimuth. Such relationships can be of either the 1-to-1 or 1-to-*n* variety, as a single unit could shell many areas. Events can also occur *to* entities in the form of *event-entity* relationships, as when a shelled area polygon intersects with a unit polygon.

8. Data analysis

Organizing data extracted from tactical maps into spatial databases opens opportunities for analysis that can yield insights into the events that the maps portray and about the mapmakers themselves. Below are outlined three examples of how the HGIS described here has been employed to gain further understanding of the events surrounding the creation of the AEF's tactical maps.

8.1 Overlaying Multiple Maps for Exploratory Analysis

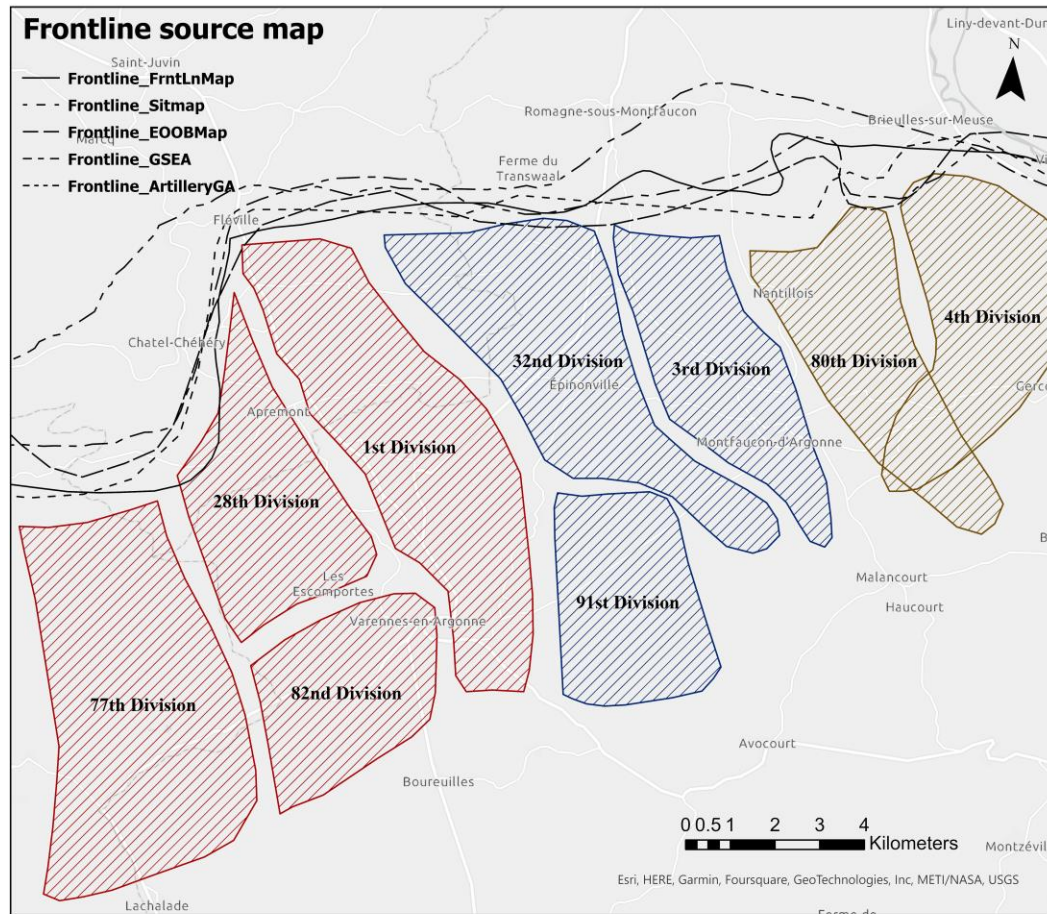


Figure 4.11 Digitized data from the October 6, 1918 editions of the AEF 1st Army headquarters' five daily tactical maps, including the front line from each map edition and the location of friendly units from the Situation Map. Note that the frontline geometry varied by more than two kilometers in some cases between map series, and even overlap with the supposed locations of friendly units (G3, 1st Army, AEF, 1918b & 1918e; G2, 1st Army, AEF, 1918b & 1918e; AIS, 1st Army, 1918b).

Overlaying data from several maps atop one another enables options for exploratory analysis. An advantage of using GIS to overlay historical military maps atop one another is the ability to remove the “noise” in the original base maps, adjust for differences in scale, and study the remaining data. Doing so reveals interesting information about what the commanders and staff at the AEF headquarters may have understood about the battlefield, as well as about how the

headquarters functioned. For example, nearly every AEF tactical map series showed the location of the front line on each day. However, overlaying various editions on top of one another reveals important variation as to where different elements within the AEF headquarters believed the front line to be located (Figure 4.11). Such variations provide evidence about how information was flowing within the headquarters. Furthermore, a query that returns types of data mapped by different staff sections reveals some of the distribution and duplication of effort within the AEF First Army headquarters, as exemplified by the G2 and artillery staff sections both mapping the location of enemy shelling, though the artillery staff did so with greater granularity (Figure 4.12).

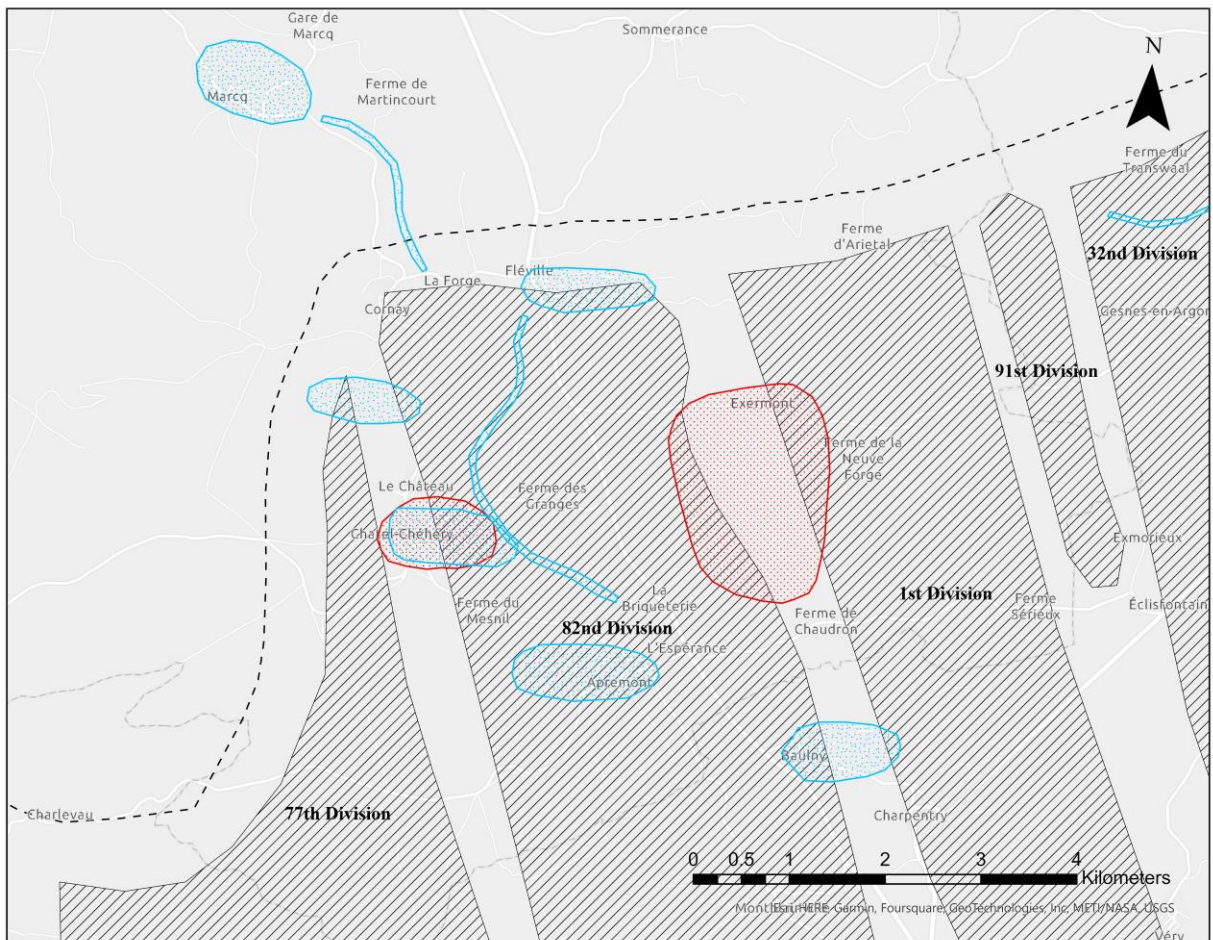


Figure 4.12 Digitized data from the October 3, 1918 editions of the AEF 1st Army Situation Map, GSEA map, and AGA map series. The shelled areas depicted by the GSEA map are

shown in red, while those depicted by the AGA maps are shown in blue (G3, 1st Army, AEF, 1918a & 1918d; G2, 1st Army, AEF, 1918a & 1918d; AIS, 1st Army, 1918a).

A second example concerns the scale and extent of the map documents and what this data reveals about the staff mapmakers. The larger scale (1:50,000) at which the G2 and Artillery staff sections charted their data indicates that these sections saw a need for greater precision in their analysis than did the G3 staff section, whose mapmakers employed a smaller scale (1:200,000). The G2's EOOB maps covered a spatial extent that portrayed the AEF's entire front, indicating the purpose of this map series to track the movement of enemy units into, out of, and within the AEF's area of responsibility. On the other hand, the G2's GSEA and Artillery staff's AGA maps only mapped events along the length of the front within which the Americans were attacking. Such data indicates the G2 staff understood that the potential for enemy offensive action along quieter parts of the front was small.

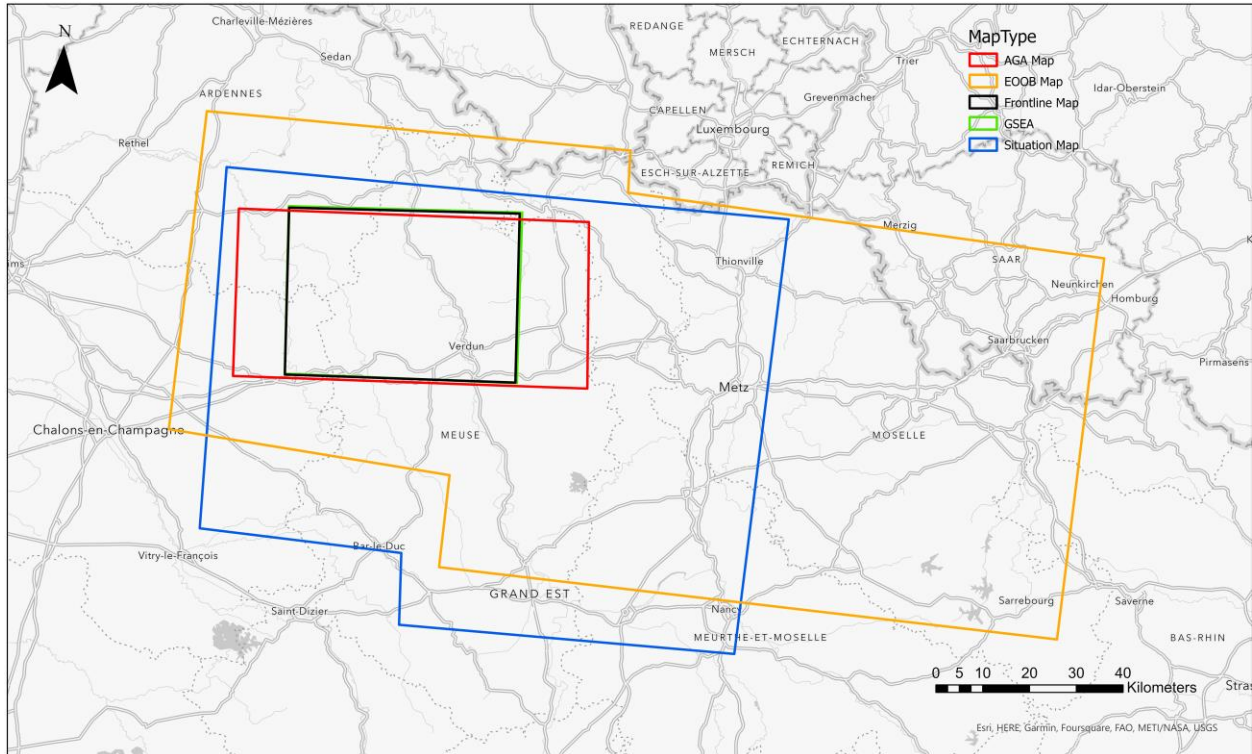


Figure 4.13 Spatial extent covered by the October 9, 1918 editions of the AEF 's daily map series.

8.2 Example 2: Quantitative Feature Comparison

A strength of spatial databases is their ability to facilitate quantitative spatial analyses. Such analysis can provide evidence of how information was flowing within the headquarters. As noted above, each map series depicted the frontline, with variations between editions measuring as much as several kilometers on some days. One hypothesis posits that dissimilarity of frontline geometries can provide evidence for which staff sections were collaborating with one another. To test this hypothesis, a comparison of all the frontlines across the five daily map series over a ten-day period from October 1-10, 1918 was conducted. Within ArcGIS Pro 3.1.1, a custom Python script was used to compare every frontline on a single day to one another and calculate

the area of difference between them (Figure 4.14). For consistency, this measurement was done within a bounding box. The area difference between frontline features over the ten days provided evidence for which staff sections within the AEF headquarters were closely collaborating and sharing information (Table 4.4).

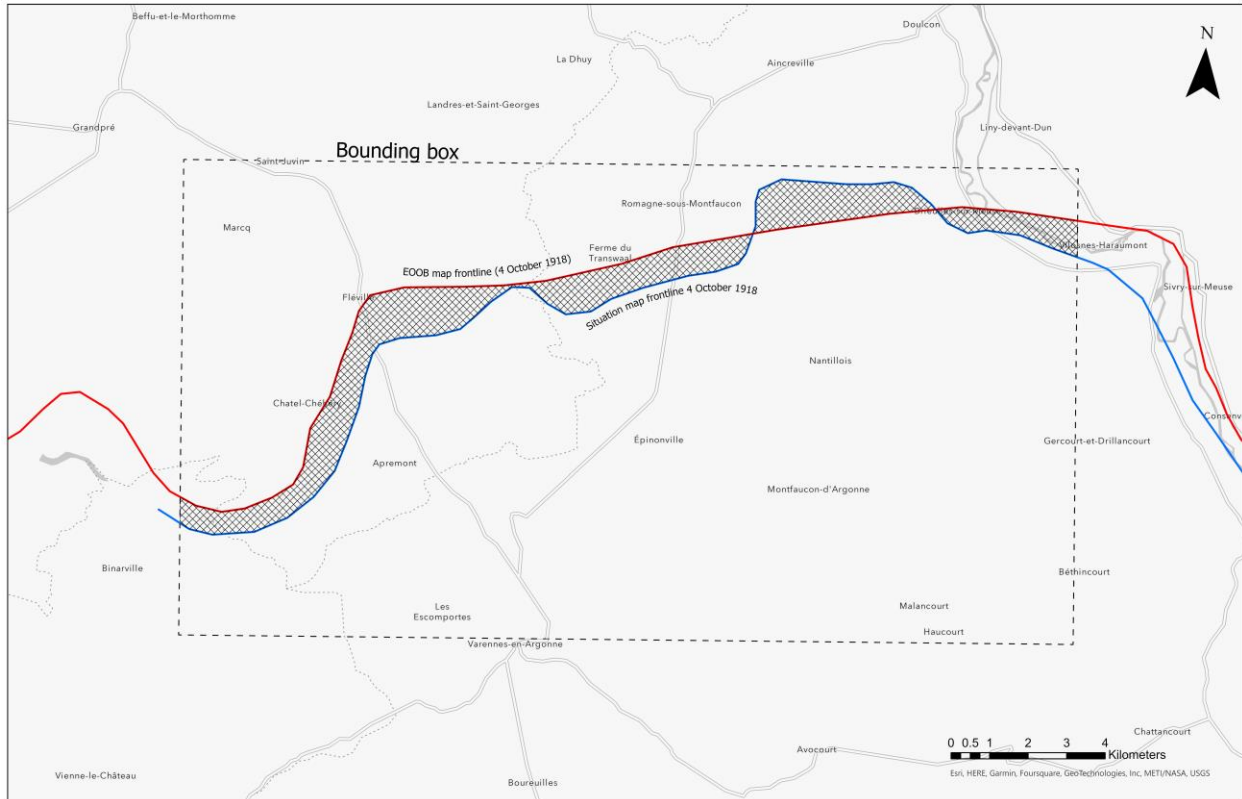


Figure 4.14 Example of a comparison of the Situation map (blue) and EOOB map (red) frontlines from the October 4, 1918 edition of each map series. A custom Python script was used in a GIS to calculate the area of difference (crosshatched area) between the two frontlines within a bounding box.

Exploratory data analysis indicates some interesting conclusions (Figure 4.15). First, the map type with the greatest median frontline difference from every other map type is the AGA series produced by the Artillery staff (Table 4.4). This series' purpose was to provide artillery planners with targeting data for the army's guns and the frontline on this map series was intended

as a control measure beyond which artillery could fire without coordination (Grotelueschen, 2001 & 2007). The fact that the Artillery staff's mapping of this feature differed so much from the other staff sections suggests a lack of communication within the broader staff. Such confusion could produce deadly consequences. Moreover, the Artillery staff appear to have understood this weakness, as after October 10 they ceased plotting their own frontline and instead began copying their data onto pre-printed GSEA maps from the G2 section.

Such datasets also allow temporal analysis. As Figure 4.16 indicates, the frontlines across all map types grew more similar to each other from October 1-4. During these days the AEF formations had paused their offensive after the initial bloody advances of September 26-30. This pause would have allowed the staff more time and a less chaotic context in which to try to understand their units' location. This could have resulted in a better shared understanding of the battlefield situation by October 5, as reflected in the small median area difference between all frontlines on that day.

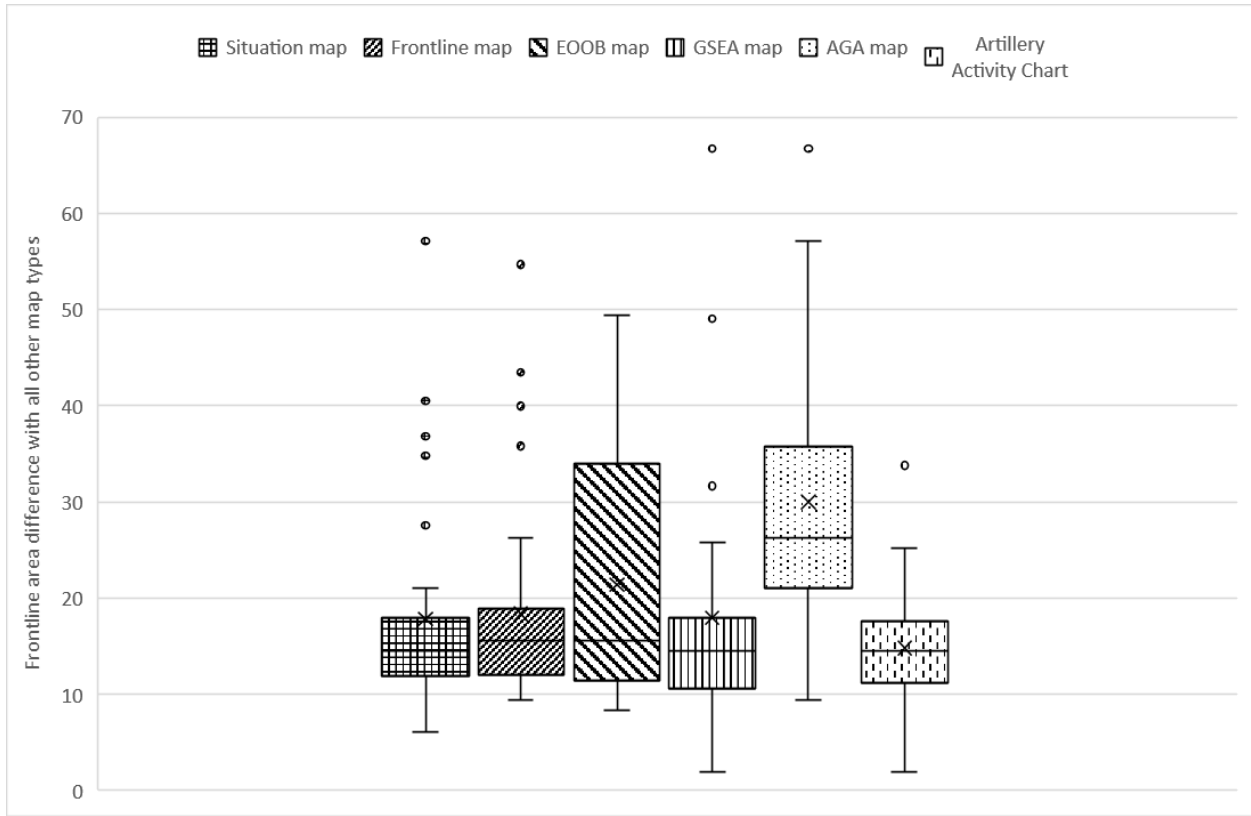


Figure 4.15 Box and whisker chart of the area difference between all frontlines plotted on six AEF map series over a ten-day period from October 1-10, 1918.

	Situation map	Frontline map	EOOB map	GSEA map	AGA map	Artillery Activity Chart
Situation map		12.4	16.5	14.3	28.3	14.6
Frontline map			17.0	14.8	26.3	15.7
EOOB map				11.5	23.5	11.4
GSEA map					25.9	10.3
AGA map						25.3
Artillery Activity Chart						

Table 4.4 Median difference in square kilometers between the frontlines plotted on the AEF tactical maps from October 1-10, 1918. The difference between the AGA map series and all other map types is highlighted in gray.

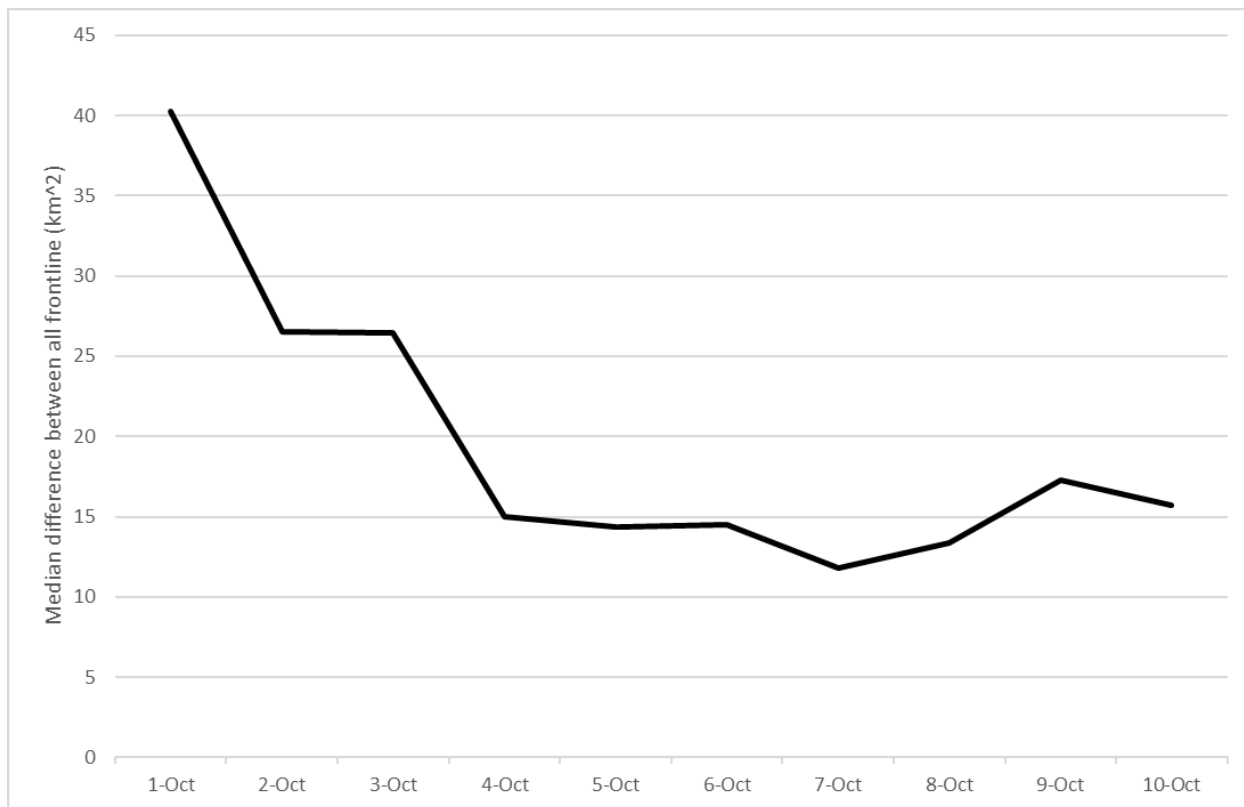


Figure 4.16 Median area difference between the frontlines from all AEF map series from October 1-10, 1918.

8.3 Example 3: Overlaying Maps with other Archival and Secondary Source Data

Furthermore, HGIS can enable revisionist interpretations of events. An example of this ability exists in the story of the “Lost Battalion.” In this incident, a battalion of the US 77th Division under the command of Major Charles Whittlesey attacked into the Argonne Forest on October 2 and became surrounded and besieged for five days (Ferrell, 2005). A controversial episode during the siege occurred on October 4 when Whittlesey’s men were struck by an artillery barrage fired by friendly guns. This incident has puzzled historians because, despite the unit’s “Lost” moniker, Whittlesey’s superiors were never in doubt as to the exact location of the

beleaguered unit (Clodfelter, 2007). This raises the troubling question as to why they then became the victims of a preplanned barrage by friendly artillery.



Figure 4.17 Location of Major Whittlesey’s “Lost Battalion” in relation to the various front lines mapped by the AEF First Army’s headquarters staff sections on October 3, 1918. Note that three of four front lines run as much as one half kilometer south of the isolated unit’s position, placing the unit at risk of receiving friendly artillery fire (G3, 1st Army, AEF, 1918a & 1918d; G2, 1st Army, AEF, 1918a & 1918d; AIS, 1st Army, 1918a).

A hypothesis in this case is that confusion at higher headquarters about the location of the front line may have contributed to the fratricide. To test this, four different maps' frontlines were overlaid in the area occupied by Whittlesey's men to see if any of the frontlines had been plotted short of their positions². The result showed that of the four frontlines, three were plotted as much as five hundred meters short of the Lost Battalion, indicating confusion at the First Army headquarters regarding how far forward Whittlesey's unit had advanced (Figure 4.17). Someone relying on the data from these maps could have mistakenly assumed that a defensive barrage placed on the Lost Battalion's actual positions would protect them from German forces attacking from the north.

Indeed, this appears to have been what occurred. Two of the artillery officers who were responsible for planning the barrage in question appear to have traced their interpretation of the front line's location from an unnamed higher headquarters map and planned the barrage accordingly (Clodfelter, 2007). Moreover, American pilots who were sent to drop supplies to the isolated soldiers on October 4 managed instead to deliver their supplies to the besieging Germans, in part because they were relying on maps that gave an inaccurate location for Whittlesey's unit (Hudson, 1968). Clearly, the role of maps and cartographic knowledge remains an underexplored facet of the Lost Battalion saga. As such, this gives an example of how a close HGIS examination of data contained in historical military maps can provide new insights into already thoroughly-studied events.

² Perhaps tellingly, the Artillery staff did not plot a front line for this day on either the AGA map or the Artillery Activity Chart.

9. Conclusions

The database structure described in this paper is necessarily optimized for the types of data contained in the AEF tactical maps and the specific scale, types and identities of units, relationships, and actions they mapped. However, given the relative uniformity of military hierarchies since at least the First World War and the commonalities that exist in how modern military forces view and map their environments, this structure can serve as a model for other researchers seeking to use HGIS to explore tactical maps. As stated above, tactical maps represent an understudied and data-rich class of archival document that can yield important insights into the development of military mapmaking and the history of cartography in general. Moreover, a common data structure for information gleaned from these documents can promote greater collaboration and data-sharing among researchers.

Another observation concerns the process of extracting data from tactical (and other) maps using GIS; the most time-consuming and effort-intensive part of this project involved the manual digitization of map features from the raster layers. This was necessary because automatic raster-to-vector digitization methods proved unreliable or unsatisfactory. This bears out some of the criticism leveled against HGIS, namely that as a tool it requires a significant investment in time and effort to yield non-superficial results. Better tools to automate or at least ease the process of vectorization would allow easier and more rapid extraction of data from historical maps in general.

Overall, HGIS databases that benefit from a disciplined organization present the opportunity for researchers to draw revisionist conclusions about past events, a weakness that many critics of HGIS have noted over the course of this method's development. Not only do

such database structures ease the process of gathering data from historical maps, but they also allow the simpler overlay and comparison of data originating across map series, editions, and scales. Work done up front in considering what type of information these map documents contain and how it should be organized can reduce the effort required down the line for researchers striving to use HGIS. As the amount of effort and time investment required of researchers to build HGIS remains a common criticism of the method, any reduction in these requirements can help to make HGIS a more approachable and more relevant tool.

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Chapter 5 - A Taxonomy of the Environmental Effects of War

1. Introduction

This chapter outlines a taxonomy for war-related disruptions in the environment. In doing so, it builds upon the general taxonomy outlined by Machlis and Hanson (2008), who suggested classifying disruptions according to their context (preparations for war, war, and post war) and scale (local, regional, global). This project accepts Machlis and Hanson's context/scale framework and expands upon it by better integrating the warfare ecology structure with concepts of scale and context drawn from military geography, as will be discussed in the next chapter (Palka and Galgano, 2012). This chapter is concerned with defining the physical, landscape-scale disruptions that are common to war-related activities. The taxonomy described below is structured as a three-tier classification scheme designed to better integrate the warfare ecology structure with earth system science (Figure 5.1). It provides a way to classify individual types of disruptions according to the earth system sphere in which the disruption occurs, the mechanism that causes the disruption, and the acuteness of the disruption. The third tier of this classification scheme, acuteness, will be discussed in Chapter 6.

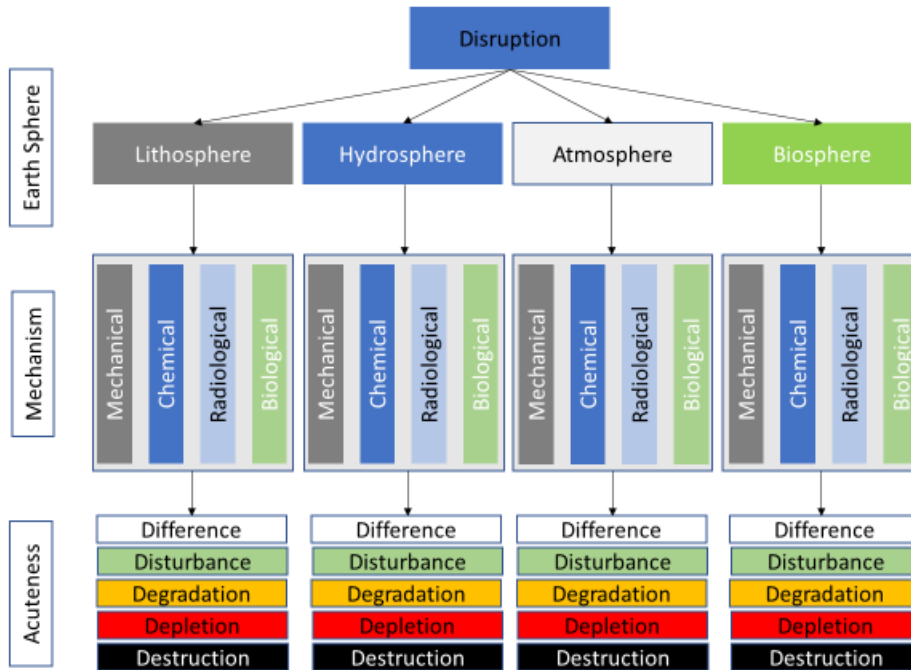


Figure 5.1 A taxonomy for classifying war-related disruptions in the environment according to the earth sphere in which the disruption occurs and the mechanism causing the disruption.

2. Methods

This classification scheme is the result of a grounded theory analysis of sources returned by database queries of war-environment search terms as described in Chapter 2 (bibliometric analysis). The initial database queries focused on the primary disciplines that engage with war-environment research and employed five search terms: “military geography”, “militarized landscape”, “environmental history of war”, “environmental geopolitics”, and “warfare ecology”. A broad reading of the sources returned by these queries then prompted further searches in both Google Scholar and Web of Science using key concepts from these subdisciplines as search terms. A sampling of some of these subsequent search terms included

“hydrological warfare”, “bombturbation”, “chemical weapons residue”, “explosive residue”, “fallout”, “military shipwreck”, “nuclear shipwreck”, “landscape abandonment + war”, “displaced persons + war”, and “military carbon emissions”, among others. Relevant articles were selected from these subsequent searches for analysis, with priority given to review articles that summarized the current war-environment-related research within various subdisciplines.

The sphere-mechanism classification scheme became apparent during the coding phase of this analysis, as most empirical studies and surveys of war-environment disruptions generally focused on one of these frameworks, but usually not both. An exception to this observation is the work of Arthur Westing who, over an extended period, published numerous books conducting ecological analyses of real and potential conflicts that occurred in the latter half of the twentieth century. However, Westing did not formalize his approach in a framework for other researchers, as the taxonomy described here attempts to do.

2.1 Sphere-Mechanism Classification

As discussed in Chapter 1, the concept of earth spheres drawn from earth system science is a useful way to encourage interdisciplinarity in research seeking to understand ecological disruptions (Martin & Johnson, 2012). This taxonomy classifies both the direct violence of the initial military activity in the preparation for war and war contexts, as well as the slow violence that can be separated in both time and space from the initial event. Though the *relationship* between direct and slow violence constitutes the regional scale as defined by this study’s concept of scale (see Chapter 1), the actual effects of incidents of both direct and slow violence operate at the landscape scale. In other words, while an incident of direct violence can cause conditions of

slow violence both locally and regionally, the actual effects of both direct and slow violence always operate on local landscapes. As such, this taxonomy focuses on this scale. The *relationships* between incidents of direct and slow violence (regional scale) and how these incidents and relationships change the underlying environmental context (global scale) will be the subject of Chapter 6, which outlines a topology of the environmental effect described in this chapter (the heuristic tool).

This chapter's ideas about the *mechanism* of disruption draw upon the prolific Arthur Westing's evolving approaches to studying the ecological disruptions of modern warfare (Westing, 1976, 1977, 1984, 1990). In this work studying the ecological consequences of the Vietnam War, Westing (1976) devoted chapters to various categories of disruptive mechanisms including "high-explosive munitions", "anti-plant chemicals," and "mechanized landclearing." While this approach was effective in demonstrating the diverse ways in which military activity disrupted the ecology of the Indochina region, he also felt the need to include a catchall category of "miscellaneous weapons and techniques," indicating that the classification technique used was insufficiently broad to capture all types of disruptive mechanisms. Other of Westing's books have attempted a deeper coverage of single classes of war-environment disruption, including his *Weapons of Mass Destruction and the Environment* (1977) and *Herbicides in War* (1984).

These studies, while detailed and groundbreaking, were also largely topical rather than systematic, focusing on specific types of *activities* in particular conflicts. This is an approach that other militarized landscape researchers such as Lanier-Graham (1994) and Bauer (2009) have also employed. However, a criticism of this approach is that the types of activities that can occur in war are so varied and unpredictable that a classification system that uses the activities themselves as a starting point will inevitably struggle to encompass the breadth of possibilities.

Addressing this challenge, in *Environmental Hazards of War* (1990, vii) Westing's approach became broader and more systematic, with chapters devoted to describing the "release in war of dangerous forces from...nuclear...chemical...[and] hydrological facilities." While still largely topical and focused on the environmental effects of the destruction of civilian artifacts in war, this approach indicates a useful framework for an all-encompassing classification system, namely using *how* a particular activity disrupts the environment as a starting point rather than the activity itself. Thus, building upon Westing (1990), this chapter's taxonomy classifies disruptions by whether their mechanism acts mechanically, chemically, biologically, or radiologically.

This classification system defines a mechanical disruption as the physical displacement of matter from one location to another, or the rerouting of an existing flow into a new course or pattern. Chemical disruptions encompass effects that change the existing chemical composition of a system or change the rate at which chemical reactions occur. Biological changes denote the destruction, enhancement, or movement of organisms that would not have otherwise occurred outside of war's ecological effects. Finally, radiological effects include the introduction of radioactive materials into the landscape either as detritus of objects that incorporate radioactive material into their construction or via the fallout of uncontrolled nuclear reactions. Pairing the mechanism of disruption with the earth sphere in which it operates then yields sixteen distinct classifications that encompass the full range of war-related disruption.

In providing examples of the diverse types of disruption, this chapter follows Clausewitz's (1993, 166) maxims that principles of war "must be derived from military history or at least checked against it," and that the more proximate a military event is to us in time, the more useful it will be in revealing knowledge about war. As such, in the discussion of each of the

sixteen classes of disruption contain examples from military geography and history that highlight how and why military forces have caused these sorts of disruptions in the past. In the interest of drawing upon temporally proximate examples, these discussions where possible highlight relevant incidents from the war between Ukraine and Russia, which is still ongoing at the time of this writing.

2.2 Integration of Military Geography Concepts

This chapter also integrates a military geographical understanding of landscapes to understand how military forces often view and operate within their environments. The “terrain and tactics” approach to military geography has been maligned for its lack of theoretical engagement, as discussed in Chapter 1 (Woodward, 2005; Lohman & Fuhrman, 2019). To mitigate this criticism, this chapter draws upon theoretical concepts from Clausewitz (1993) about the dialectical nature of war to better show how the ways in which military forces perceive terrain during war shapes the ways in which they act upon landscapes in both the preparation for war and wartime contexts. Clausewitz noted that activities in war were either “offensive” or “defensive,” depending upon the tactics chosen by the combatants, and that these two forms of warfare were fundamentally different and unequal. The type of operation (offensive or defensive) each side perceives themselves to be engaged in will shape how they view and operate upon the terrain. Clausewitz further posited that the nature of war was like a “duel,” or, better yet, like two wrestlers seeking to impose their will upon one another, meaning that both sides will also exert an influence on one another in how they view and use terrain.

The usefulness of the analogy of the wrestlers paired with Clausewitz's concepts of offense and defense cannot be overstated in its ability to explain how military forces come to perceive terrain. According to such a dialectical interpretation of the relationship between terrain and tactics, the opposing ways in which opposing forces in combat perceive a landscape will control how they both act upon it. Take for example a ridgeline, a comparatively simple terrain feature, set in three historical contexts: the Battle of Hastings during Norman invasion of England in 1066, the Battle of Waterloo in 1815, and battles for Messines Ridge that occurred on the Western front of the Great War from 1914-1918, as discussed below.

During the Battle of Hastings in 1066, the defending English army established itself atop a ridgeline to force the invading Normans to attack uphill. By contrast, the Normans attempted to use tactics of feigned retreat to lure the English infantry down the slope, where the cavalry-heavy Norman forces could isolate and destroy them. Here, both sides perceived the ridgeline in terms of the usefulness of its slope as a physical and psychological impediment to mobility. The English, fighting defensively, tried to use the slope to mitigate the strength of the Norman attacks, while the Normans tried to use the same slope and the English soldiers' psychological urge to charge down it to break up the disciplined English formation (Brown, 2017).

The perception and use of ridgelines was entirely different at the Battle of Waterloo in 1815. In this struggle between an attacking French army under Napoleon and a generally defending English-Dutch-Prussian force under the Duke of Wellington, Napoleon attempted to employ one of his most effective tactics, massing his army's artillery into a "grand battery" to blast a hole in his enemy's defenses, through which he could then pour a massed infantry and cavalry attack. Placing artillery atop a ridgeline, as Napoleon did at Waterloo, extended the range of the guns and provided them with clear fields of fire, in theory increasing their effectiveness.

Wellington, whose army was positioned atop a ridgeline parallel to the one on which Napoleon had massed his grand battery, chose to use the terrain differently. During the French bombardment, he withdrew his forces behind the ridgeline to shield them from the enemy fire, employing what in modern terms is called a “reverse-slope defense.” Thus, two different interpretations of the meaning of the terrain feature, one in which it was perceived to enhance the effects of firepower and another in which it could mitigate the effects of the same, shaped how the opposing commanders acted upon it (Townsend, 2000).

In the battles of Messines Ridge in the Great War, the perceived meaning of this type of terrain for both sides had shifted once again. Artillery in the Great War had moved from employing “direct fire,” engaging targets that the gunners could see, to instead using “indirect fire,” where the guns fired at targets beyond the gunners' field of view using mathematical formulae to calculate the fall of the shell. For indirect fire to be effective, the gunners required observers who could see the impact of the shells and communicate corrections to the guns. Thus, ridgelines such as Messines Ridge in Belgium became important not as features that provided a physical or psychological advantage to defenders posted atop it, nor for the ways in which it enhanced the firepower of weapons, but rather as an observation post that afforded persistent views deep into the enemy defenses and prevented the same sort of observation of friendly positions. Possession of the ridgeline itself was vital, but for different reasons than the opposing forces at Hastings or Waterloo would have cited. Thus, the German and British Empire forces waged numerous bloody battles over possession of Messines Ridge, with the feature changing hands at least twice during the war. Indeed, possession of the ridge was so vital that the British forces in the end largely destroyed it altogether, detonating mines containing hundreds of tons of

explosives under the ridge in one of the largest non-nuclear explosions ever ignited (Doyle et al, 2002).

These brief examples demonstrate why a dialectical approach to understanding how military forces understand terrain is vital to understanding how they operate upon that terrain. Moreover, these examples also highlight how the evolution of military technology changes how terrain is perceived and used. Thus, understanding not just how military forces physically act upon terrain, but also how they perceive it in relation to one another in the context of military struggle, is a key element that can guide researchers to where environmental disruptions have occurred, and can also provide insights into where such effects might occur in the future.

The rest of this chapter is devoted to describing the common types of military activities that disrupt the environment within the taxonomic framework described above. Each section includes a brief description of the common types of military activities and actions that often contribute to the classification of the disruption in question, with examples drawn from military history and geography to illustrate them. Each section also includes current and historical examples drawn from militarized landscape research and environmental history that demonstrate the effects of both direct and slow violence on landscapes, allowing for an initial assessment of the relative acuteness of each classification category, as will be discussed in the following chapter.

3. Disruptions in the Lithosphere

Martin and Johnson (2012) define the lithosphere as “the solid outer layer of the Earth that is largely inorganic and covers the entire planet.” As this is the primary sphere in which

human activity has occurred throughout history, it has also been the scene of the greatest amount of war-related activity and contains the most historical evidence of war-environment disruptions (Table 5.1). Because of its solid nature, slow violence disruptions in the lithosphere tend to remain localized unless they cause secondary effects of slow violence in one of the other spheres, such as changes to hydrology. However, this sphere's solid state also means that effects of slow violence can persist in landscapes for prolonged periods. Moreover, the context in which these disruptions occur is important; direct violence that occurs in the preparation for war context will usually remain highly localized in established training areas, but will also be highly concentrated because of repeated acts of violence against the same landscapes. Wartime direct violence, by contrast, will often occur over a much larger area, but landscapes may experience violence for only a fleeting period in each conflict. In the post-war context, the social meaning cultures attach to sites of preparation and war can lead to further disruptions in the landscape and complicate efforts to remediate environmental degradation.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		

Table 5.1 Common environmental disruptions in the lithosphere due to military activity.

3.1 Mechanical Disruptions in the Lithosphere

Mechanical disruptions in the lithosphere encompass military actions that add, remove, or transfer solid mass in a landscape. Such activities have been a feature of warfare since antiquity, and the evidence of these actions can persist for millennia. Not all such disruptions are

destructive, as military forces often engage in extensive construction projects, the results of which are often permanently incorporated into post-war landscapes.

3.1.1 Construction and Excavation

In the early months of 2023, following the stunning Ukrainian counteroffensives around Kharkiv and Kherson that liberated large swaths of Russian-occupied Ukraine, analysts of open-source satellite imagery began to report upon what appeared to be a massive construction effort being undertaken by Russian forces in occupied southeastern Ukraine (Africk, 2023, November 8). The imagery revealed an emerging extensive system of trenches fortified with bunkers and supported by belts of concrete “dragon’s teeth” anti-vehicle obstacles and anti-tank ditches. By summer 2023, these defensive structures, dubbed the “Surovikin Line” after the Russian army commander (later arrested and deposed following the abortive Wagner Group mutiny) who had ordered their construction, stretched for hundreds of kilometers, extending from Crimea in the south to the Russian-Belarus border in the north and prompting comparisons to the trench warfare of the Western Front of World War I.

Of course, the Russian construction of extensive field fortifications such as the Surovikin Line is nothing new. One of the most common and longest lasting ways in which military forces alter landscapes through direct violence is through acts of construction. When military forces build structures that are wholly or partially subterranean, such as trenches or bunkers, they also employ excavation. Construction can occur in all three contexts of war-environment activities but is most common in the pre-war and wartime contexts. Nor does construction only include fortifications (which can be built in both the preparation and wartime contexts). Fighting forces

require barracks, dining facilities, warehouses, and any number of other types of facilities necessary for sustaining them both in preparation for and during war. Construction activities can be defensive, as in the case of fortifications, but can also denote offensive activities, such as the excavation of sap tunnels. In the post-war context, the social meaning that cultures can attach to landscapes where violence occurred can prompt the construction of memorials and attempts to preserve landscapes as they appeared at the time of conflict (Figure 5.2). Alternately, the disappearance of wartime imperatives can result in the abandonment of structures and fortifications by military forces, resulting in degraded and polluted landscapes.



Figure 5.2 Memorial constructed in 1918 to honor the soldiers who trained at Camp Funston, Kansas, in preparation for their participation in World War I (author's photograph).

During both preparation for war and war proper, military forces can construct billeting facilities for fighting forces that, to their largest extent, resemble small cities containing barracks, family homes, dining facilities, maintenance sheds, warehouses, and structures used for training (Witte, 2015). These sites can become permanent communities that attain significant cultural

importance, such as the US Army posts established in the southeastern United States during the Great War or long-standing military posts that have existed in the UK since well before that conflict (Woodward, 2005). Alternately, they can become abandoned once their perceived wartime need no longer exists, such as was the case for Camp Hale in Colorado, where US troops trained during the Second World War for action in the Aleutians, Norway, and Italy (Witte, 2015). In other cases, these sites can transition from military spaces into permanent civilian ones, as was the case for many military posts in the US after the end of the Cold War in the 1990s (Dillon, 2015).

Other types of long-lasting non-combat facilities constructed by or for military forces include logistical nodes such as airfields, ports, railyards, and fuel storage facilities. Like billeting facilities, these types of structures can possess varied afterlives ranging from abandonment to permanent repurposing (Lackenbauer & Farish, 2007). As warfare has become more industrialized, these facilities have also increasingly become storage areas for hazardous materials such as petroleum products, ammunition and explosives, and even radioactive elements such as fuel for nuclear reactors or warheads for nuclear weapons (Westing, 1977). As these facilities age and degrade or are abandoned, they can release these materials into the broader environment, creating long-term chemical and radiological disruptions that can cross into other spheres as well (Westing, 1976).

Military forces also construct fortifications in both the preparation and wartime contexts. These kinds of structures can range from simple foxholes and trenches to massive complexes of bunkers and tunnels. The form and types of materials used to construct these types of structures has changed significantly over time. Before the widespread use of gunpowder weapons, fortifications were usually constructed of stone or various types of brick in the preparation

contexts (Parker, 2005). During wartime or in areas where more durable building materials were difficult to obtain or too expensive, fortifications often took the form of wooden palisades. Pre-gunpowder fortifications tended to be above-ground structures designed to prevent the physical entry of enemy forces into an area, or otherwise to restrict their mobility (Parker, 2005). By contrast, fortifications designed and built in the gunpowder era are usually intended to mitigate the effects of enemy firepower. They tend to be excavated below-ground structures such as trenches that use the ground to protect occupants from projectiles and explosives. When below-ground structures are impractical, modern fortifications are usually constructed of earth and/or concrete, often reinforced with metal (Doyle et al, 2002).

Regardless of the era of construction, fortifications are designed to be durable enough to withstand the enemy's best efforts to destroy them. As such, they can persist in the landscape for prolonged periods of time, often centuries or even millennia, as is the case for pre-gunpowder castles in Europe or *tels* in southwest Asia (Parker, 2005). Even supposedly temporary or hastily constructed fortifications such as trenches and foxholes can remain in battlefield landscapes for decades or more, even when abandoned (Funk et al, 2020). Moreover, the cultural importance of these structures can evolve in the post-war context as fortifications become ideologically or economically important artifacts, as when a castle or fortress becomes a tourist attraction (Woodward, 2005). In some cases, fortifications are even repurposed as personal or public residences, such as Windsor Castle in the UK or abandoned ICBM silos in the American Midwest (Inskeep, 2023, July 14).

Finally, the purpose of military construction can also be offensive, to enhance the operational or tactical mobility of attacking forces. Such construction in the preparation context has usually consisted of military roads and railroads designed to speed the movement of military

forces to points of deployment or embarkation. This type of infrastructure, however, is often shared with civilian users, as was the case with the Roman roads that crisscrossed the Mediterranean world during the heyday of the Roman Empire, blurring the distinction between war-related construction and that primarily intended for more peaceful activity (Dalgaard *et al*, 2018). However, some mobility-focused infrastructure can be intended purely for military use, especially when the impetus to build it is tactical rather than operational or strategic. Such structures can be small, such as a temporary bridge, or massive, such as the ramp built by the Roman Legions to attack the cliff-top fortress of Masada during the Jewish revolt of AD 70 (Figure 5.3). Moreover, as with the previous types of construction, these disruptions in the landscape can take on layers of cultural meaning unanticipated by their original builders, such as the Roman ramp at Masada now providing a route for tourists to access the fortress, which has itself become intertwined with the national identity of the Israeli state (Olgul, 2013).



Figure 5.3 Present-day photograph of the ramp constructed by Roman legionnaires to attack the Judean defenders in the cliff-top fortress of Masada (Holy Land Photos, 2023)

Regardless of structure type, the direct violence associated with military construction and excavation can persist in the environment for a long time, though the effects of the disruptions also usually remain in the local environment. In general, those structures built in the preparation for war context tend to be of more durable construction since they are constructed in anticipation of some future war rather than under the immediate pressures of an ongoing one. These structures are often attempts to reshape the operational and even strategic geography of an anticipated conflict. Because conditions at these higher levels of war tend to be far more predictable than at the tactical level, political and military decisionmakers can be more willing to devote resources to these types of projects, especially when such construction can produce an economic benefit for non-military users, such as is often the case with transportation infrastructure like airfields or ports (Lackenbauer & Farish, 2007; Clausewitz, 1993, 247). Those structures built in the wartime context, by contrast, are often constructed in a time-constrained environment with the threat of enemy action forcing a “good enough” approach to both materials and quality. The unpredictable nature of tactical military activity means that wartime construction often lacks the type of logic that can yield dual-use military-civilian structures such as those built in anticipation of war. In these cases, either abandonment or memorialization tend to become the likely fate of the disrupted landscape.

3.1.2 Deposition

In the spring of 2023, the Ukrainian military launched a long-awaited counteroffensive against the Russian forces occupying southern Ukraine (Financial Times, 2023, November 20). Though the attacking Ukrainians gained some ground and eventually breached the Surovikin

Line, the overall results of the offensive disappointed many experts who had hoped for more sweeping advances, such as those made by Ukrainian forces the previous fall around Kharkiv and Kherson (Zafra & McClune, 2023, June 26). A major reason for the Ukrainians difficulty lay in the dense minefields sown by the Russians as part of their preparation of the Surovikin line, which restricted mobility and caused casualties to troops and equipment (Africk, 2023, November 8). To overcome this tactic, the Ukrainians requested and eventually received artillery-delivered cluster munitions from the United States (Kerr and Feickert, 2023, October 25). This type of ammunition consists of an artillery shell that dispenses explosive sub-munitions over a broader area than could be damaged by the explosion of a unitary warhead. Cluster munitions are notorious for their high “dud” rates that can leave large numbers on unexploded submunitions scattered across a target area. Both landmines and cluster munitions represent classes of weapons that have been banned by treaty by most of the world’s state governments (though neither Russia, Ukraine, nor the US are signatories to these agreements) (United Nations, 1997 & 2008). Nevertheless, the perceived importance of the outcome of the Russia-Ukraine War has led both sides in the conflict to employ them in increasing quantities.

Both types of weapons, landmines and cluster munitions, represent examples of another form of military disruption of the lithosphere: *deposition*. Deposition denotes the addition of some form of solid foreign material, usually manufactured, into the local lithospheric environment. Deposition can occur due to both offensive and defensive actions by military forces, and its effects can range from benign to forms of danger that can cause death or long-term health effects. Moreover, because acts of deposition usually occur during unpredictable and chaotic tactical actions, the distribution of the resulting disruptions can also be unpredictable,

leading in many cases to the post-war abandonment of landscapes deemed too dangerous for regular human activity. Such abandonment can last for decades in many cases (Witmer, 2008).

Weapons fire is a major contributor to military deposition in the lithosphere and is the most common activity to cause this form of disruption in the preparation for war context. Small arms (pistols, rifles, and machineguns) fire non-explosive metal projectiles, while larger weapons such as grenade and rocket launchers, mortars, and artillery, typically fire various types of explosive shells (Certini *et al*, 2013). Solid projectiles and residue from explosive projectiles (shrapnel and duds) end up in the lithosphere of targeted areas, scattered randomly and often buried under centimeters of soil. In the preparation context, weapons fire usually impacts in designated “impact areas.” In the case of small arms, this can eventually result in serious pollution as in some cases millions of projectiles composed of reactive metal cumulatively weighing thousands of kilograms are deposited into small areas (USDA Forest Service, 2020). Larger-caliber weapons add the dimension of possible dud rounds, in which case primed explosive warheads are deposited into the landscape, prompting military forces to usually restrict human access to impact areas for these sorts of weapons. In both cases, landscapes that receive prolonged use as impact areas can often become “sacrifice zones,” areas where continual degradation is perceived as acceptable because of the extent of past degradation (Lackenbauer & Farish, 2007). By contrast, weapons fire in the wartime context is far more randomly distributed but also less concentrated. Even so, the possible presence of unexploded ordnance is often sufficient justification for military and political authorities to restrict post-war access to areas that have been the site of intense artillery bombardment (Pollard, 2022).

Landmines represent the other major form of military deposition in the lithosphere. Military forces emplace these weapons either on top of the ground or bury them to prevent their

detection. They are defensive weapons designed to restrict the mobility of an attacking enemy. Landmines are designed to explode after being triggered by an enemy soldier or vehicle. However, because of the unpredictability of tactical military operations, relatively few landmines explode in most combat situations (Pollard, 2022). While many modern types of landmines include a self-destruct or disarming mechanism to render the weapon inert after a certain period, older or simpler types do not (Croll, 2009). Thus, once a minefield is emplaced, it often remains in the landscape, especially when the defenders who emplaced it are killed or driven away by an attacking force. Landmines are almost always emplaced in the wartime context, though some examples of emplacement in the preparation context exists, such as in areas of persistent geopolitical tension like the demilitarized zone (DMZ) between North and South Korea (Troxell, 2020). In either case, the presence of unexploded landmines primed to detonate often leads post-war military officials to restrict access to former battlefields, sometimes for many decades. In many if not most cases, the perceived cost of thoroughly clearing heavily mined battlefield landscapes is considered too expensive for remediation (Chiovelli *et al*, 2018).

Another form of deposition that can disrupt military landscapes is the discarding of damaged military equipment. Objects deposited in the lithosphere from this source can range in size from the litter left by soldiers in training and battlefield situations, to the hulks of damaged and destroyed military vehicles left to rust at the site of their destruction (Certini *et al*, 2013). Like weapons fire, the effects of this form of deposition can be more geographically localized but also more concentrated in the preparation context since military forces usually repeatedly use the same local landscapes for training. In the wartime context, such detritus will usually be more broadly distributed but often less concentrated, as battles usually move on to other landscapes after the conclusion of an engagement.

A final type of depositional disruption in the lithosphere is the internment of human and animal remains. The disposal of human and animal remains has always been a part of the wartime experience, as removal of dead bodies from sight bears both psychological and health imperatives (Sledge, 2005). In many cultures and contexts throughout history, the bodies of humans and animals killed in battle were burned, either for ceremonial reasons or expediency (Arrington, 2014). Burial is the other major way in which military forces dispose of bodies and has become the dominant method in the modern era. During wartime, bodies are often interred hastily, sometimes in mass graves when loss of life has been severe. Since at least the nineteenth century, states have also often expended great effort and resources in the postwar context to disinter the bodies of fallen soldiers and reinter them in cemeteries that can be local or distant to the battlefield (Sledge, 2005). Prominent examples of this process include Arlington National Cemetery in Virginia (created to inter US Army dead from fighting in northern Virginia and elsewhere during the American Civil War), the French Ossuary at Verdun, and British and American WWI and WWII cemeteries in France (Capdevila *et al*, 2006). While the physical remains of course decompose, these sites of internment can possess a long-lasting afterlife. In the post-war context burial can assume great ideological, political, and even economic meaning, as they become sites of remembrance, pilgrimage, and even tourism (Winter, 2011).

Each form of depositional degradation can produce lasting effects of slow violence on landscapes. In the cases of unexploded artillery shells and landmines, their presence in an area can influence officials to designate these landscapes as areas of risk, justifying restrictions on access or leading to landscape abandonment. Much of the non-explosive detritus of military activity is composed of reactive metal, meaning that deposition can result in chemical disruptions as well, especially when such materials remain in the ground for extended periods (Broomandi *et*

al., 2020; Williams & Rintoul-Hynes, 2022). Finally, in some cases deposition can result in radiological contamination, as will be discussed further in a subsequent section of this chapter.

3.1.3 Cratering

Another form of mechanical disruption in the lithosphere common to military activities is the cratering caused by the detonation of explosives. The process of cratering can occur either by the physical displacement of material due to an explosion (called “bombturbation” by militarized landscape researchers), or the subsidence of material above areas of underground detonation (Hupy & Koehler, 2012). As high explosives are ubiquitous in modern war, this form of disruption can occur in all three contexts, though it is most common during preparation for war and war proper. Military forces create cratered landscapes in several ways, which include the impact of explosive artillery shells and aerial bombs, the detonation of subterranean mines, the testing of new types of weapons, and the controlled detonation of unexploded ordnance (Hupy & Schaeztl, 2006). These disruptions can range in size from very small, such as those created by the detonation of single artillery shell, to exceedingly large, such as craters created by the detonation of large mines under enemy defensive positions, as exemplified by the British destruction of Messines Ridge during World War I (Doyle et al, 2002). The subterranean detonation of nuclear weapons in testing can create yet larger cratered disruptions (Yoon *et al.*, 2021).

As with deposition, the geography of cratered disruptions is dependent upon the context in which the direct violence of explosive detonation occurs. As noted in the previous section, training areas in which weapons fire is common will tend to produce highly localized but also

highly concentrated areas of disturbance. These types of areas run the risk of becoming sacrifice zones, as is the case of the highly cratered landscape of the Nevada Test Site, where the US military detonated nearly a thousand nuclear weapons in testing over the latter half of the twentieth century (Figure 5.4) (Schlosser, 2013). By contrast, wartime detonations are usually less concentrated and more widely distributed across battlefields, though conflicts in which siege warfare is common, such as the Western Front of the Great War or some areas of eastern Ukraine in the ongoing conflict there, can also produce densely cratered landscapes (Hupy & Schaetzl, 2008; Hupy & Koehler, 2012).



Figure 5.4 Aerial photograph of the Nevada Nuclear Test Range Aera 9 showing the craters formed from past underground nuclear test detonations (Department of Energy, 1972, December 21).

Like other forms of mechanical disruption in the lithosphere, craters can persist in local landscapes for a long time (Note *et al*, 2018). Moreover, by changing a landscape's topography, craters can also change their hydrology, affecting erosion, drainage, and aquifer recharge, creating conditions of slow violence in other spheres (Wilson *et al*, 2000; Hupy & Koehler, 2012).

3.1.4 Compaction

Finally, another way in which military forces commonly disrupt the lithosphere is through the compaction of soil. Surface compaction occurs when heavy vehicle or foot traffic increases the bulk density of the underlying soil (McDonald, 2004; Rijal *et al*, 2018). This form of disruption can occur in any context wherever many troops or military vehicles are moving. In general, the most severe effects of compaction occur away from combat, as the capabilities of modern military technologies necessitate that military units operate in dispersed formation on the battlefield (Parker, 2005). As such, compaction is generally a disruption associated with areas of frequent troop training in the preparation context, and areas of operational maneuver in the wartime context. Even so, even the passage of a single heavy vehicle like a tank can, in certain circumstances, compact soil in ways that can create lasting alterations to the topography of a landscape (Althoff & Thien, 2005; Rijal *et al*, 2018).

The types of slow violence disruptions associated with compaction can include changes to drainage patterns, plant cover, and erosion patterns, effects that spill over into other earth spheres (McDonald, 2004). Loss of water content in compacted soil can lead to increased erosion from wind and overland flow, leading to faster rates of erosion and deposition in nearby landscapes (Perkins *et al*, 2007). Alternately, compaction can channelize erosion patterns leading to permanent changes in topography, such as gully formation (Rijal *et al*, 2018). Even the passage of a single heavy vehicle can cause subsoil compaction that remains measurable decades after the initial act of direct violence. Additionally, plant life can struggle to recolonize compacted soils, leading to changes in land cover (Garten & Ashwood, 2004). However, in most cases the effects of this type of disruption are highly localized along particular routes or in

specific areas, which can allow natural processes to remediate these changes once military activity ceases (Prose, 1985; Halvorson *et al*, 2001).

3.2 Chemical Disruptions in the Lithosphere

As already noted, chemical disruptions encompass effects that change the existing chemical composition of a system or change the rate at which chemical reactions occur. In the lithosphere this class of disruption is often (but not always) a result of unintended processes of slow violence rather than intended direct violence. In general, chemical disruptions in the lithosphere are the result of the mechanical deposition, intended or otherwise, of foreign materials into this sphere. These can be solid, as in the case of the reactive metal and explosive components of ordnance and other detritus of warfare, or liquid, as exemplified by spills of petroleum products that have become increasingly vital to the operations of modern militaries. The use of chemical weapons since World War I has added another source of highly volatile materials to the landscape, the effects of which can persist in the lithosphere for decades (Westing, 1977). As with other disruptions in this earth sphere, the geography of effects is dependent upon context, with effects during the preparation context being predictably localized and concentrated, and wartime effects being more broadly distributed. However, the greatest effects of chemical disruptions in the landscape can be observed in the long-term slow violence that these materials create in landscapes.

3.2.1 Chemical Weapons Residue

Military forces employ two broad categories of chemical weapons: persistent and non-persistent (Shea, 2013). Within these categories, chemical weapons fall into numerous lethal sub-categories differentiated by their effects; blister agents that attack the skin, nerve agents that damage the nervous system, blood agents interfere with life-sustaining processes in the blood, and choking agents than cause asphyxia (chemical defoliants, such as those widely used by the US military in the Vietnam War, will be discussed in this chapter's section on chemical disruptions in the biosphere) (Shea, 2013). Both persistent and non-persistent chemical weapons were used widely by all sides in World War I. Since WWI chemical weapons use against humans has occurred in numerous conflicts, most widely in the Iran-Iraq War, where Saddam Husein's Iraqi army repeatedly used both persistent and non-persistent chemical weapons against Iranian forces from 1983-1988 (Haines & Fox, 2014). Troublingly, since WWI chemical weapons have also often been used in attacks against civilian targets, most recently by the Syrian military against urban areas during the Syrian civil war (Chapman *et al*, 2018).

In the wartime context, non-persistent chemical weapons are tactical offensive weapons designed to incapacitate enemy troops in an area but then break down rapidly so as not to produce negative impacts on friendly troops moving into the area. Persistent chemical weapons, by contrast, are designed to break down slowly. Military forces use this type of weapon defensively to deny an area to enemy forces by saturating the terrain with toxic chemicals. While most chemical compounds in these types of weapons break down over a period of days, some can persist in the environment for weeks or even months depending on climate and weather conditions (Broomandi *et al*, 2020).

Chemical weapons also pose serious dangers in the preparation and post-war contexts. The manufacture and transport of these weapons presents the risk of their accidental release, as occurred on at least two occasions during the Second World War, a conflict in which chemical weapons were not actually used on the battlefield (Bajgar *et al*, 2020). Moreover, the disposal of these weapons in the post-war context poses serious challenges as well, carrying with it the risk of accidental release of toxic compounds (Watson & Griffin, 1992). In some cases, chemical weapons have been dumped in the ocean as a disposal method, as will be discussed in this chapter's section covering chemical disruptions in the hydrosphere.

In terms of slow violence, the effects of chemical weapons on the lithosphere tend to remain temporally brief and spatially local, largely because the compounds that compose the toxic elements of these weapons break down relatively rapidly. While these toxic compounds remain in the lithosphere, they can disrupt other spheres too. For example, nerve and blister agents that can persist for longer periods of time in humid environments can cause harm to both plant and animal life that encounters them (Broomandi, 2020). These effects can be severe, causing rapid death in many cases. Even so, the effects of this contamination, while severe, are usually brief and thus also localized to the area of initial contamination.

3.2.2 *Explosive Residue*

The residue from the detonation of explosive and incendiary compounds forms one of the most common and widespread sources of war-related chemical disruptions in the lithosphere (Certini *et al*, 2013). Indeed, in modern warfare nearly every weapon relies on some sort of explosive either as a propellant for a projectile or as an explosive warhead, and frequently both.

Moreover, the weight of explosives used in warfare increased rapidly over the course of the twentieth century (Westing, 1985). Indeed, the weight of explosives detonated in both the Korean and Vietnam Wars far exceeded the entire expenditures of both World Wars (Westing, 1985). The process driving this increase reflects the dialectical nature of war advocated by Clausewitz; more destructive weapons drive military forces to fight in increasingly dispersed formations, which in turn drives greater profligacy in the use of these weapons to achieve the same effect. The development of “smart” weapons in the latter half of the twentieth century has in some ways reversed this trend, allowing military forces to substitute accuracy for weight of fire, but the ongoing Russo-Ukrainian War gives indications that such advances in weaponry have failed to entirely displace the utility of mass in terms of firepower (The Economist, 2023, July 3).

Residue from many types of commonly used modern high explosives, including TNT, RDX, and HMX (among others), can persist in soils for a long time due to their resistance to volatilization, hydrolysis, and biodegradation (Certini *et al*, 2013). The residue of these compounds can be toxic to plants and animals and can also contaminate groundwater over time (Von Stackleberg *et al*, 2005). Even so, some chemical effects of this type of disruption upon landscapes appear to be benign, if not beneficial in some cases. The common chemical components of many types of explosives like gunpowder and nitroglycerin tend to break down relatively quickly into their component molecules, which include nitrogen and potassium. Similarly, the residue of incendiary munitions like white phosphorus can deposit phosphorus into soil. When not highly concentrated, these elements can act as fertilizers over time in disturbed soils, facilitating plant regrowth (Bohn *et al*, 1970; Rodriguez *et al*, 1972). However, these benign

effects are often overcome by more toxic byproducts of military disruptions of the lithosphere. Regardless, the effects of explosive residue on landscapes tend to remain local, if not brief.

3.2.3 *Metal Residue*

Metal residue deposited into the lithosphere represents one of the longest lasting sources of chemical disruption in this sphere, and one which can affect the hydrosphere as well through infiltration into groundwater (Certini *et al*, 2013). As already noted, metal can be deposited in landscapes in many ways in both preparation and wartime contexts. This metal detritus of war can release a host of heavy metals into the soil, including lead, chromium, antimony, arsenic, cadmium, copper, mercury, nickel, and zinc (Lin *et al*, 1995; Vasarevičius & Greičiūte, 2004; Lewis *et al*, 2010). This form of heavy metal pollution can affect the development of both plant and by extension animal life in the local area. Moreover, depending on climate, weather, and soil conditions, these effects can persist for decades and even centuries after the initial event of direct violence (Souvent & Pirc, 2001; Van Meirvenne *et al*, 2008; Meerscham *et al*, 2011). While long-lasting, the slow violence of weapons-related heavy metal contamination appears to remain localized to the landscapes of initial direct violence. In most cases, training ranges as the sites of repeated weapons firing over time will tend to become more polluted than battlefields, where weapons fire is usually comparatively brief and transitory, though exceptions such as the Western Front of World War I and possibly some areas of the ongoing war in Ukraine present exceptions to this rule (Kantsios *et al*, 2016). Remediation of heavy-metal contaminated soils is possible, but expensive (Certini *et al*, 2013).

3.2.4 Petroleum Product Spills

Another form of chemical disruption of the lithosphere is the spilling, both intentionally and unintentionally, of petroleum products like fuel and lubricants into the soil. Petroleum products in military service have become ubiquitous since the introduction of the internal combustion engine to warfare. Such disruptions are accidental and rare in the preparation and post-war contexts, but can become common during wartime, when belligerents deliberately target each other's fuel supplies for destruction as an indirect means of hampering each other's operational mobility. Leaking petroleum products can also result from the intentional destruction of vehicles and aircraft, or from the intentional destruction of oil wells as a form of economic warfare (Khordagui & Al-Ajmi, 1993). Flammable petroleum products can be used defensively as well, as when Iraqi forces in the Persian Gulf War filled trenches with oil that they could then ignite to form fire barriers to slow advancing enemy troops (Al-Damkhi, 2007). The contamination from such events can persist for decades as the chemical compounds degrade slowly and remain toxic to both plant and animal life (Hussain & Gondal, 2008). Moreover, as most petroleum products are liquid in both their raw and refined forms, they have the potential to spill over and contaminate other spheres and other landscapes over time.

3.3 Radiological Disruptions in the Lithosphere

On March 4, 2022, Russian forces stormed the Zaporizhzhia nuclear power plant near Enerhodar, Ukraine (Associated Press, 2022, August 10). As viewers from around the world watched via the plant's monitoring cameras, large caliber rounds from both attackers and

defenders riddled buildings across the compound of Europe's largest nuclear power facility, starting at least one fire and raising the troubling prospect of a war-induced meltdown (Kurando, 2023). Troubling as this incident was, it was not the first radiological-tinged incident to have occurred during the Ukraine War, nor even the first time military forces had deliberately targeted an active nuclear power plant. In the opening days of the Russian invasion of Ukraine, unprotected Russian forces advancing from Belarus towards Kyiv moved through the containment area of the Chernobyl nuclear disaster area, kicking up dust containing radioactive fallout and tripping sensors on radiological monitors (Reuters, 2022, March 29). More than four decades earlier, the Israeli Air Force conducted a long-range bombing attack against Iraq's Osirak nuclear power plant to prevent the Iraqi government from obtaining weapons grade fissile material (Kirschenbaum, 2010). The actual detonation of nuclear weapons has often been the obvious concern for researchers examining the radiological effects of war, but the above incidents highlight other ways in which war-related disruptions can cause cases of radiological slow violence in the environment.

3.3.1 *Fallout*

The longest-lasting and farthest-reaching war-related disruptions in the lithosphere originate from nuclear and radiological technology and weapons (Certini *et al*, 2013). Indeed, some scholars argue that the detonation of nuclear weapons in the mid-late twentieth century marks the beginning of a new epoch for Earth's global environment: the Anthropocene, (Smith & Zeder, 2013; Waters *et al*, 2014; Lewis & Maslin, 2015). Uncontrolled above-ground nuclear reactions such as the detonation of a nuclear weapon or the melt-down of a nuclear reactor

produce radioactive residue termed “fallout” (Izrael, 2002). Fallout attached to dust particles can be carried far from the point of initial contamination by weather patterns. Indeed, researchers have shown that nowhere on Earth is untouched by the radiological markers of the thousands of nuclear detonations that occurred in the mid-late twentieth century, with fallout reaching as far as Antarctica (Severi *et al*, 2023).

Nuclear weapons have been used in the wartime context only twice, famously at Hiroshima and Nagasaki in Japan in the closing days of the Second World War (Townsend, 2000). Nuclear detonations during the preparation context have been far more common, with thousands of atmospheric, oceanic, and underground tests performed since 1945 (Prävālie, 2014). The distribution of these tests tends to be clustered across a few “sacrifice landscapes” where the degradation of past nuclear tests justified the environmental costs of future tests in the same local area, as exemplified by locations like the Nevada Nuclear Test Site in the US (see Figure 5.2). During the Cold War, all of the nuclear powers developed plans for large-scale nuclear weapons use (Schlosser, 2013). Tactically and operationally, nuclear weapons have been viewed as very large explosives that can be useful for attacking targets that would be difficult or impossible to destroy using only conventional weapons, either because the target is too widely distributed, as in the case of a deployed military ground unit or military base, or because the target is too well fortified, as in the case of a deep bunker (Townsend, 2000). However, nuclear weapons are in most cases viewed as strategic assets, more useful because of their deterrent value against aggression than in their actual use (Schlosser, 2013). Even so, nuclear-armed states continue to develop new types of nuclear weapons and delivery methods to deploy them (Medalia, 2005). Furthermore, some nuclear-armed states including the US officially reserve the right of first use of nuclear weapons (Tannenwald, 2019).

As demonstrated both by nuclear testing and by the non-war-related meltdowns of the Chernobyl and Fukushima nuclear plants, the fallout from an uncontrolled nuclear reaction has the potential to spread globally. The long half-life of the radioactive particles that compose fallout means that their effects can remain measurable in the landscape for tens of millennia, making the temporal effects of this sort of slow violence essentially permanent in human terms (Severi *et al*, 2023). Exposure to fallout, including internally by ingesting food contaminated with radioactive particles, can cause a broad range of health problems to humans and animals, including radiation sickness and various forms of cancer (Simon & Bouville, 2015). In the post-war context, governments often restrict access to areas disrupted by nuclear weapons use, exemplified by access restrictions to the Trinity Site in New Mexico where the first nuclear weapon was detonated, citing both security and health concerns (National Park Service, ND).

3.3.2 *Depleted Uranium*

Another source of war-related radiological disruption in the lithosphere is the use of depleted uranium (DU) in armor and armor-piercing munitions, where its use is advantageous because of its high density (Bleise *et al*, 2002). As an element, DU is not dangerous, emitting less radiation than the natural uranium that is ubiquitous in most soils. However, when DU interacts violently, such as when armor composed of DU is struck by a projectile or a DU projectile strikes an object, it can form dust that is harmful to humans and animals if ingested, as shown by numerous studies of the effects of DU munitions used by US forces in both the Gulf War and the NATO intervention in Kosovo (McDiarmid *et al*, 2013; Durante & Pugliese, 2003). Research has shown that DU contamination in the lithosphere is relatively short lived, with

studies of battlefield landscapes in Iraq indicating no evidence of the element within thirty years of its use in a landscape (Salama et al, 2019). However, other studies speculate that DU can become concentrated in groundwater, leading to toxic levels of both radiological and chemical contamination (Durante & Pugliese, 2003). Regardless, the small amounts of DU dust released in any single engagement seems to indicate that its effects will remain localized to the battlefield landscape.

3.4 Biological Disruptions in the Lithosphere

The combined effects of the above-described disruptions in the lithosphere can have far-reaching impacts on the plants, animals, and humans who interact with this sphere. While direct attacks against the biosphere will be discussed later in this chapter, the direct and slow violence of war and its related activities can change the relationship of organisms to the lithosphere in various ways. Two broad categories of this sort of relational disruption include the physical destruction of ground habitat for organisms, and the abandonment of landscapes by humans due to the real and perceived risks created by war-related violence.

3.4.1 Habitat Disruption

At the end of the Third Punic War, the conquering Roman army is said to have salted the earth around the razed city of Carthage to prevent their long-time enemies from ever again using the soil there. While almost certainly apocryphal, this legend highlights relationships between humans, organisms, and the lithosphere that are relevant to this taxonomy. The separate or

combined use of mechanical, chemical, and radiological mechanisms of violence can result in landscapes denuded of many types of life. Aerial observers of the months-long Battle of Verdun in the Great War frequently commented on the fact that the landscape for miles around appeared brown and gray, as opposed to the green hues of the surrounding country (Hooton, 2010). These observations reflected the incredible mass of explosive and chemical weapons that both sides had poured into this landscape over the course of the battle, a deluge of direct violence that physically removed and killed vegetation and animal life and polluted it with the residue of explosive and chemical weapons.

On a smaller scale, researchers have shown how chemical and radiological contamination in the lithosphere has made local landscapes into hostile environments for organisms that once populated an area, such as earthworms or plants (Di Lella, 2005). In some cases, as when a landscape is denuded of life due to mechanical effects such as explosive blasts and cratering, this sort of disruption can be relatively brief, with nearby organisms rapidly reclaiming the disrupted areas (Certini *et al*, 2013). However, especially in cases of chemical disruptions such as those caused by petroleum spills, local areas can remain hostile to life for long periods (Lawrence *et al*, 2015). Alternately, organisms can find themselves reclaiming degraded habitats that cause disease and early death, especially in the case of landscapes disrupted by radiological effects.

3.4.2 *Landscape Abandonment*

Another form of disruption in the lithosphere caused by war-related violence is the abandonment by humans of landscapes that they once inhabited or used. This can occur for various reasons, including the death or migration of the original inhabitants, perceptions of risk

by individuals and government organizations, and the securitization of landscapes by military and political authorities. Examples of long-term landscape abandonment in modern war are numerous. They include the evacuation by the US military of the indigenous peoples of several of the Aleutian Islands during the Second World War, the restriction of human access to heavily mined areas such as those in the Falklands, and ongoing access restrictions to areas degraded by military training, including sites long abandoned by military forces such as Camp Hale in Colorado (Figure 5.5) (US Forest Service, 2020). Alternately, the violence associated with war can alter the meaning of a landscape, resulting in changes in its use, such as when former farm fields or pasturelands become cemeteries or sites of war monuments, such as occurred on the battlefields of Gettysburg, Waterloo, and Normandy, among many others (Capdevila *et al*, 2006).



Figure 5.5 A militarily disrupted landscape at the Camp Hale and Continental Divide National Monument near Vail Colorado (author's photograph).

Regardless, the ability of a landscape to return to its pre-war use in the post-war context is highly dependent on the interaction of political, economic, and ideological forms of power with the local area. Remediation of war-degraded landscapes is almost always expensive, and cultures have been historically far more willing to expend resources to cause destruction to remote and underdeveloped areas in the preparation and wartime context than they are to fund remediation in such areas in the post-war context (Hanson *et al*, 2008). Thus, disruptions in the lithosphere tend to persist far longer in marginalized, rural, or under-developed areas than they do wealthy or urban ones. By way of example, a visitor to Dresden, or even to Hiroshima, might struggle to perceive evidence of the massive violence that was visited on these urban landscapes in the 1940s if they were not already aware that it had occurred. On the other hand, a visitor to the island of Kiska in the Aleutians, where no battle occurred, can still find the trenches, bunkers, and minefields constructed by the occupying Japanese forces in much the same condition that they were in when they were abandoned in 1944 (Funk *et al*, 2020).

4. Disruptions in the Hydrosphere

The hydrosphere includes all liquid water on the planet, including oceans, lakes, rivers, groundwater, clouds, and precipitation. Military violence often interacts with the hydrosphere, most often in the realms of naval and riverine warfare (Table 5.2). Land combat also frequently interacts with the hydrosphere when water bodies become obstacles to maneuver, such as when armies must conduct river crossing operations or use bodies of water as transportation routes. Military forces use and manipulate the hydrosphere in both offense and defensive ways, often

radically changing the flow of rivers to gain military advantages. Oceans frequently become battlefields between naval forces, with different forms of direct and slow violence across the range of mechanisms causing many disruptions for aquatic life. Because of the fluid nature of the hydrosphere, such disruptions can diffuse over large areas. Even so, as in the lithosphere, the slow violence associated with military activity in the hydrosphere can persist long after the end of a conflict.

Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		

Table 5.2 Common military disruptions in the hydrosphere.

4.1 Mechanical Disruptions in the Hydrosphere

Military forces mechanically disrupt hydrological environments in two major ways: *inundation* and *diversion* (Francis, 2011). Inundation denotes the act of intentionally causing a flood event, often in an established river channel. Diversion involves channeling some or all the water in an established channel into a new one. In general, military forces use inundation during wartime as part of a defensive effort to place or enhance a water obstacle in the path of an advancing enemy to slow or stop their attack. Diversion, by contrast, often occurs in the preparation phase and usually encompasses the digging of canals to enhance the mobility of military forces. Other shorter-duration mechanical disruptions that can occur in the hydrosphere are blast and noise effects from explosives and sonar systems. Finally, the deposition of foreign

material into the hydrosphere, such as shipwrecks or changes to stream transport loads, represents another form of mechanical disruption in the hydrosphere.

4.1.1 Inundation

On June 6, 2023, a series of explosions breached the Kakhovka hydroelectric dam on the Dnipro River, thirty-five kilometers east of the southern Ukrainian city of Kherson (Blann, 2023). The dam's destruction inundated the floodplain of the lower channel of the Dnipro River as the upstream Kakhovka Reservoir poured through the breach. While neither the Ukrainians nor Russians claimed responsibility for the dam's destruction, the structure itself was under the control of Russian forces, and the fact that the Ukrainian military was at the time preparing to launch a major counteroffensive in southern Ukraine lends credence to the analysis of numerous commentators and journalists that the Russians intentionally breached the Kakhovka dam in an effort to prevent Ukrainian forces from crossing the Dnipro River (Beehner *et al*, 2023). While a dramatic event, the destruction of the Kakhovka dam represents only the latest example of inundation as a defensive tactic in war. Indeed, this incident was not even the first time the tactic has appeared in the Ukraine War. During the initial Russian invasion in February 2021, Ukrainian military and civilian forces intentionally inundated stream channels both east and west of the Dnipro River's Kyiv Reservoir north of the Ukrainian capital to slow the advance of Russian forces attacking southward from Belarus (Thebault & Moriarty, 2021).

Similar examples of such "hydraulic warfare" are common in military history. In the classical era, the Roman historian Tacitus records that Batavian rebels in what today is the Netherlands breached dikes to inundate the low-lying areas around their camps to slow the

attacks of Roman legionnaires (Tacitus, 2004). Indeed, since 1500 AD Dutch forces have used inundation as a common tactic to stop military invasions. Other prominent examples of inundation as a defensive tactic include the Chinese Nationalists' destruction of dikes to flood the Yellow River valley in 1938 to slow the advance of Japanese forces, and Soviet forces' destruction of the Zaporizhya dam on the Dnipro River in 1941 to slow the advance of German forces across southern Ukraine (Dutch, 2009; Wu, 2020; Moroz & Bigg, 2013).

Inundation has appeared as an offensive tactic during wartime as well. In this context, the usual objective of the tactic is the destruction or denial of an operationally or strategically valuable resource to the defender. One famous example of this tactic is the Royal Air Force's audacious "Dambuster raid" (Operation Chastise) during the Second World War, which used custom-designed bombs that bounced across the surface of the water to attack four dams in the Ruhr Valley. The objective of this attack was to flood important industrial areas, thus denying their output to the Germans (Cockell, 2002). Another prominent example was revealed by Lacoste (1972), whose influential study demonstrated through mapping and pattern analysis that the US Air Force had been waging a systematic bombing campaign to breach dikes around the Red River basin in North Vietnam. Had these attacks been successful, the resulting inundation could have submerged large areas of farmland and killed or displaced millions of North Vietnamese civilians.

4.1.2 Diversion

In April 2021, as many as fifteen ships of the Russian navy's Caspian Sea Flotilla began transiting from their home waters to those of the Black Sea via a route that included the Volga-

Don Canal (Goble, 2021). In the preceding weeks, the government of Turkey had activated a clause in the Montreux Convention that closed the Turkish Straits to transit by Russian warships. Thus, the Russian Federation's inland waterways represented the only way for the Russian navy to reinforce its Black Sea Fleet, the main naval force involved in the Ukraine War. While the Russian ability to transfer naval forces from a landlocked sea may seem surprising, the use of canals for military purposes to increase the mobility of attacking forces has roots that stretch back to ancient times.

The diversion of waterways represents the second major way that war-related activities cause mechanical disruption of the hydrosphere. The most common method of diversion is the digging of canals to create artificial waterways, diverting an existing stream onto a new course. Most canals are not built primarily for military purposes, but rather as highways for commerce and economic activity. However, the military importance of canals has often been an explicit part of their justification, as they allow military forces to circumvent major natural maritime chokepoints (Mahan, 1914). As such, canal-building usually constitutes a preparation activity at the strategic or at least operational level of war. One example is the already-mentioned Don-Volga Canal. Other examples include the Suez, Kiel, and Panama Canals, all of which were built at least partially to improve the strategic and operational mobility of British, German, and US military forces, respectively (Gollasch *et al*, 2006).

Canal-building to divert waterways occurs during wartime to gain tactical mobility as well. In an example from antiquity, the Greek historian Herodotus records that during their siege of Babylon the Persian forces under Cyrus dug a series of canals to divert water from the Euphrates River, lowering the river's level and allowing the Persian army to enter the city under the water gates via the riverbed (Herodotus, 1998). In a more modern example from the

American Civil War, US Army forces under U.S. Grant attempted to dig a canal across the neck of a meander in the Mississippi River to allow gunboats and transports to bypass the defenses of the Confederate-held city of Vicksburg (Harrelson *et al*, 2016). Defensive examples of water diversion as a tactic include the construction of water-filled moats around medieval castles and early modern fortresses (Rees, 1997). Canals can provide corridors for invasive species to transfer between water bodies (Gollasch *et al*, 2006). However, without active maintenance they will normally silt up relatively quickly, often within months or years, with water flows returning then to natural stream channels.

Like inundation, military forces can also use diversion as an offensive tactic to deny an enemy access to a strategic resource. The Ottoman Empire employed this technique in a counterinsurgency campaign against the Marsh Arabs of southern Iraq, draining water away from the Arabs' lands to deprive them of agricultural resources and force them to submit to Ottoman political authority (Husain, 2014). More recently, India's Prime Minister Modi has threatened that, in a military confrontation with Pakistan, India might use their control of the headwaters of the Indus River in Kashmir to divert its flow as a means to pressure the Pakistani government into concessions (Slater, 2019).

4.1.3 Noise and Blast Energy

Another source of disruption in the hydrosphere is via mechanical waves, which propagate more powerfully through water than through atmosphere. Anthropogenic noise can interfere with marine animals' communication and navigation, while explosive force can damage organs (Popper and Hawkins, 2019). These sorts of disruptions usually occur during the

preparation context as naval forces train and test weapons, and during the wartime context as naval forces seek to locate and destroy each other. The immediate effects of the direct violence of these disruptions, though severe, tend to be localized and brief, though secondary effects of slow violence can be far reaching both spatially and temporally.

Since the First World War, sonar, a sensor that uses sound waves to detect underwater objects, has become the primary means by which military forces search for and track submarines. While passive sonar systems consist only of a hydrophone that listens for the noise emitted by a ship or other object, active sonar systems emit sound waves across a broad range of frequencies and then measure the echo return of these waves to precisely locate underwater targets. Studies have shown that naval sonar use is closely linked to mass stranding events among several species of whale (Parsons *et al*, 2008). Similarly, mechanical energy emanating from the detonation of explosive weapons can kill and injure aquatic life over a large area (Keevin, 1995). Other common sources of anthropogenic noise in the hydrosphere include ships' propulsion systems, though studies have shown that ship traffic often declines in areas of active warfare, reducing noise levels overall (Holm, 2012). Regardless, the primary effects of these disruptions of the hydrosphere's environment persist in the form of changes to the marine biosphere.

4.1.4 Deposition

In the summer of 2023, after the collapse of the "Grain Deal" by which Russia and Ukraine had agreed to non-interference in the export of food products from Ukrainian ports, Russian forces began laying sea mines in unspecified areas of the Black Sea, purportedly to deter commercial ships from calling on Ukrainian ports (LaGrone & Mongilio, 2023). While

escalatory in the context of the geopolitics surrounding the Ukraine War, the employment of sea mines as a wartime tactic is common in modern warfare. Moreover, this tactic represents just one of several sources of mechanical disruption in the hydrosphere that can fall under the definition of deposition. Like deposition in the lithosphere, deposition in the hydrosphere denotes disruptions in which a foreign material is moved from a location and deposited into a new site, in this case a marine one. Besides sea mines, other sources of war-associated deposition in the hydrosphere include shipwrecks and the dumping of derelict equipment and refuse.

Since at least the First World War, when belligerents began deploying extensive minefields to limit their enemy's maritime mobility, sea mines have come to represent a major source of foreign material that military forces deposit into the hydrosphere during wartime. Sea mines typically consist of an explosive charge coupled with a triggering mechanism designed to detonate the weapon in the proximity of a ship. The simplest forms of this sort of weapon are usually tethered via an anchor to the sea floor, but more modern types are designed to lay entirely on the seafloor and propel themselves upwards towards their target like a torpedo once its sensors detect a ship (Fanta, 1995). Modern versions of sea mines also typically feature a self-destruct mechanism designed to disarm the mine after a certain period, a feature not present in older designs. In Europe, both Britain and Germany employed extensive minefields in both the North and Baltic Seas in both the First and Second World Wars, while American and Japanese forces heavily mined the waters around the Japanese Home Islands and Indochina during the Pacific War (Fanta, 1995). During the Vietnam War, US forces used air-deployed sea mines in an attempt to close the North Vietnamese port of Haiphong (Fanta, 1995). In the 1980s, the Islamic Republic of Iran deployed sea mines in the Persian Gulf to limit their adversaries' naval mobility, as did Saddam Hussein's Iraq during the Gulf War of 1990-1991 (Fanta, 1995). Once

deployed, sea mines can remain in the environment for decades, making travel hazardous, particularly when the mines drift with ocean currents after their tethers break (The Maritime Executive, 2023, January 24). Moreover, disarming them often involves the controlled detonation of the mines' explosives charges, causing blast and noise effects in the immediate area.

Shipwrecks represent another source of depositional disruption in the hydrosphere. During wartime, naval and commercial ships become targets as belligerents use firepower to try to limit each other's operational and strategic mobility. While naval shipwrecks can become sources of chemical and radiological pollution (as will be discussed in following sections), their primary effect on the marine environment is surprisingly beneficial. Numerous studies have shown that shipwrecks can act as artificial reefs that provide habitat for diverse aquatic life (Consoli *et al*, 2015). Indeed, modern navies in recent years have often intentionally sunk decommissioned warships to create such habitats in a sanitized postwar analog to the wartime sinking of ships (Hynes *et al*, 2004). Due to the inaccessibility of the seafloor to human exploration, shipwrecks can remain intact underwater for centuries or even millennia.

Finally, the exigencies of wartime operations often lead military forces to dispose of derelict equipment and refuse by simply dumping these items into the ocean. The objects deposited in such acts can range from whole aircraft and shipping containers that sink to the ocean floor to bags of garbage that join other sources of trash floating in the currents of the world's oceans (Charrière, 2023). The length of time such objects remain intact in the hydrosphere will obviously vary with the type of material.

4.1.5 *Slow Violence and Mechanical Disruptions in the Hydrosphere*

Because of this environment's fluid nature, mechanical disruptions in the hydrosphere can tend to be short-lived but far reaching. Moreover, the intentional disruption of the hydrosphere for military purposes is common and possesses deep historical roots. As an example, inundation possesses a history stretching back to antiquity. Indeed, this method appears to be one of the most common ways that military forces use direct violence to disrupt the existing landscape. De Kraker (2014) has shown that up to a third of all flooding events in the Netherlands since 1500 AD have occurred as a direct result of warfare. While smaller flood events, such as that caused by Ukrainian forces north of Kyiv in February 2022, can remain localized, disrupting only the immediate landscape, larger events can produce devastating results on a regional scale, transforming landscapes distant from the immediate point of violence both downstream and upstream from the event. These disruptions can then spill over into the biosphere, either by drowning plants and animals downstream from the immediate disruption or stranding aquatic life in rapidly emptying reservoirs. Inundation disruptions can also interact with the lithosphere by altering patterns of erosion, transport, and sediment deposition. However, given the economic importance of the dams, levies, and reservoirs that make inundation possible, postwar reconstruction will usually tend towards returning environments effected by inundation to their pre-war conditions, meaning that the slow violence of inundation is usually mitigated rather quickly.

The slow violence associated with diversion, by contrast, often relies upon non-human forces to erase the evidence of wartime disruptions. Siltation tends to fill anthropogenic canals and moats with sediment in a brief time without active efforts by humans to dredge these

channels and keep them open. However, the long-term disruption to the marine biosphere caused by the invasive species transiting these artificial channels while they are open can be far-reaching and long enduring (Gollasch et al, 2006). Extensive acts of diversion can also, in some cases, permanently change the course of natural streambeds, even when these disruptions are not maintained in the post-war context (US Forest Service, 2020).

The immediate effects of noise and blast disruptions are the briefest of all mechanical hydrological disruptions, lasting only as long as the associated mechanical waves propagate. However, because these disruptions occur continuously thorough the preparations, war, and post-war contexts, their cumulative impact on the marine biosphere can be devastating, especially in their effects on large marine animals such as whales, which are especially sensitive to the long-range noise disruptions associated with the operation of naval sonar systems. As a contributing factor to non-military activities such as industrial fishing, such disruptions have the potential for serious long-term depletion of vulnerable marine populations.

Finally, the effects of deposition on the hydrosphere can be especially long lasting, but in many cases can exert a beneficial effect on the marine biosphere. The presence of naval sea mines both during war and in the post-war context can reduce stresses associated with overfishing by preventing the safe operation of commercial vessels in conflict and post-conflict areas (Holm, 2012). At the same time, shipwrecks sunk in naval combat or in the post-war disposal of derelict hulls, can provide long-term habitats in the form of artificial reefs that increase the health of marine ecosystems. However, the potential for chemical and radiological contamination from shipwrecks, especially those not intestinally sunk as reefs, will be explored more fully in the following sections.

4.2 Chemical Disruptions in the Hydrosphere

On the night of April 13, 2022, two Ukrainian anti-ship missiles struck the Russian *Slava*-class cruiser *Moskva*, flagship of the Russian Navy's Black Sea Fleet, causing extensive damage (Lubold, 2022). Other Russian ships attempted to tow the stricken *Moskva* to port, but after several hours the Cold War-era warship rolled over and sank in fifty meters of water. Shipwrecks such as the *Moskva* represent a major source of deposition of foreign material into the hydrosphere by military forces, with the broken hulls of sunken vessels from conflicts throughout history littering the seafloor. However, especially since the adoption of hydrocarbon-powered propulsion for vessels, shipwrecks have become an important source of chemical pollution in the hydrosphere. Moreover, the proliferation of high explosive weapons and later missile and rocket propellants in warships during the twentieth century represents another source of chemical pollution from shipwrecks. Modern ships use various kinds of reactive metals in their construction, maintenance, and operation, making them a potential source of heavy metal contamination in the hydrosphere, as opposed to earlier types of vessels that were built largely of wood and other organic materials. Finally, direct violence that occurs on land can have secondary effects in the lithosphere, as when chemical pollutants from terrestrial infrastructure and from combat infiltrate ground and surface water (Francis, 2011). Indeed, freshwater ecosystems like lakes and rivers are especially susceptible to the accumulation of war-related pollutants because of their networked and interconnected nature (Francis, 2011). The effects of these disruptions can diffuse over a large area depending on hydrology or ocean currents, affecting organisms like fish and seabirds distant from original site of violence

4.2.1 Hydrocarbon Spills

On the night of 4-5 August 2023, a Ukrainian sea drone packed with explosives attacked the Russian oil tanker *Sig*, which was anchored in the Kerch Strait off the southeast coast of Crimea (Harmash, 2023, August 5). The resulting explosion ripped a hole in the engine room of the large vessel and forced the crew to fight flooding to keep the tanker afloat. The *Sig* up to that point had played a key role in transporting various kinds of fuel from terminals in Russia to supply Russian forces operating in Syria. The Ukrainian attack highlights how wartime contexts can cause the belligerents to intentionally take actions (such as breaching the hull integrity of an at-sea oil tanker) that in peacetime nearly everyone would exert great effort to prevent. In the hydrosphere, episodes like this can result in severe and long-term pollution of marine environments.

Modern shipwrecks represent one major source of chemical contamination in the hydrosphere (Ndungu et al, 2017). Most modern vessels rely upon some form of hydrocarbon-fueled internal combustion engine, which requires them to carry fuel in bunkers as well. In the case of warships, these fuel bunkers have in some designs also acted as a layer of armor, meaning that they can be the first part of a ship compromised by anti-ship weapons. Thus, both sunken and damaged ships in wartime have often spilled large amounts of fuel into the water. In some cases, shipwrecks can continue to leak fuel into the surrounding water for decades, as in the case of the USS *Arizona*, which was destroyed by Japanese aerial bombs at its berth in Pearl Harbor, Hawaii, on December 7, 1941, and continues to leak fuel oil in iridescent plumes that fascinate tourists who come to the ship's memorial to this day (Zabawski, 2017). Since the widespread adoption of internal combustion engines in seafaring in the early twentieth century,

thousands of vessels (including hundreds of oil tankers) have been sunk in wartime in nearly every corner of the globe (Monfils, 2005). Because of the often-chaotic nature of damage in these contexts, some ships sink with intact fuel bunkers that can maintain their integrity for decades or even centuries until corrosion allows the fuel to escape, while others suffer catastrophic damage that immediately releases large amounts of fuel into the sea (Carter et al, 2021). In other cases, as with the USS *Arizona*, small leaks can result in low-level but long-term pollution.

Most war-related sinkings occur in the wartime context, when belligerents intentionally seek to destroy each other's naval assets or water-borne commerce. However, the already-discussed issue of abandoned sea mines can also result in post-war sinkings (Turner, 2005; Rapakko, 2020). The resulting fuel leaks can be toxic to marine life, and moreover can spread over large areas of seascape with ocean currents, damaging ecosystems distant from the original site of sinking (Ndungu, 2017). Finally, remediation of these shipwrecks, such as salvaging the fuel from intact bunkers, can be difficult and expensive, especially when vessels sink in deep water.

Another source of hydrocarbon pollution in the hydrosphere is accidental leakage from fuel storage infrastructure on land. Such leaks can contaminate groundwater, as in the case of the US Navy's Red Hill facility on the island of Oahu, where thousands of gallons of leaking fuel polluted the water supply of nearly a hundred thousand residents of the island in 2023 (McAvoy, 2023, October 13). Leaks can also contaminate marine environments, as is exemplified by numerous naval facilities hastily constructed in Alaska during the Second World War that continue to be sources of pollution in the surrounding seas decades after the end of the conflict (Anthony et al, 2007; Burger et al, 2007, 2009). Such leaks can occur in any context, but

infrastructure constructed to fulfil urgent wartime demands appear to pose special risks due to hasty construction and greater risks of post-war abandonment.

4.2.2 *High Explosives and Propellants*

Both the detonation and dumping of explosives and propellants can create another form of chemical disruption in marine environments (Francis, 2011). Most modern naval weapons contain some form of explosive element, either in their warhead, as a propellant, or both. Like on land, the detonation of these weapons can leave trace amounts of explosive compounds in the surrounding water and the underlying sediment (Ampleman *et al*, 2004). Moreover, the deposition of these sorts of weapons into marine environments without detonating, either via shipwrecks and aircraft crashes during wartime or intentional dumping in the post-war context, them can expose the volatile explosives to slower breakdown, resulting in long-term leaching of component compounds into the surrounding environment (Van Landuyt *et al*, 2022; Maser *et al*, 2023). To date, millions of tons of various kinds of explosives have been deposited in marine environments, with resultant detrimental health effects observed in various kinds of marine life directly tied to this residue (Maser & Strehse, 2020). In the case of detonations, the chemical residue of the explosives breaks down relatively quickly. However, unexploded ordnance can continue to contaminate surrounding water for decades and even centuries (Francis, 2011).

4.2.3 *Heavy Metals*

Similarly, shipwrecks, onshore infrastructure, and intentional dumping can be sources of heavy metal contamination in marine environments (Francis, 2011). Numerous heavy metals, including mercury, arsenic, cadmium, chromium, and lead from modern shipwrecks, weapons, and explosives, and infrastructure, can persist in marine environments long after military activity has moved on from a location (Anthony et al, 2007; Burger et al, 2007). As in terrestrial cases, such pollution can affect the health of marine and bird life and has the potential as well to contaminate the food chains of even distant ecosystems (Burger et al, 2009).

4.3 Radiological Disruptions in the Hydrosphere

Radiological disruptions in the hydrosphere originate from several sources, including fallout from nuclear weapons testing, meltdowns in the nuclear power plants of military ships, and the accidental deposition on the seafloor of radiological materials such as nuclear warheads and the power plants of nuclear-powered shipwrecks. As with terrestrial radiological disruptions, those that occur in the hydrosphere can produce far-reaching and exceedingly long-lasting conditions of slow violence in the form of health impacts on marine life and food chains. To date, all incidents of direct radiological violence in the hydrosphere have occurred in the preparation for war context due either to weapons testing or accidents related to naval and aerial training (Schlosser, 2013). However, particularly during the Cold War, all of the nuclear-armed powers made plans for the widespread offensive use of nuclear weapons in ocean environments as anti-ship and anti-submarine weapons (Schlosser, 2013). Troublingly, after a hiatus in the aftermath of the Cold War, the hydrosphere has once again become a potential arena for nuclear combat with the Russian Federation's development of new classes of nuclear-armed naval weapons (Kauer, 2023, June 13).

4.3.1 *Fallout*

In the aftermath of the Second World War and during the second half of the twentieth century, the US, Britain, and France all conducted nuclear weapons testing in the South Pacific Ocean, collectively detonating hundreds of nuclear weapons, some with explosive yields in the multi-megaton range, with the last such test occurring in 1996 (Norris, 1996). Many of these detonations, such as the visually famous Operations Crossroads test, occurred underwater, while others such as the massive Castle Bravo thermonuclear detonation, occurred on uninhabited or artificial islands. These tests spread fallout globally and deposited radioactive material on the seafloor in the vicinity of these tests, resulting in long-term detrimental health effects for both the marine life in the vicinity of the tests and the human populations that rely on the surrounding waters as a food source (Cronkite et al, 1997).

Another source of maritime fallout can come from the meltdown of nuclear power plants aboard warships. The US and French navies both operate nuclear-powered aircraft carriers, while the navies of the US, France, the UK, Russia, and China all operate numerous classes of nuclear-powered submarines, with the Australian and Indian navies both planning to construct nuclear-powered submarines in the coming years (World Nuclear Association, 2023, October). Nuclear propulsion is attractive for naval architects because it allows ships to remain at sea for long periods without needing to refuel, increasing naval operational reach and simplifying logistics in many ways.

Russian submarines suffered several nuclear accidents in the latter half of the twentieth century, at least one of which, an explosion aboard the submarine *K-431* near Vladivostok, resulted in the meltdown of the reactor (Sarkison & Vysotskii, 2018). This incident spread fallout

across both the Sea of Japan/East Sea and into the Siberian interior, highlighting the far-ranging danger posed by such accidents. The potential of a large-scale war between modern well-equipped navies, such as a theoretical conflict between China and the US or between NATO and Russia, also raises the troubling prospect of the intentional destruction of nuclear-powered vessels, with attendant heightened risks of wartime meltdowns and radiological contamination.

4.3.2 *Lost Nuclear Weapons and Reactors*

Even when nuclear weapons do not detonate or when reactors do not melt down, military activity can still deposit radioactive material into the hydrosphere. Two major sources of radioactive deposition in the hydrosphere are the accidental loss and sinking of nuclear-powered vessels and nuclear weapons (Solomon, 1988). At least nine nuclear-powered submarines have sunk with their reactors on board since the development of nuclear-powered propulsion, with at least four of these reactors remaining unrecovered (Solomon, 1988). An unknown number of nuclear weapons have also been lost in several incidents and remain in the ocean, including the crash of nuclear-armed American B-52 bomber off the coast of Spain (one nuclear warhead), the accidental sinking of the Soviet submarine *K-129* in the Pacific Ocean in 1968 (at least two warheads), the loss of the USS *Scorpion* in the Atlantic Ocean in 1968 (two warheads) and the accidental sinking of the Soviet missile submarine *K-219* in 18,000 feet (about 5.49 km) of water in the Atlantic Ocean (up to 48 warheads) (Schlosser, 2013). Beyond the obvious security and safety concerns of unaccounted-for thermonuclear weapons lost on the ocean floor, the uranium in the weapons warheads is water-soluble, meaning these objects represent possible point sources of radiological contamination near the loss sites (Solomon, 1988). Moreover, security concerns

from the losing governments and the hostile environment of the deep ocean make recovery and remediation of these objects a fraught and difficult task (Gorvett, 2022, December 23).

4.4 Biological Disruptions in the Hydrosphere

The above-described mechanical, chemical, and radiological disruptions in the hydrosphere can combine to cause long-term damage to marine ecosystems and habitats, degrading the quality of marine life, poisoning food chains, and in some cases making entire swaths of the hydrosphere uninhabitable for some organisms (Lawrence et al, 2015). Counterintuitively, however, the wartime and postwar contexts can also become a boon for the health of marine ecosystems when perceptions of risk and danger interfere with peacetime fishing activities. Numerous studies have shown that in both the First and Second World Wars marine life in the North Atlantic was both far more numerous and individual animals had grown significantly larger than was the case in pre-war populations (Holm, 2012). This was due to reduced fishing because of ongoing combat in these waters during the periods 1914-1918 and 1939-1945, as well as the impressment by belligerent governments of commercial fishing trawlers for use as military minesweepers. Thus, the abandonment of fisheries by humans during wartime represents a case in which the presence of wartime violence can represent at least a temporary reprieve from human-induced pressure for some types of marine life.

5. Disruptions in the Atmosphere

The atmosphere encompasses all the layers of gases that surround the earth. Active warfare has extended into the atmosphere only relatively recently with the development of lighter-than-air craft in the eighteenth and nineteenth centuries and powered flight in the twentieth and twenty-first centuries (Townsend, 2000). Even so, the introduction of airpower into the mixture of technologies that together create modern warfare has been transformative to the conduct of war, expanding the reach, speed, and destructiveness of military forces in ways that would have been largely unimaginable in earlier periods of history (Table 5.3) (Knox & Murray, 2001). Indeed, some scholars speculate that the increasingly ubiquitous use of unmanned aerial vehicles in warfare represents yet another revolution in military affairs because of the ability of these craft to remain airborne for longer periods than would be possible with human-piloted aircraft (Farish, 2015). In terms of firepower, aircraft allow military forces to observe and attack the enemy in far greater depth than is possible with ground-based technology. In terms of maneuver, aircraft facilitate the rapid tactical and operational movement of military ground forces.

Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use Burning of toxic materials Atmospheric carbon balance	Fallout	Habitat disruption

Table 5.3 Common military disruptions in the atmosphere.

Despite the profound impact of airpower on modern warfare, measurable disruptions by military actions in the atmosphere far predate human flight. Some researchers have advanced humanity’s ability to manipulate fire as a possible marker of the start of the Anthropocene epoch because of the addition by combustion of carbon into the atmosphere, and fire has been an

endemic component of war even in pre-modern warfare (Dalby, 2018). Alternately, the widespread death and collapse of human populations caused by some conflicts can measurably alter the global balance of atmospheric carbon (Dull et al, 2010).

Even so, incidents of direct violence of war in the atmosphere, though increasingly frequent, are necessarily brief due to the constraints of gravity and human and mechanical endurance. Similarly, the effects of slow violence are, for the most part, relatively brief when compared to similar disruptions in other spheres. Despite this, these disruptions can be startlingly far-reaching due to the fluidity of weather and climate systems, giving certain disruptions in the atmosphere the potential for global impacts.

5.1 Mechanical Disruptions in the Atmosphere

Unlike mechanical disruptions in other spheres, these types of effects in the atmosphere are the briefest and most transitory, consisting almost entirely of the effects of noise and blast energy propagated through the medium of atmospheric gases. Many types of military activities and technology produce this sort of disruption, including the detonation of propellants and explosives, as well as the operation of vehicle and aircraft engines. This sort of disruption, though brief, can cause distress to wildlife in areas where disruptions are frequent, sometimes affecting reproductive habits, hunting and grazing patterns, and migration routes (Lackenbauer & Farish, 2007). In some cases, this sort of disruption can be surprisingly far-reaching. For example, the detonation of the 50 megaton “Tsar Bomba” thermonuclear device in the Arctic by the Soviet Union in 1961 caused mechanical blast and sound waves to circle the globe multiple times, flattening trees and causing other forms of damage hundreds of kilometers away from the

blast site and measurably affected atmospheric pressure as far away as New Zealand, mimicking in some ways the power of major volcanic eruptions (Wiley, 2021).

Even so, mechanical disruptions in the atmosphere are necessarily brief, continuing only until the energy of the mechanical wave dissipates. Also, they usually remain very localized, affecting landscapes that are proximate to the site of military activity. Thus, the severity of the slow violence associated with mechanical disruptions in the atmosphere is perhaps more heavily dependent on the frequency and duration of incidents of direct violence. As such, landscapes that host preparation for war activities, such as military training facilities, will more frequently show the slow violence effects of atmospheric mechanical disruptions than will sites of more transitory violence, such as battlefields in the wartime context.

5.2 Chemical Disruptions in the Atmosphere

Several types of war-related activity, both intentional and unintentional, can alter the chemical balance of the atmosphere. Most of these disruptions are relatively brief, while some can persist for decades or even centuries. Furthermore, weather and climate patterns can carry local disruptions to other landscapes, causing regional and even global scales of disruption. Gaseous chemical weapons represent perhaps the most immediately toxic form of atmospheric chemical disruption, though also the most localized. The use of explosive and incendiaries munitions in both training and combat often results in uncontrolled burning of landscapes and equipment, which can also frequently release toxic chemicals into the atmosphere. Finally, the operation of military equipment and the broader disruptions to human activity caused by war can cause significant changes to the balance of carbon in the atmosphere.

5.2.1 *Chemical Weapons*

Military forces since the First World War have deployed chemical weapons almost exclusively in gaseous form. This method of deployment allows a single chemical weapon to disperse its contaminants over a broad area. It also deposits these contaminants into the atmosphere, at least temporarily, where they can be dispersed by wind and weather (Baigur *et al*, 2020). However, most gaseous chemical weapons agents are heavier than the natural atmosphere, meaning that they will relatively rapidly settle into low areas. These gases can persist in these low areas for hours or even days, but will then settle onto the ground, causing contamination in the lithosphere. In the meantime, the gaseous elements of chemical weapons are toxic and often deadly to human, plant, and animal life with which they come into contact. The potential for this form of disruption is highest in the wartime context, but also exists in the preparation and postwar contexts in the form of accidental releases of chemical weapons during their manufacture, transport, training, and disposal (Matoušek, 2006).

5.2.2 *Toxic Burning*

A more common source of chemical contamination of the atmosphere related to warfare is the burning of toxic materials. Fire is ubiquitous in war, and many types of war-related material are toxic when burned. Large battles can result in hundreds of pieces of burning military equipment and infrastructure, including vehicles, aircraft, ships, and ammunition and fuel dumps. Moreover, military forces often attack non-military infrastructure and materials during wartime,

causing further incidents of toxic burning. A famous example of this is the destruction by Iraqi forces of Kuwaiti oil wells during the 1991 Persian Gulf War, resulting in widespread fires that spread toxic petroleum-based chemicals across the region (Khordagui & Al-Ajmi, 1993). Toxic burning can occur in more mundane settings as well, such as the intentional disposal of waste or sewage. The US government has recently acknowledged the contamination of hundreds of thousands of its service members who were affected by airborne pollutants originating from “burn pits,” a catchall term covering the intentional burning of trash and sewage mixed with diesel fuel or kerosene, which occurred in numerous conflicts from at least Vietnam through the Afghanistan War (McLean et al, 2021).

Toxic burning is most common in the wartime context. During war, belligerents make concerted efforts to burn one another’s equipment and infrastructure, and the austerity of many wartime environments and wartime exigencies make the burning of waste and sewage an attractive form of disposal. In other contexts, military forces usually exert normal peacetime efforts to prevent this sort of violence. Geographically, because of unpredictable atmospheric conditions, particulates released into the air from toxic burning can spread to landscapes distant from the original site of violence, creating regional impacts.

5.1.3 Fallout

Similarly, nuclear fallout caused by uncontrolled nuclear reactions can contaminate the atmosphere, if only relatively briefly. Atmospheric and ground detonations of nuclear weapons often throw large amounts of material into the atmosphere which, when a radioactive particle

attaches to it, becomes fallout (Schlosser, 2011). This material can then be carried very long distances by atmospheric weather patterns before settling back to the lithosphere or hydrosphere.

5.1.4 Atmospheric Carbon

Finally, slow violence associated with military activities can alter the balance of carbon in the atmosphere by both increasing and decreasing the amount of carbon locally and in some cases globally. The powerful engines of modern military vehicles, aircraft, and naval ships are notoriously fuel-hungry, with correspondingly large greenhouse gas emissions during operation (Belcher *et al*, 2020). Thus, the operation of military equipment can represent an important source of atmospheric carbon. Even so, the scale of military fossil fuel use, while important, still pales in almost every respect to non-military sources of greenhouse gas emissions. Indeed, studies have shown that at least initially, wars often reduce fossil fuel burning in conflict areas because of the departure of civilians from areas of combat and resulting economic conditions that depress normal peacetime civilian activities (Wang *et al*, 2023).

In perhaps the most extreme example of military actions disrupting the atmosphere, Dull *et al* (2010) present evidence that that massive death toll due to violence and disease associated with the European conquest of the Americas in the sixteenth century may have altered the global atmospheric carbon balance enough to have measurably amplified the global cooling trend known as the Little Ice Age. Their argument is that the rapid death of as many as 100 million indigenous peoples of the Americas would have produced a correspondingly large reduction in anthropogenic burning, leading to a lower overall release of carbon into the atmosphere. This

provides an extreme example of how the post-war effects of slow violence can continue to disrupt and alter the global environment long after direct military violence has ceased.

5.2 Biological Disruptions in the Atmosphere

Because most atmospheric disruptions are relatively brief, biological disruptions in this sphere are also correspondingly so. Moreover, the mobility of flight-capable animals means that even when a severe disruption has occurred, avian and insect life can rapidly recolonize affected areas. Even so, sites of repeated military-related violence, such as airfields or firing ranges, can over time cause animal life to habitually avoid certain areas, as has been observed around some Canadian military infrastructure in the arctic and subarctic (Lackenbauer & Farish, 2007). Similarly, military-caused wildfires can disrupt the biological and terrestrial habitats of flying animals, whether killing them or causing them to temporarily abandon sections of the sky (Anthes, 2022, April 13). Thus, disruptions of the atmospheric portions of animal habitats exert an important, if usually brief, effect on life in this sphere.

6. Disruptions in the Biosphere

The biosphere encompasses all organic life on earth, including human, animal, and plant forms of life. The previous sections of this chapter have focused on how war-related violence alters the other earth spheres within which organisms in the biosphere live. This section will focus on direct and slow violence against organisms themselves (Table 5.4). The infamous Confederate cavalry commander (and founder of the racist Ku Klux Klan) Nathan Bedford

Forrest noted that “War means fighting, and fighting means killing,” a quote that is no less true for its distasteful source (Steplyk, 2020). Indeed, Forrest’s famous quote echoes Clausewitz’s warning that theorists of war cannot remove the inherent bloodshed from this form of human discourse. Nor is this violence only understood to occur between humans.

Wartime violence against animal and plant life is recorded as far back as antiquity. To the present animals remain important participants in military activities, either as beasts of burden or specialist sensors like bomb-sniffing dogs, though the scale of direct animal involvement in war has declined in favor of mechanization since the beginning of the twentieth century (Townsend, 2000). Animals often become direct targets of wartime violence due to their perceived military or even economic value to enemy elements. Plants too can become targets of military violence for reasons ranging from tactical to strategic (Westing, 1976). Finally, the unintended slow violence resulting from the broad range of already-discussed direct military disruptions can produce long lasting and far-ranging changes to the ecology of habitats in areas both proximate and distant to locations of direct violence.

Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 5.4 Common military disruptions in the biosphere.

6.1 Mechanical Disruptions in the Biosphere

Mechanical disruptions to the biosphere consist of the physical movement of life forms from one location to another. Because of the already discussed exceptional nature of war, the patterns of such movements and displacements are often very different from peacetime patterns. Moreover, as wars are intended to alter the geopolitical context in which the belligerents operate, the postwar effects of a conflict's resolution can also alter patterns of movement and habitation in important ways.

6.1.1 Military Deployment

Military units are at their most basic level communities of humans gathered and equipped to execute the policy aims of their government. Depending on a unit's hierarchy, these communities can consist of tens or even hundreds of thousands of individuals, all of whom require food, water, waste disposal, and any other number of services that make society possible. During military operations, these communities often deploy into areas that would otherwise be sparsely populated. Indeed, even in today's urbanized world, military conflict continues to occur disproportionately in rural landscapes, partly because of the recognized difficulty of combat in urban terrain (Hanson et al, 2009). For example, during the Battle of Gettysburg a combined total of over 150,000 US and Confederate soldiers converged on a small area in southern Pennsylvania, temporarily making this landscape one of the most densely populated places on the American continent (Fiege, 2012). While modern combat is far more dispersed, military operations still deploy a significant number of people into environments that would otherwise be

thinly inhabited. The life processes of so many individuals cannot help but exert a disruptive influence on the ecology of these landscapes.

These sorts of deployments occur relatively predictably in the preparation context, as military forces generally conduct mobilization and training at established facilities and on designated landscapes. Wartime disruptions are less predictable, but also more brief, as military forces don't generally remain on battlefields after the conclusion of conflict, though long-term occupation of battlefields such as those of the Western Front in World War I or areas of the front lines in the Ukraine War provide examples of long-term deployments into otherwise rural landscapes. Thus, areas of frequent military training may in fact experience more profound transformation due to the life processes of soldiers than battlefields in many cases.

6.1.2 Movement of Animals

Similarly, the exceptional nature of war can cause the mass dislocation of animal life. Until the mid-twentieth century, even relatively well-equipped armies still relied heavily upon animal muscle power to move supplies and heavy equipment (Townsend, 2000). For example, the US Army's 10th Mountain Division training at Camp Hale, Colorado, during the Second World War boasted several thousand mules among their ranks of approximately fifteen thousand human soldiers, all concentrated in a valley that had previously only contained transitory human habitation and sparse populations of elk, deer, and other wild animals (Whitlock & Miller, 2023). While this war-driven relationship between humans and animals has waned in the modern era of warfare, military forces still employ animals as partners in specialist situations, such as mules as beast of burden in mountain environments or bomb-sniffing dogs in counterinsurgency or post-

war recovery contexts. Indeed, Russian forces are reported to have deployed trained dolphins to thwart Ukrainian seaborne attacks against the naval base at Sevastopol (Hutton, 2023, June 14).

Movement of animal populations can occur as a process of slow violence as well. New patterns of military activity can cause both wild and domesticated animals to move away from the sites of violence, altering the ecological make-up of the local environment and that of the landscapes to which the animals move. Once again, such disruptions in the geography of animal populations will often be longer lasting in landscapes where military forces prepare for war as opposed to ones where wartime violence occurs.

6.1.3 Refugees

Another ubiquitous consequence of war-related violence is the displacement of civilian populations, voluntary or otherwise, from areas of military activity. Large numbers of refugees often voluntarily leave areas where active combat is occurring during wartime, abandoning these landscapes and often placing increased strain on landscapes where these populations settle (Gbanie et al, 2018). In some cases, these displacements can become semi-permanent, as exemplified by refugee communities in Turkey housing people fleeing from the long-running violence of the Syrian Civil War (Koca, 2016). Such displacements can occur in the preparation and post-war contexts as well. Securitization of certain places can cause governments to require the evacuation of civilian populations from areas where military forces train and operate in peacetime, as occurred with the indigenous peoples of the Aleutian Islands at the beginning of the Second World War campaign there (Rutherford, 2022). Similarly, perceptions of risk can cause governments to disallow the return of civilian refugees to places of former habitation, as

occurred in the Demilitarized Zone (DMZ) of the Korean Peninsula following the Korean War of 1950-53 (Kim *et al*, 2021).

6.1.4 New Economic Patterns

Finally, the alterations caused by both the physical, economic, political, and ideological outcomes of war-related actions can change the patterns of economic activity on human communities. For example, the construction of dual-use infrastructure, such as the Panama Canal, can create new opportunities for more efficient sea commerce. In the case of Panama, the construction of the canal that was at least partially an overt a piece of military infrastructure caused far greater volumes of sea traffic to transit Central America, with a corresponding reduction of traffic around Cape Horn (Maurer & Yu, 2008). Similarly, the construction of militarily useful infrastructure such as the Roman Empire's famous roads or the US's Interstate Highway System has caused major changes in how goods move on land (Dalgaard et al, 2018). While the direct violence of such construction usually occurs in the pre-war context, the slow violence of these altered patterns is usually a reflection of the altered conditions of the post-war context.

6.2 Chemical Disruptions in the Biosphere

Because organisms must operate in the contaminated environments created by war and its related activities, they are inevitably affected by them. These effects usually occur as a process of slow violence in which animal and plant life is inadvertently poisoned by the chemical residue

of military actions. In other instances, as in the use of chemical weapons, such poisoning is a form of direct violence. In the biosphere, these contaminants can affect the food chain, becoming more concentrated the higher an animal feeds in the chain (Lawrence et al, 2015). Moreover, military action can also directly target plant and animal life with chemicals, such as in the use of pesticides and defoliants, in attempts to alter the operational context in which military action is occurring. These disruptions can produce long-lasting health problems in the landscapes where they occur and affect distant communities as well through food chain propagation.

6.2.1 Chemical and Heavy Metal Poisoning

Chemical and heavy metal contaminants deposited in the other three earth spheres can disrupt the biosphere as well. The sources of this contamination are numerous and have already been described above, including chemical weapons, explosives, toxic spills and burning, and metal debris. Animals can become contaminated in several ways, including external contact, inhalation of airborne particles, and ingesting contaminated water and food. Plants can also be affected by such contamination through external contact and by the uptake of toxins through soil and roots (Peralta-Videa *et al*, 2009). When not immediately fatal, such disruptions can cause illness and reproductive problems, as evidenced by the widespread “Gulf War Syndrome” experience by veterans of that conflict, which has been tied to poisoning from burning oil wells and other chemical sources of contamination that were present on the battlefield (White *et al*, 2016).

Furthermore, as animals are mobile, they can carry contaminants to different landscapes from the site of the initial contamination, causing regional impacts of slow violence and in some

cases disrupting the food chain, as described below. In the case of highly reactive contaminants, such as those common in chemical weapons, the risk of immediate death is greater, but the risk of chronic health issues is reduced as the contaminants break down relatively quickly. However, in the case of other toxins, such as heavy metals, the contamination can remain in the environment for long periods of time, continuing to degrade the quality of life of organisms that come in to contact with them.

6.2.2 *Food Chain Contamination*

Organisms that ingest contaminated food ingest the toxins contained in that food as well. The higher in the food chain an animal operates, the more contaminants become concentrated as they feed (Lawrence et al, 2015). Thus, long-term contamination, such as the leaching of heavy metals or hydrocarbons into the environment from abandoned infrastructure or shipwrecks, can produce long-lasting negative impacts for the health of animals in the area. A clear example of this sort of food chain contamination exists in seabirds in the Northern Pacific Ocean. Around coastal military infrastructure built hastily during the Second World War and then abandoned, researchers have tied high levels of heavy metal poisoning in eagle and gull eggs to contaminants leaking from these abandoned facilities (Anthony *et al*, 2007; Burger *et al*, 2007, 2009). Contaminants from the abandoned infrastructure leak into the sea, where it then works its way up the marine food chain and eventually into the avian one as seabirds hunt and eat fish. Thus, this sort of slow violence can expand geographically as animals move and are eaten, temporally as they suffer the ill effects of contamination and pass these on to their offspring and can also cross habitat boundaries.

6.2.3 *Pesticides*

Until the early twentieth century deaths from disease represented the single greatest source of mortality in nearly every war for which records are available (Goniewicz, 2021). As understanding about disease vectors such as mosquitos and lice improved in the nineteenth and twentieth centuries, animals that could potentially act as disease vectors became targets for military action. Indeed, pesticide use by military forces has become widespread enough for some researchers to classify it as a form of chemical warfare directed against the environment (Tucker & Russell, 2004). In nearly every case, pesticides are used to improve the operational mobility of a military force by making an area safer in terms of disease for military activity. Examples include widespread spraying of pesticides by the US military in the South Pacific during the Second World War to suppress mosquito populations, and similar actions during the Vietnam War. While these efforts to suppress vector populations appear to be relatively successful in the short-term, in the longer-term these populations appear to rebound relatively quickly (Tucker and Russell, 2004).

6.2.4 *Defoliants*

The use of defoliants and herbicides is another way military forces employ direct violence against the biosphere. Vegetation can provide concealment for military forces, enhancing both their tactical and operational mobility. Military forces have at times employed defoliants to degrade this advantage, most famously when the US military employed the

compound Agent Orange to defoliate swaths of jungle in Vietnam and neighboring Cambodia to strip the advantage of concealment away from North Vietnamese and Viet Cong forces (Westing, 1984). These sorts of chemical attacks damage and kill vegetation, but can also contaminate humans and animals, as shown by the high number of US Vietnam veterans suffering ill health effects tied to their service in that country (Stellman & Stellman, 2018). The chemical destruction of vegetation can also degrade the habitat for other forms of life.

6.2.5 Burning

Finally, perhaps the most ubiquitous chemical war-related process that can disrupt the biosphere is fire. Military forces employ broad ranges of pyrotechnics, from high explosive munitions and incendiaries to signaling flares and tracer rounds. All of these can cause uncontrolled fires that burn landscapes and vegetation, destroying habitats and forcing organisms to relocate (Dalby, 2018; Anthes, 2022, April 14). Military-related wildfires are a threat in all three contexts, as a result of training, combat, or the postwar disposal of munitions. Depending on the severity and extent of the fire, landscapes can recover relatively quickly, but in some cases the evidence of disruption can remain for years or even decades.

6.3 Radiological Disruption in the Biosphere

Organisms that encounter high doses of radiation can experience ill health effects, including acute radiation sickness, cancer, and reproductive issues. External sources of radiation tend to cause the most immediate disruption in organisms' health, such as burns and radiation

sickness that can in severe cases result in death. The ingestion by animals of sources of radiation, such as fallout contaminated food or the inhalation of fallout contaminated dust particles, can also cause radiation sickness, as well as various forms of cancer and reproductive problems (Centers for Disease Control and Prevention, ND). A tragic example of this exists in South Pacific Islands near areas where nuclear weapons were tested. Residents of these islands, including the Marshall Islands, Bikini Atoll, and Eniwetok, experience significantly higher rates of leukemia and thyroid cancer than do other populations (Cronkite, 1997). Such contamination, because it is not immediately fatal and persists in the environment for long periods, represents a near-permanent form of slow violence caused by military activity.

6.4 Biological Disruption in the Biosphere

War-related activities often alter the underlying ecology of the areas they disrupt. War often results in both the temporary and long-term alteration of environmental habitats due to both direct and slow violence, allowing some organisms to thrive and others to collapse. Moreover, the increasingly global mobility of military operations raises the prospect of the introduction of invasive species into landscapes that can struggle to accommodate them, disrupting these areas permanently. Finally, perhaps the most obvious and most distasteful disruption caused by war is the intentional killing of humans and animals. All these activities can alter biological makeup of a landscape, and cause rippling effects of slow violence in distant areas.

6.4.1 *Habitat Disruption*

Numerous of the above-discussed disruptions illustrate ways that military activity can alter human and animal habitats in all three war-related contexts. This section will not rehash these descriptions but will instead focus on ways that the mere presence of war and its related activities can alter the environment of local landscapes. As discussed earlier, the deployment of military forces involves the movement of large numbers of humans and animals, along with their life support services, into areas that would otherwise be sparsely populated. Such conditions can alter the underlying balance of a landscape with far-reaching effects.

In one example, McNeil (2010) shows how the water storage practices of invading European armies in the Caribbean during the seventeenth and eighteenth centuries created ideal conditions for the locally endemic *Aedes aegypti* and *Anopheles* mosquitoes to thrive. These then became vectors for yellow fever and malaria, which then infected the blood of the invading soldiers, creating nearly perfect ecological conditions for these viruses to thrive as long as the invading army remained in the area. Another example involves the spread of the Spanish flu during the First World War, when the concentration and then deployment of hundreds of thousands of soldiers living in austere conditions in Kansas helped to create and propagate a global pandemic (Hoingsbaum, 2018).

More benign examples include the ways in which sites of military training or areas abandoned by humans due to military activity or perceptions of risk can become de facto reserves for wildlife. Numerous studies have shown how the regulation of military training areas in the United States has provided favorable conditions for the recovery of numerous endangered species (Stein et al, 2008). Similarly, landscapes abandoned due to perceptions of risk or for

security purposes, such as the DMZ on the Korean peninsula, can afford wildlife a reprieve from the normal pressures associated with peacetime human activity (Kim *et al*, 2021).

These examples, alongside the already-discussed habitat destruction that can occur both intentionally and unintentionally due to military action, illustrate how the ecological disruptions of war and its attendant activities can spread far and wide, often in unanticipated ways.

6.4.2 *Invasive Species*

The increasingly global mobility of military operations presents the threat of the introduction of invasive species into vulnerable ecosystems due to military action. Such disruptions have occurred frequently in the past half millennia. Examples include the introduction of hogs and horses into the Americas by Spanish military expeditions, which had brought these animals along to improve their mobility and act as food on the hoof (Sharp *et al*, 2011). More recently, US forces inadvertently introduced numerous novel species into the ecosystems of several Pacific islands during the Second World War, with disruptive consequences for these fragile local environments (Tucker & Russell, 2004; Renner *et al*, 2017). Globally mobile military forces today are aware of the potential for this sort of disruption and take precautions to avoid transporting foreign organisms between regions, but the potential for such precautions to be disregarded in wartime is high. Thus, the introduction of invasive species may represent one of the longest-lasting disruptions attributable to war-related activities.

6.4.3 *Killing*

The last disruption of the biosphere to discuss is the direct killing of humans and animals. Clausewitz contends that “the character of battle is slaughter, and its price is blood” (Clausewitz, 1993, 307). While different theorists have advanced constructs of war that emphasize ways to achieve victory which minimizes bloodshed, the sad fact remains that war almost always involves killing. In the extreme, this killing can be genocidal in scale, fundamentally altering the population density and cultural makeup of a region, as occurred during the European conquest of the Americas (Dull et al, 2010). Nor is such widespread killing confined to humans; the destruction of the American bison population in the nineteenth century was a military campaign designed to constrain the operational and strategic mobility of the indigenous peoples of the Great Plains in North America that very nearly resulted in the extinction of the species, and from which bison populations have never recovered (Utley, 1984).

At the individual scale, killing represents perhaps the ultimate expression of slow violence. If the definition of slow violence is the difference between what could have been and what is, then the loss of each individual life represents a permanent deviation from a potential world in which war did not exist. While studies at the population scale may mask the tragedy of this fact, studies of the environmental effect of war upon the environment should always keep in mind that each death is both individual and permanent.

7. Conclusions

This lengthy chapter has laid out a taxonomical scheme for organizing and classifying the different types of disruptions that military power can cause in the environment in the contexts of

preparation for war, war, and postwar activities. In doing so, it has attempted to weave in examples of the various forms of disruption from military geography, military art and science. In doing so, this chapter seeks to show how a better integration of military geography and history with other academic disciplines can deepen researchers' understanding of not just what military activity does to the landscape, but where and why it does so as well. The following chapter will build upon this taxonomy to create a topology that can help researchers better understand how these disruptions interact with and amplify one another. Furthermore, the heuristic tool that is a product of this topology can also help researchers gage the actual severity of environmental disruptions associated with a particular conflict and identify areas requiring deeper study.

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Chapter 6 - Topology and Heuristic

1. Introduction

This chapter builds upon the taxonomy outlined in Chapter 4 to construct a heuristic tool that can help contextualize and organize research examining the impact of war on the environment. The heuristic incorporates a topology of the different types of environmental effects of war that examines the relationships between the context, scale, severity, and duration of both the direct and slow violence of war-related disruptions. In doing so, it builds upon theoretical concepts from the fields of warfare ecology, militarized landscape research, environmental geopolitics, and military art and science. The resulting tool can serve as a rough predictor of the types of environmental impacts that can persist in the aftermath of a given conflict based on the types of direct violence employed by the belligerents, as also as a framework to identify gaps in research about the environmental legacy of specific conflicts.

The first section of this chapter outlines a way to visualize the severity of specific types of war-related environmental disruptions. This section once again engages with Clausewitzian ideas about the nature of war, in this case his concepts of the difference between “absolute” war (sometimes also referred to as “pure” war) and “real” war, to differentiate between potential and actual environmental impacts of military action (Clausewitz, 1993). This discussion is then integrated with concepts drawn from ecological theory and militarized landscape research about ways to classify or quantify the severity of disruptions. This layer of the classification system is the final component of the taxonomy of war-environment disruptions outlined in the previous

chapter and forms the vital link connecting the taxonomy to the structure of the heuristic (Table 6.1).

Earth sphere	Mechanism	Direct violence	Context of direct violence	Slow violence (spatial)	Slow violence (timescale)	Slow violence (severity)	Slow violence (pactness)	Slow violence (other spheres)	
Lithosphere	Mechanical	Construction and excavation	Preparation, war	Local, regional	Millennia	Disturbance	3 (Significant)	Hydrosphere, biosphere	
		Deposition	Preparation, war, post-war	Local	Centuries	Disturbance	3 (Significant)	Biosphere	
		Gratering	Preparation, war	Local	Decades	Difference	1 (Minimal)	Hydrosphere	
	Chemical	Soil compaction	Preparation, war	Local, regional	Decades	Disturbance	1 (Minimal)	Hydrosphere, biosphere	
		Chemical weapons residue	Preparation, war, post-war	Local	Days	Disturbance	0 (No impact)	Hydrosphere, biosphere	
		Explosive residue	Preparation, war	Local	Decades	Disturbance	1 (Minimal)	Hydrosphere, biosphere	
		Metal residue	Preparation, war	Local	Centuries	Disturbance	2 (Moderate)	Hydrosphere, biosphere	
		petroleum product spills	Preparation, war, post-war	Local	Decades	Degradation	2 (Moderate)	Hydrosphere, biosphere	
		Fallout	Preparation, war	Local, regional, global	Millenia	Depletion	5 (Catastrophic)	Hydrosphere, biosphere	
		Depleted uranium	War	Local	Centuries	Disturbance	2 (Moderate)	Hydrosphere, biosphere	
Hydrosphere	Biological	Habitat destruction	Preparation, war	Local, regional	Decades	Disturbance	1 (Minimal)	Biosphere	
		Landscape abandonment	Preparation, war, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	Hydrosphere, biosphere	
		Inundation	War	Local, regional	Decades	Degradation	2 (Moderate)	Lithosphere, biosphere	
	Mechanical	Diverson	Preparation, war, post-war	Local, regional, global	Decades	Degradation	2 (Moderate)	Lithosphere, biosphere	
		Noise and blast energy	Preparation, war	Local, regional	Years	Disturbance	0 (No impact)	Biosphere	
		Deposition	War, post-war	Local, regional	Millennia	Difference	2 (Moderate)	Biosphere	
		Hydrocarbon spills	Preparation, war, post-war	Local, regional	Decades	Degradation	2 (Moderate)	Biosphere	
		Chemical weapon residue	Preparation, war, post-war	Local, regional	Years	Disturbance	0 (No impact)	Biosphere	
		Explosive residue	Preparation, war	Local	Decades	Disturbance	1 (Minimal)	Biosphere	
		Metal residue	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	Biosphere	
Atmosphere	Radiological	Fallout	Preparation, war	Local, regional, global	Millennia	Depletion	5 (Catastrophic)	Lithosphere, biosphere	
		Nuclear shipwrecks	War	Local	Centuries	Difference	2 (Moderate)	Biosphere	
		Lost nuclear weapons	Preparation, war	Local	Centuries	Difference	2 (Moderate)	Biosphere	
	Biological	Habitat disruption	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	Biosphere	
		Fishery abandonment	War	Local, regional	Years	Disturbance	1 (Minimal)	Biosphere	
		Noise and blast energy	Preparation, war	Local	Years	Disturbance	0 (No impact)	Biosphere	
		Chemical	Chemical weapons use	Preparation, war, postwar	Local	Days	Disturbance	0 (No impact)	Lithosphere, hydrosphere, biosphere
			Burning of toxic materials	War, post-war	Local, regional	Weeks	Degradation	1 (Minimal)	Lithosphere, hydrosphere, biosphere
			Atmospheric carbon balance	War, post-war	Global	Centuries	Difference	1 (Minimal)	Lithosphere, hydrosphere, biosphere
			Fallout	Preparation, war	Local, regional, global	Months	Depletion	2 (Moderate)	Lithosphere, hydrosphere, biosphere
Biosphere	Radiological	Habitat disruption	Preparation, war	Local	Days	Difference	0 (No impact)	Biosphere	
		Military deployments	Preparation, war, postwar	Local, regional	Years	Disturbance	0 (No impact)	Lithosphere, hydrosphere, biosphere	
		Movement of animals	Preparation, war, postwar	Local, regional	Years	Disturbance	0 (No impact)	Lithosphere, hydrosphere, biosphere	
	Mechanical	Refugee flows	War, postwar	Local, regional	Decades	Disturbance	1 (Minimal)	Lithosphere, hydrosphere, biosphere	
		New economic patterns	Postwar	Local, regional, global	Centuries	Disturbance	2 (Moderate)	Lithosphere, hydrosphere, atmosphere	
		Chemical/metal poisoning	Preparation, war, postwar	Local	Decades	Degradation	2 (Moderate)	Lithosphere, hydrosphere, biosphere	
		Food chain contamination	Preparation, war, postwar	Local, regional	Decades	Degradation	2 (Moderate)	Lithosphere, hydrosphere, biosphere	
		Pesticide use	Preparation, war	Local	Months	Disturbance	1 (Minimal)	Lithosphere	
		Derollant use	War	Local, regional	Years	Degradation	1 (Minimal)	Lithosphere	
		Burning	Preparation, war	Local, regional	Days	Disturbance	0 (No impact)	Lithosphere, atmosphere	
Biological	Radiological	Radiation sickness	Preparation, war	Local	Days	Degradation	1 (Minimal)	Lithosphere, hydrosphere, biosphere	
		Cancer	Preparation, war	Local	Years	Depletion	2 (Moderate)	Lithosphere, hydrosphere, biosphere	
		Habitat alteration	Preparation, war, postwar	Local, regional	Years	Disturbance	0 (No impact)	Lithosphere, hydrosphere	
	Mechanical	Invasive species introduction	Preparation, war, postwar	Local, regional	Centuries	Degradation	3 (Significant)	Lithosphere, hydrosphere	

Table 6.1 A topology for the ecological impacts of military activity that builds upon the taxonomy described in Chapter 5

2. Acuteness of Impacts

Classifying the acuteness or severity of war-related environmental disruptions is a complicated problem with which few war-environment researchers have so far systematically engaged (Brauer, 2009). As Brauer (2009) notes, one factor that complicates efforts to grade the acuteness of a disruption is the lack of standard against which to measure particular incidents. To overcome this challenge, this chapter builds upon Bauer's (2009, 24) suggested scheme for grading the "ecological severity" of war-related environmental disruptions by integrating it with Clausewitz's concept of the difference between "absolute" war and "real" war. Doing so can provide a firm standard, the worst-case *potential* ecological impact of a specific disruption, against which to grade *actual* environmental impacts. In the resulting scheme, the worst-case potential impact of a war-related disruption represents an upper ceiling, as all actual disruption will register a level of acuteness somewhere beneath this absolute standard.

2.1 *Potential versus Actual Violence*

In both Books 1 and 2 of his unfinished treatise developing a holistic theory of war, Clausewitz (1993) argues that the inherent logic of the nature of war drives belligerents to employ their entire capacity for violence immediately upon the commencement of hostilities to defeat their enemy and compel them to submit to their opponent's policy objectives. Clausewitz defines this state of unrestrained violence as "absolute" or "pure" war. However, Clausewitz also observes that few if any historical conflicts, which Clausewitz calls "real" war, have attained the

theoretical ideal of absolute war. He cites various reasons for the discrepancy between the extreme levels of violence that war should theoretically display and what examples of historical conflicts actually demonstrate, including problems of military logistics and communications and uncertainty on the part of military commanders. Moreover, and perhaps more importantly, Clausewitz argues that the very impetus for war, the imperative by a government to alter their geopolitical context through policy, often exerts a powerful restraining influence upon the amount and level of violence that military forces can employ to affect this alteration, as extreme military violence will often work at cross purposes with a government's desired outcome in a conflict.

Some scholars have criticized Clausewitz's ideas about absolute war, noting that his definition of the concept is nebulous and incoherent (Holmes, 2017). This criticism is perhaps borne out further in debates that have occurred among military historians and strategists since World War I about the definition of "total" war, a concept that is analogous to Clausewitz's absolute war (Bell, 2007). These debates also revolve around whether a coherent definition of total war exists, and whether any historical military conflict has actually attained it. These criticisms and debates highlight a potential weakness of using an analogue of the concept of absolute war as a standard by which to grade war's environmental disruptions, namely that the actual standard of what a worst-case potential impact would be is difficult to define and will invariably be disputable. Even so, as Clausewitz noted in preemptively answering these critiques,

“War can be a matter of degree. Theory must concede this; but it has the duty to give priority to the absolute form of war and to make that form a general point of reference, so that he who wants to learn from the theory becomes accustomed to keeping that point in

view constantly...and to approximating it *when he can* or *when he must*" [emphasis in the original] (Clausewitz , 1993, 702).

As Clausewitz here argues, an extreme standard of violence against which to measure lesser violence is vital, even if nebulous or ill-defined, because it provides a reference point for approximating the degree of violence in a given case. Nonetheless, those trying to use this ill-defined reference point bear some responsibility to attempt to approximate it, a task which this chapter attempts to accomplish.

Nuclear weapons are a useful medium through which to illustrate how the concepts of absolute and real war can act as analogues for potential and actual war-related environmental disruptions. To date, the United States is the only government to have employed nuclear arms in wartime, famously dropping two of these weapons on Hiroshima and Nagasaki in 1945 to compel the surrender of the Japanese government. Since 1945, several governments have detonated thousands of nuclear devices in tests, most of which were of far higher explosive yield than the relatively crude weapons used in wartime against Japan (Schlosser, 2013). During the Cold War, the US and USSR each fielded arsenals of tens of thousands of nuclear weapons, many with explosive yields hundreds or even thousands of times more powerful than those employed against Japan. Even today, the US and Russian militaries each maintain stockpiles of several thousand nuclear weapons, with the world's other nuclear armed states contributing at least several hundred more (Schlosser, 2013). What then would the absolute form of a war using nuclear weapons take?

Interestingly, American war plans from the 1950s provide a picture of what such a conflict might look like, as well as a view into how political, economic, and ideological factors can work to constrain the absolute war ideal. As the American nuclear arsenal expanded rapidly

under the Eisenhower administration, strategists struggled to develop a coherent plan for their use (Schlosser, 2013). The plan that emerged under the aegis of the Eisenhower administration's policy of "massive retaliation" imagined the US military expending every one of its tens of thousands of nuclear devices against targets in the USSR, China, and Eastern Europe over the course of just a few hours in the event of war with the Soviet Union (Wyrick, 2016). One would be hard pressed to imagine any realistic scenario that could be more destructive than the one here described.

However, these war plans remained unused. Indeed, in the 1960s the Kennedy administration directed military planners to revise these initial plans to provide the US president with a more flexible "menu" of nuclear options (Wyrick, 2016). This new policy, known as "flexible response", reflected a recognition by the US government that a maximum expenditure of violence during even a nuclear war would not be the best means by which to achieve the government's policy objectives because of the political, economic, and ideological costs that the massive retaliation strategy would entail (Schlosser, 2013). This demonstrates how war, being an inherent extension of policy in the Clausewitzian sense, is constrained in terms of violence by the same policy objectives that cause it to occur.

In terms of environmental impact, the analogous worst-case potential impact of an all-out thermonuclear war in which the nuclear-armed states of the world expend their entire nuclear arsenals over the course of an afternoon would theorize about the local, regional, and global disruptions caused by such a conflict. Indeed, Westing (1977; 1981; 2013) speculated about just such a scenario in his research examining the potential ecological ramifications of an all-out nuclear war, providing in the process a useful reference point for studying the impacts of lesser forms of nuclear violence.

However, as noted above, despite (or perhaps because of) the horrifying *potential* destruction that could be wrought by nuclear weapons, the *actual* damage they have caused to the environment is far less. This fact highlights both the importance of considering elements of social power other than military as constraints upon wartime violence, as suggested by Clausewitz, as well as the importance of the context in which the actual violence occurs. As noted, even without an actual nuclear war, nuclear-armed states have still detonated thousands of these weapons in preparation for one. Even so, the locations and geographical distribution of these tests in the preparation for war context were generally designed to mitigate their environmental costs, whereas a full-scale nuclear war would in many ways maximize those costs (Cronkite *et al*, 1997; Schlosser, 2013). Thus, the imagined potential worst-case scenario remains a useful benchmark against which to grade lesser forms of nuclear violence.

The above example of nuclear weapons illustrates the importance of a conceptual environmental analogue to Clausewitz's ideas about the disparity between absolute and real war. The value of this concept lies in its ability to provide a ceiling for the magnitude of damage that war-related activity can cause, thus allowing researchers to make a rough gradation of disruptions that fall short of the theoretical maximum. A framework for expressing the relative magnitude of these lesser disruptions is outlined in the next section.

2.2 Severity of Disruption

So far, this chapter has discussed the conceptual upper limit of environmental disruption that military action can cause, with the lower limit being no measurable difference on landscapes on which military activity has occurred. Between these two extremes lie innumerable gradations

of measurable effects. To provide some structure for these gradations, the topology and heuristic described in this chapter rely and expand upon Bauer’s (2009) framework for classifying the ecological costs of war. Bauer grades ecological disruptions on a five-tiered scale, with the lowest tier denoting mere ecological difference in a landscape, and the highest tier marking a landscape’s complete destruction (Table 6.2).

Severity of disruption	Definition
Difference	Environmental dissimilarities not associated with damage
Disturbance	Full recovery of its ecological richness expected
Degradation	Different ecosystem of comparable richness expected to emerge
Depletion	Different ecosystem of impoverished richness expected to emerge
Destruction	No possible restitution of ecosystem

Table 6.2 A framework for grading the severity of war-related environmental disruptions (after Bauer, 2009, 24).

Bauer’s (2009) concept is a useful qualitative framework for classifying gradations of environmental damage because it encourages the contextualization and interpretation of these disruptions. However, as Baur also notes, it is imperfect for at least three reasons. First, the framework fails to account for scales of time. Damage from which a landscape can recover its pre-war ecological richness after a few months and equivalent immediate damage that nonetheless requires centuries for complete recovery should not be considered comparable. Second, the understanding of the relative “ecological richness” of a landscape is a matter of interpretation for ecologists and is also constantly changing even without the disruptions of military activity. Third, the framework does not account for mitigating factors of social power that can cause humans to assist in a landscape’s recovery. The following sections of this chapter build upon Bauer’s (2009) framework to address these issues and construct a broader heuristic structure to incorporate them into a more holistic tool to assess the ecological impact of war.

2.3 Duration of Disruption

As noted, a criticism of Brauer's (2009) framework for grading the severity of war-related ecological disruptions is that it does not take into account timescales for recovery. Indeed, few researchers have used a systematic approach to attempt to gage the overall ecological impact of war on the environment, and fewer still have engaged meaningfully with timeframes of recovery in war-ravaged landscapes, other than to differentiate between acute and chronic timescales of environmental effects and to discuss how perceptions of landscapes' cultural or economic value can prompt human efforts to recover war damage (Lanier-Graham, 1993; Lawrence *et al*, 2015). This provides little foundation on which to construct a framework for measuring such timescales, impelling a search for concepts of time and recovery or change from outside of war-environment research.

Two related fields that can provide a possible framework for measuring the timescale of a landscape's recovery are landscape evolution modelling and succession theory. Landscape evolution models (LEMs) attempt to predict or understand the geomorphic changes that occur in landscapes at various timescales ranging from months through geologic time measured in millions of years (Tucker & Hancock, 2010). Succession theory studies the biological changes that occur in landscapes over time after a disturbance event (Poorter *et al*, 2023). Both approaches usually use steps of years raised to powers of ten to model the stages of landscape transformation (Coulthard, 2001; Walker & Wardle, 2014). The fact that both approaches to studying landscape change and recovery, one focusing physical geomorphic changes and the other biological ones, tend to employ the same basic form of timescale measurement suggests

this framework as a promising one for measuring the persistence of war-induced changes in landscapes. However, since the historical and archeological evidence of human activity on landscapes does not usually yet extend deeper into the past than several thousand years BCE, this sort of framework should also consider any impacts that persist for more than a millennium to be effectively permanent, thus providing an upper limit.

2.4 Framework for Judging Acuteness

Combining the scales for both the severity and timescale of a particular disruption allows a more holistic grading of its ecological impact. However, doing so also poses the problem of combining two forms of measurement, one qualitative and one quantitative, which do not share units of measure in common. As such, the resulting grade of disruption must necessarily be both abstract and unitless. Precedent for such a form of grading exists in war-environment literature in the form of a Green Cross International study of the ecological costs of the Persian Gulf War in which the authors coded components of disruptions on a simple numeric scale of 1 (low), 2 (medium), or 3 (high), then combined the component scores to give provide an overall grade for the severity of an impact (Charrier, 1998; Bauer, 2009). A similar structure can be useful in communicating the magnitude of a disruption's impact using the intersection of severity and timescale, as shown in Tables 6.3 and 6.4. This structure for acuteness of impact then forms the third axis of the heuristic tool, which will be described further in subsequent sections of this chapter.

Code	Definition
0	No impact
1	Minimal impact
2	Moderate impact
3	Significant impact
4	Severe impact
5	Catastrophic impact

Table 6.3 Coding of impact acuteness for use as a key in deciphering Table 6.4

<i>AND</i>	Less than year	Less than a decade	Less than a century	Less than a millenium	Permanent
Difference	0	0	1	2	3
Disturbance	0	1	2	3	4
Degradation	1	2	3	4	4
Depletion	2	3	4	4	5
Destruction	3	4	4	5	5

Table 6.4 Framework for grading the relative ecological acuteness of war-related disruptions that incorporates a qualitative measure of severity and a quantitative measure of the impact’s timescale.

This grading scheme, like Bauer’s (2009) system of classifying the severity of impacts, is no doubt imperfect. The qualitative portion of the structure is necessarily reliant upon subjective interpretations of a disruptions’ impact, while the steps of the timescale structure can mask more fine-grained gradations of change and recovery that a less logarithmic measure of time might reveal. Moreover, combining a timescale with Bauer’s (2009) definitions requires a modification of the definition of “destruction” in an ecosystem. In Bauer’s (2009) framework, destruction denotes damage to a landscape from which the ecosystem can never recover, making the concept of a timescale irrelevant. However, such a condition existing amid a wider regional or global ecological system that can eventually recolonize a destroyed landscape seems unlikely. As such,

this framework reclassifies “destruction” as conditions that make survival of most forms of life in an area impossible for a non-defined period of time. Such conditions could include chemical or radiological contamination, burning, or any other types of conditions in which non-extremophile forms of life cannot persist for long. Modifying the definition of destruction in this way acknowledges that natural processes can mitigate the damaging effects of disruption over time, while still considering its initial catastrophic severity.

Furthermore, numerous underlying factors can work to mitigate or amplify the effects of slow violence on landscapes. Broadly, these factors will be either social or environmental. Social factors, such as the economic condition of the population among whom the conflict occurs, the ideological meaning that the conflict itself assumes, or the political realities in which the war occurs or that it creates, can all work to exacerbate or mitigate a war’s environmental legacy due to the ways that they can shape human responses to this legacy. Similarly, the environmental context of local landscapes can be important in determining the persistence and reach of environmental impacts. Disruptions that occur within more fluid settings may be more prone to operating at the regional scale as effects can move more easily from one landscape to another, while the ambient temperature of a landscape will affect the rate at which chemical reactions occur and thus the rates at which contaminants break down or biological life can recover. As such, frameworks for modifying the heuristic’s outputs based on social and environmental conditions will be important when comparing conflicts that occur in different social and environmental settings.

2.5 Impact across Earth Spheres

A final consideration when grading the ecological impact of war-related disruptions is understanding how a disruption that occurs in one earth sphere can relate to conditions of slow violence in another. For example, chemical contamination of the lithosphere can result in similar contamination in the hydrosphere as groundwater and overland flow dissolve and transport the contaminants. Both spheres can then pass this contamination on to the biosphere in the form of food chain contamination. Table 6.1 gives an initial indication of the relationships that certain kinds of disruptions can exert between spheres, a concept which the final heuristic tool will also address. However, whether an impact in one sphere spills over into another is also highly dependent on the context in which the disruption occurs. Different contexts, both environmental and social, can act as mitigating or amplifying factors for the severity, scale, timescale, and relational impact of a disruption.

Inherent in the taxonomy described in Chapter 5 and the topology outlined in Table 6.1 is a weighting system for the relative environmental impacts across earth system spheres. The identification of broad categories of disruption types within each earth sphere informs this system by the number of categories within each sphere. Summing each category's maximum acuteness (from Table 6.1) within each earth sphere and then dividing by the total sum of acuteness across all categories can provide a relative weight for the overall weight of environmental disruption across earth system spheres. The resulting ratio of weights for the acuteness of individual environmental impacts within each sphere is outlined in Table 6.5.

	Lithosphere	Hydrosphere	Atmosphere	Biosphere
Relative weight	0.34	0.33	0.06	0.27

Table 6.5 Weighting ratio for the relative acuteness of environmental impacts across earth system spheres based on the number of categories of disruption identified within each sphere and the maximum acuteness of the slow violence of each type of disruption as identified in Table 6.1.

This weighting system is not without weaknesses. Based as it is on the categories of disruption identified in Chapter 5 and the grades of maximum acuteness assigned in Table 6.1, these weights are obviously sensitive to changes or reinterpretations of either of these factors. For example, another researcher might argue that construction and excavation represent two separate categories of disruption in the lithosphere rather than one. Doing so would result in a greater number of categories of disruption within the lithosphere and thus (presumably, assuming both categories received an acuteness score equivalent to the one assigned the combined category) resulting a greater weight being assigned to disruptions in the lithosphere overall. This demonstrates both the importance of a thorough analysis of the categories of environmental disruptions, as conducted in Chapter 5, as well as the inherently interpretive nature of studies that seek to combine quantitative and qualitative elements.

3. Heuristic Part 1 – Context, Scale, and Acuteness

The basic structure of the heuristic tool is a three-dimensional graph where the x-axis represents the scale at which a disruption operates (local, regional, or global). As discussed in Chapter 1, these definitions of scale are not simply larger baskets in which to classify greater numbers or sizes of incidents, but rather represent difference processes that affect the

environment by different means and mechanisms. The local scale scale denotes processes that operate within a single landscape. The regional scale denotes processes that can disrupt landscapes other than the one affected by the initial incident of direct violence. Global influences change the overall regional or global environmental context. The y-axis represents the acuteness of a disruptions impact (scored 1-5 for each disruption type, as described in Table 6.4). The z-axis denotes the context in which a disruption can occur (preparation for war, war, or post-war) as suggested by Machlis and Hanson (2008). The overall structure then creates a surface that can express the acuteness of an impact for each of the nine scale/context combinations, as well as the slope in between categories (Figure 6.1).

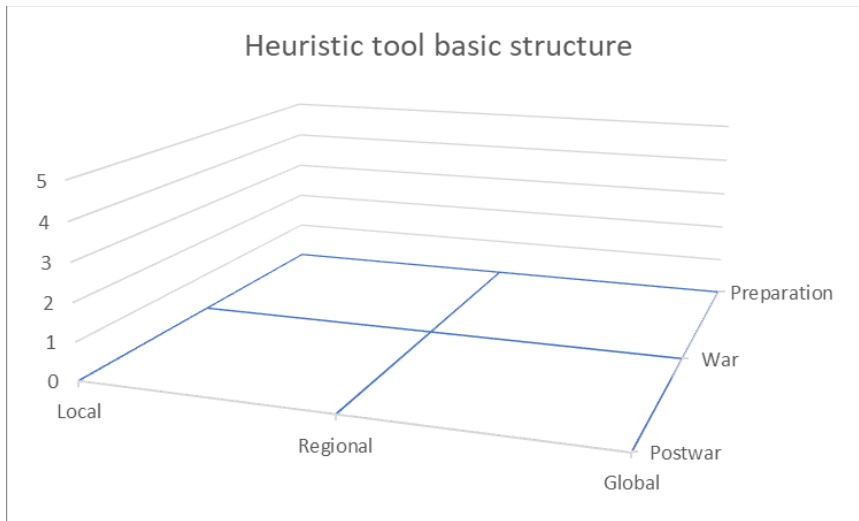


Figure 6.1 Basic structure of the heuristic tool where the x-axis represents the spatial scale of a disruption, the z-axis represents its acuteness, and the y-axis represents the context in which the disruption can occur.

The above-described tool for visualizing the ecological war-environment disruptions possesses several strengths that should recommend it to researchers. First, by integrating measures of acuteness with the complex concepts of scale and context, this structure can

communicate which contexts and scales will likely experience the most acute impacts of a given disruption. Second, and more importantly, this structure can highlight relationships between all three dimensions in the form of the slope and curvature of the resulting surface. For example, a hypothetical disruption with a wartime acuteness rating of 5 locally, 3 regionally, and 1 globally would indicate that the effects of the initial disruption decreased linearly across the three conceptions of scale. Alternately, if the same hypothetical disruption received an acuteness rating of 1 at the local scale in both the preparation and post-war contexts, the steep upward and downward slope across the z-axis would indicate that the activity was most likely to occur in wartime and that its effects were likely to be of relatively short duration. A third strength of this structure is its scalability, as discussed in the next section.

4. Heuristic Part 2 – Mechanisms, Earth Spheres, and Ecological Relationships

The above-described heuristic tool can be used additively, with multiple disruptions “stacking” one atop another to provide an overall visualization of the cumulative impacts of multiple types of disruptions at once. To demonstrate this ability, this section will describe the construction of a generic “worst-case” visualization of a hypothetical war in which every disruption outlined in this chapter’s topology (Table 6.1) occurs to the worst degree possible across each scale and context.

In the first step of this process, within each of the four earth spheres, the ratings for each type of disruption within each mechanism were summed according to the worst-case acuteness rating they received in each scale/context combination (as indicated in Table 6.1). This produced an overall additive indication of the magnitude of impact to be expected within each mechanism,

and subsequently, after another process of compilation, within earth sphere (Figure 6.2). A final process of additive compilation gives an indication of the overall ecological impact of the hypothetical conflict by combining the weighted graphs for each earth sphere into a composite whole (Table 6.6). Thus, the acuteness grades in each scale/context combination in Tabel 6.6 represent the worst case or “absolute war” potential effects that these categories can cause. This provides an upper limit against which to grade “real” war environmental effects. Dividing the corresponding, similarly derived scores of a “real” conflict by the acuteness of the theoretical maximum can provide a ratio for how destructive a conflict was compared the the theoretical “absolute.”

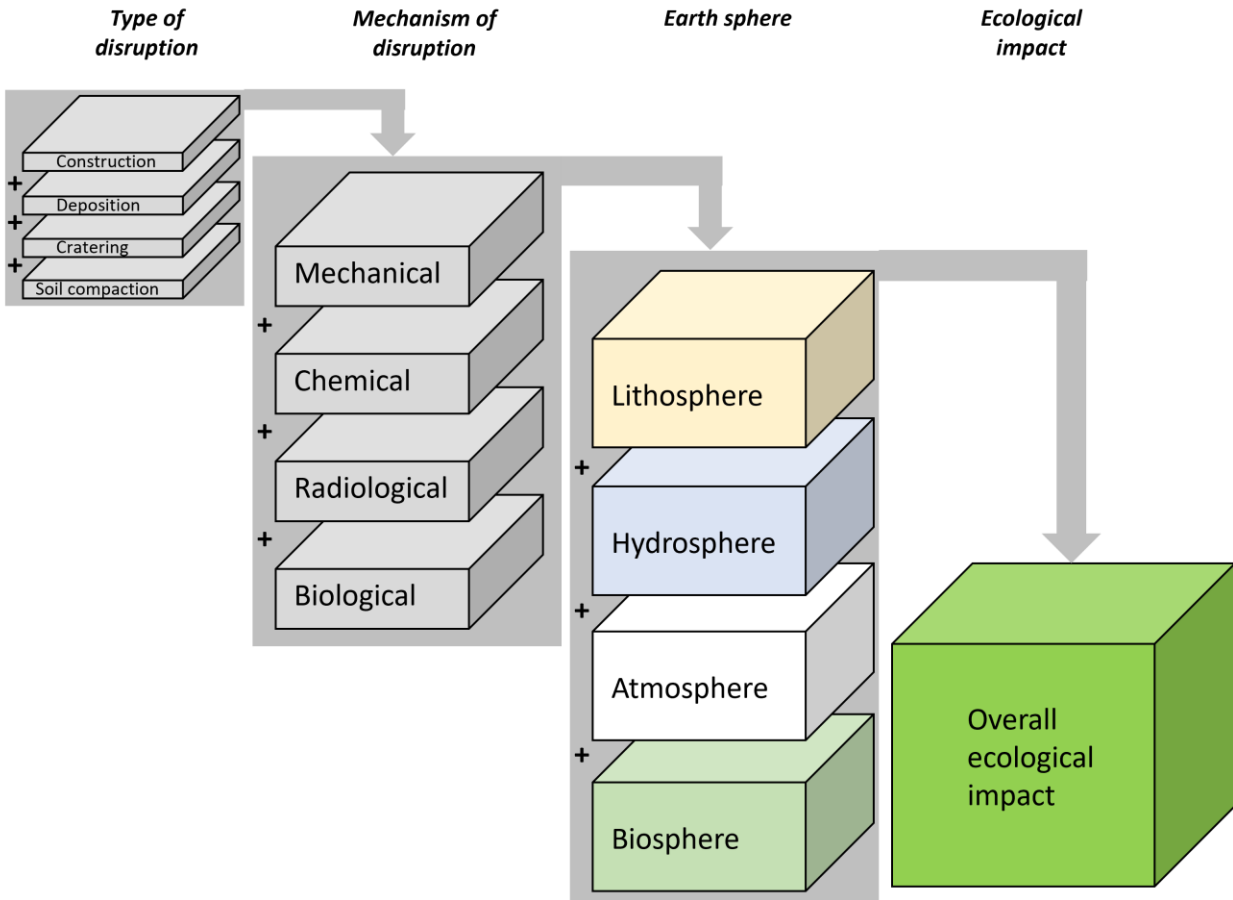


Figure 6.2 The process of additively scaling the basic heuristic tool to assess environmental impact across the different conceptual scales of the taxonomy described in Chapter 4. Each box represents an application of the tool at the scale indicated. In the first step, only the lithosphere-mechanical combination is shown for the same of the figure's clarity.

		Mechanical			Chemical			Radiological			Biological			Weighted Composite		
		Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global
Lithosphere (.34)	Postwar	3	0	0	2	2	0	5	5	5	1	1	0	11	8	5
	War	8	4	0	5	4	0	7	5	5	2	2	0	22	15	5
	Preparation	8	4	0	5	4	0	5	5	5	2	2	0	20	15	5
Hydrosphere (.33)	Postwar	2	2	2	3	3	0	5	5	5	1	1	0	11	11	7
	War	7	7	0	4	3	0	9	5	5	2	2	0	22	17	5
	Preparation	3	3	0	3	2	0	9	5	5	1	1	0	16	11	5
Atmosphere (.06)	Postwar	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
	War	0	0	0	1	1	0	2	2	2	0	0	0	3	3	2
	Preparation	0	0	0	0	0	0	2	2	2	0	0	0	2	2	2
Biosphere (.27)	Postwar	3	3	2	5	2	0	0	0	0	3	3	0	11	8	2
	War	1	1	0	6	3	0	3	0	0	5	5	0	15	9	0
	Preparation	0	0	0	3	2	0	3	0	0	3	3	0	9	5	0
Overall	Postwar	8	5	4	11	8	2	10	10	10	5	5	0	34	28	16
	War	16	12	0	16	11	0	21	12	12	9	9	0	62	44	12
	Preparation	11	7	0	11	8	0	19	12	12	6	6	0	47	33	12

Table 6.6 Additive magnitude scores for the worst-case ecological disruption in each context/scale combination of disruption types according to the topology described in Table 6.1. The bottom row gives the overall magnitude of potential disruptions within each mechanism while the right-most column gives the total potential magnitude within each earth sphere. The magnitude of the overall potential disruption is highlighted in gray. These grades represent the theoretical maximum environmental disruption of an “absolute” war in which every possible disruption occurs to its most destructive extent, providing an upper limit against which to grade the effects of “real” wars.

Using the heuristic tool in this manner at different conceptual scales can reveal yet more patterns about the potential environmental impacts of war. At the disruption scale, the tool can help to visualize the different context/scale patterns of individual types of disruptions.

Combining these within a mechanism allows the same sort of pattern visualization within this

conceptual scale, and so on through earth spheres and the overall ecology of an environment (Figures 6.3, 6.4, 6.5, 6.6, & 6.7, Table 6.6).

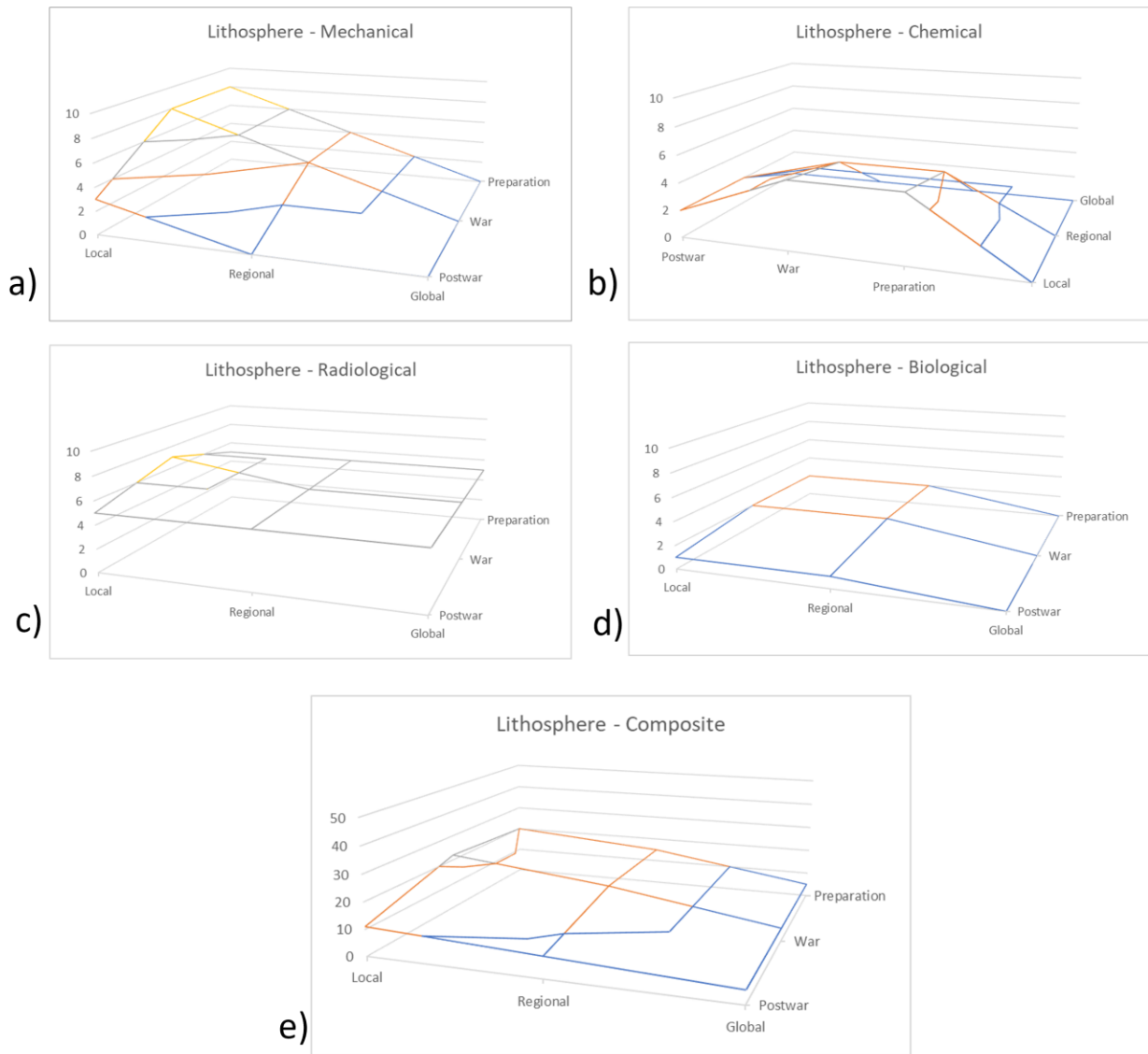


Figure 6.3 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions caused by mechanical (a), chemical (b), radiological (c), and biological (d) mechanisms within the lithosphere (e). The additive magnitude of impact in each chart represents the sum total of all specific disruption types outlined in Table 6.1

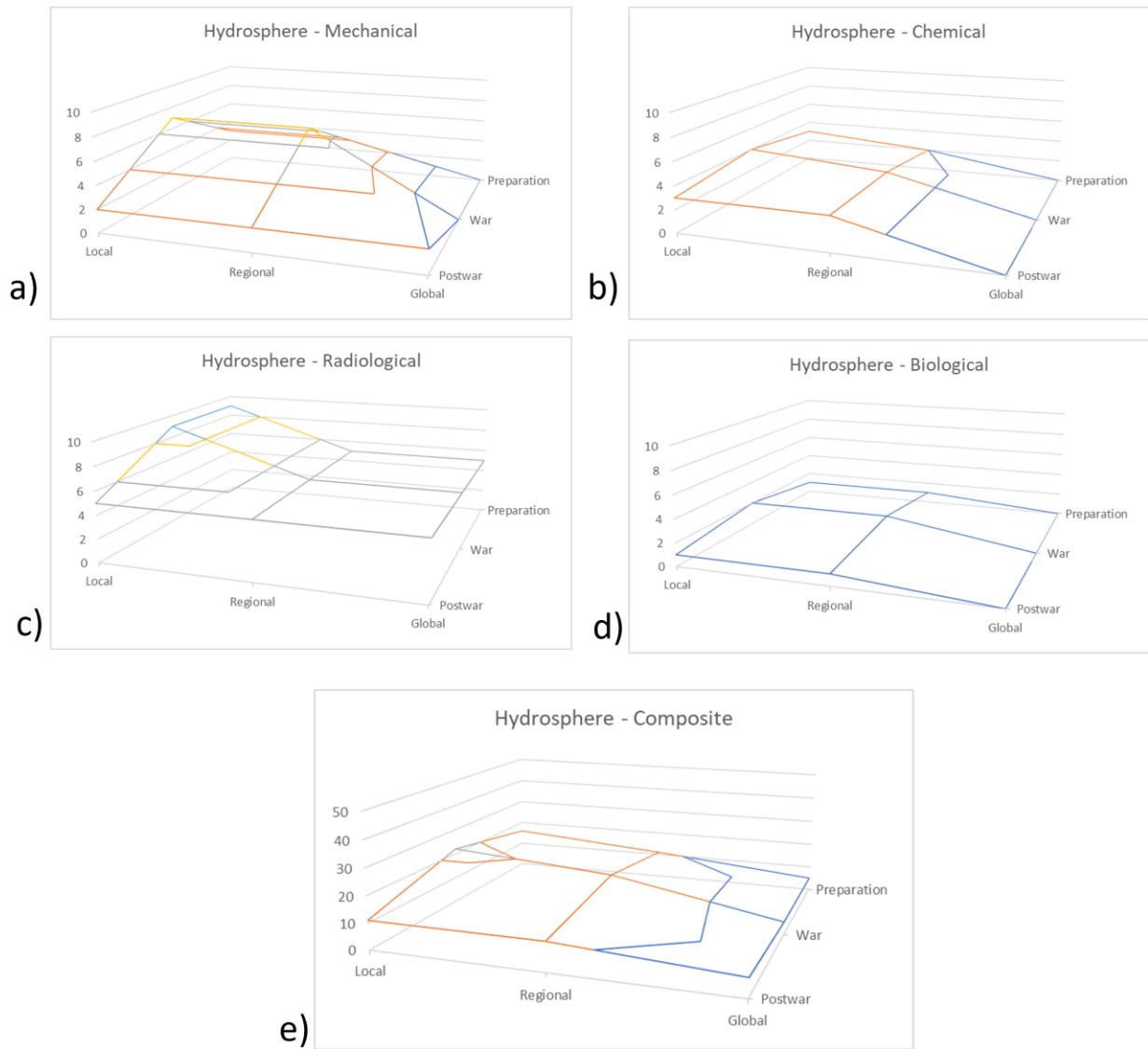


Figure 6.4 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions caused by mechanical (a), chemical (b), radiological (c), and biological (d) mechanisms within the hydrosphere (e). The additive magnitude of impact in each chart represents the sum total of all specific disruption types outlined in Table 6.1.

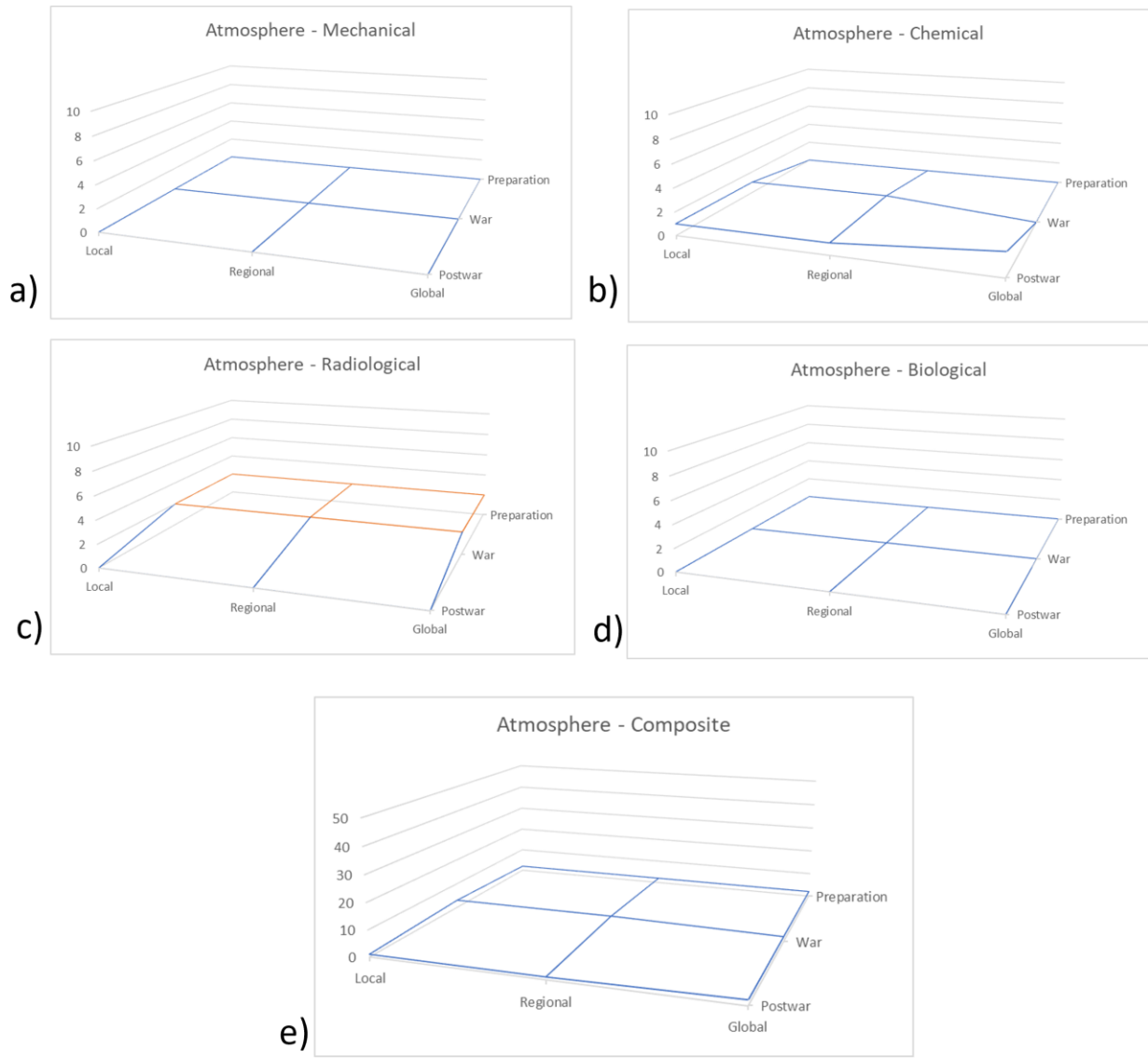


Figure 6.5 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions caused by mechanical (a), chemical (b), radiological (c), and biological (d) mechanisms within the atmosphere (e). The additive magnitude of impact in each chart represents the sum total of all specific disruption types outlined in Table 6.1.

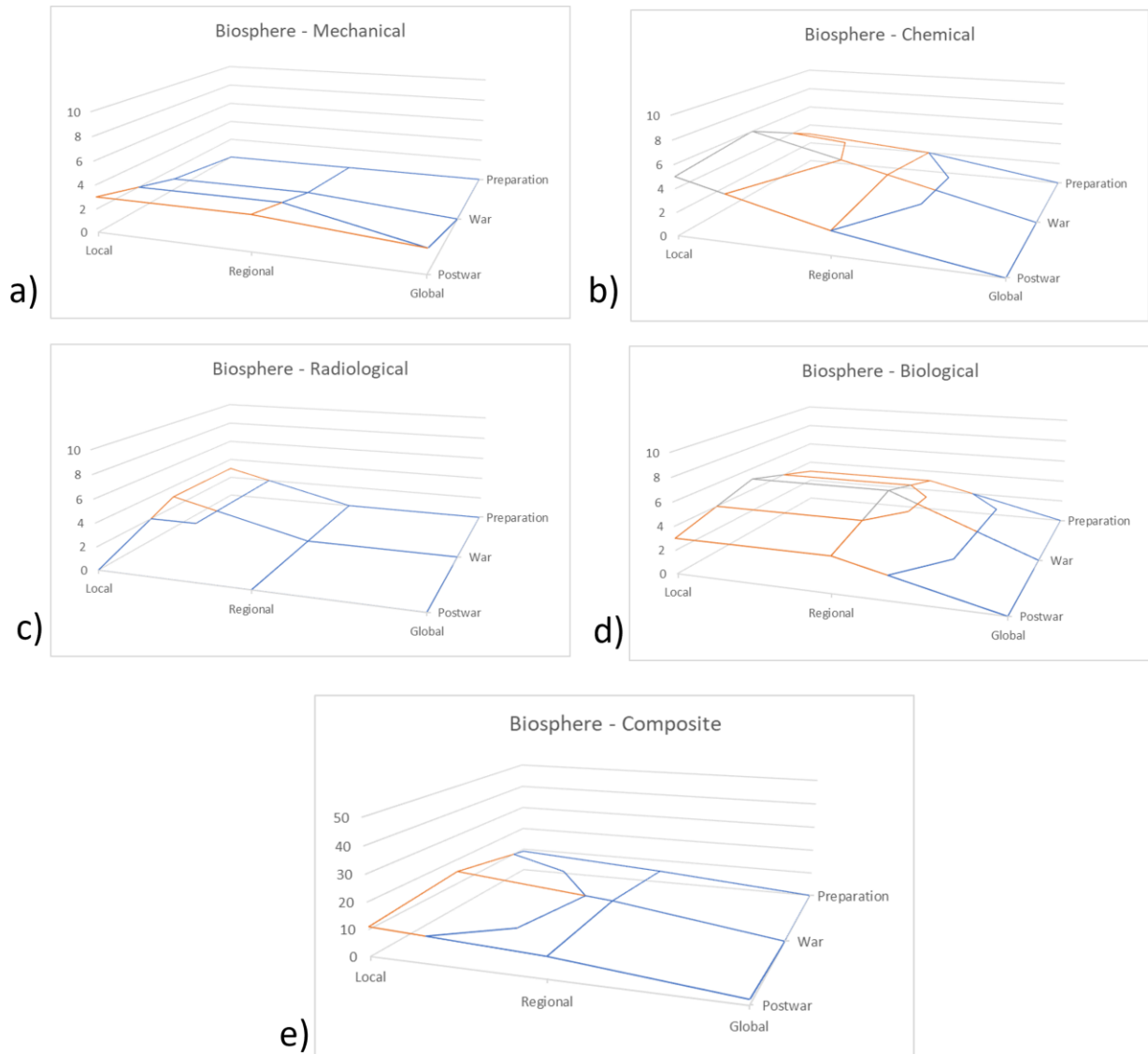


Figure 6.6 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions caused by mechanical (a), chemical (b), radiological (c), and biological (d) mechanisms within the biosphere (e). The additive magnitude of impact in each chart represents the sum total of all specific disruption types outlined in Table 6.1

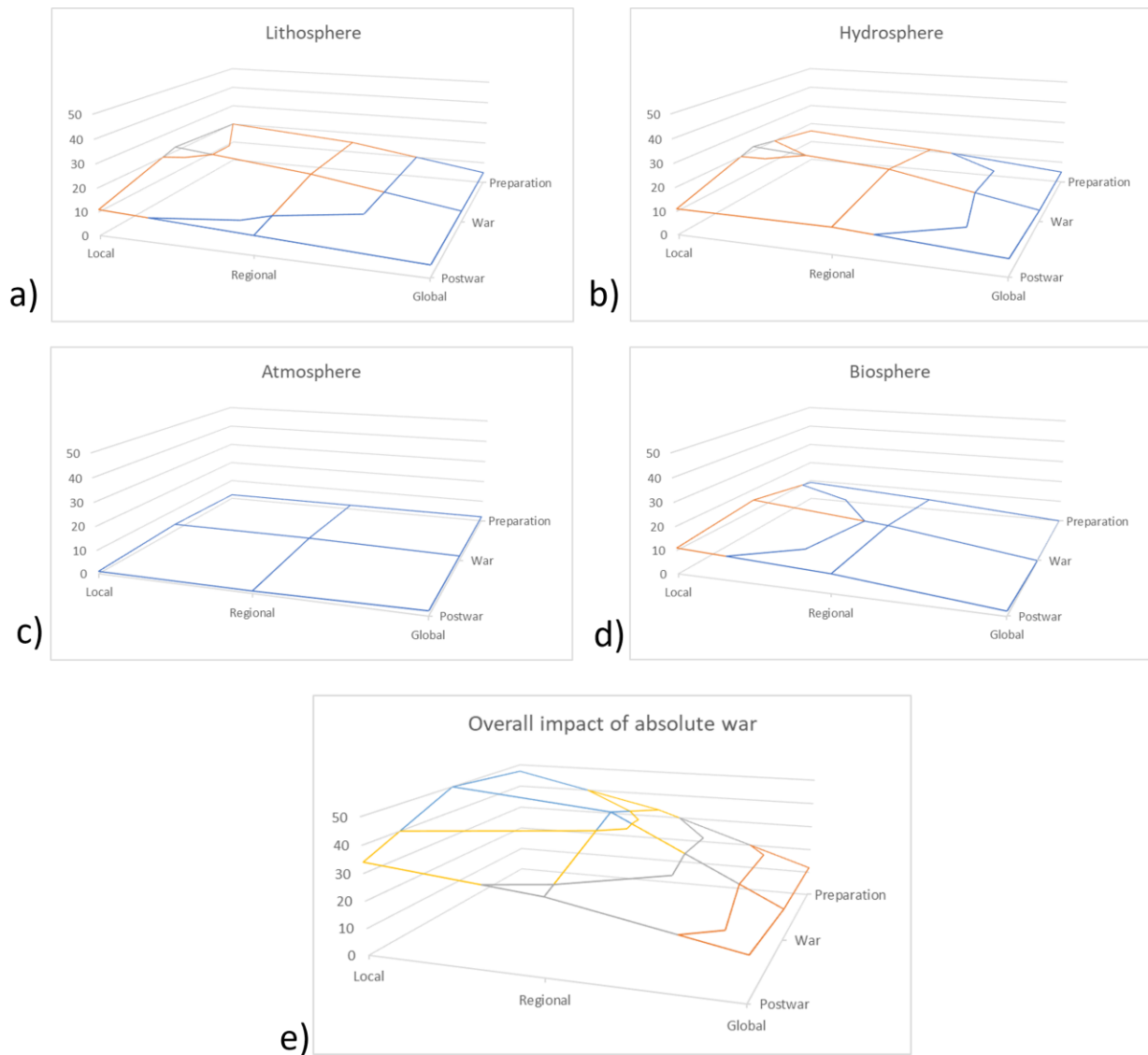


Figure 6.7 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions within the lithosphere (a), hydrosphere (b), atmosphere (c), and biosphere (d), culminating in a visualization of overall worst case acuteness (e) for absolute war.

Visualizing the potential ecological impact of war this way indicates some interesting conclusions about the environmental consequences of military activity. In terms of magnitude, war-related impacts are greatest within the lithosphere, with the hydrosphere showing the next-greatest overall impact, and the biosphere the third greatest. This pattern likely reflects the inherent qualities that define each sphere. The solid state of the lithosphere can preserve the

evidence of war-related disruptions far longer than can the other more fluid spheres, resulting in overall higher magnitude scores. The hydrosphere's high score, by contrast, is likely due to its fluidity, which can allow disruptions to spread regionally much easier than can occur in the lithosphere. These conclusions are borne out by the scores within each mechanism, which the mechanical disruptions driving the lithosphere's high magnitude and chemical disruptions dominating in the hydrosphere. Radiological disruptions are also worse in the lithosphere and the biosphere because of the ability of radioactive fallout to settle onto the ground or the ocean floor. Within the biosphere, radiological effects can be severe but of short duration, since the worst effects of radiation often either kill victim organisms or render them incapable of reproduction, limiting the temporal impact in terms of individual organisms.

In terms of scale and context, the most acute effects of war-related disruptions appear to occur locally and in the wartime context, with effects decreasing at the regional and global scales. This pattern no doubt reflects Tobler's first law of geography that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, 2008). Indeed, few disruptions appear to exert influence on a global scale, with the effects of radioactive fallout and changes to the carbon dioxide balance of the atmosphere due to war-induced population collapse being the exception. In the lithosphere, regional disruptions usually occurred because of interactions with the hydrosphere such as changed patterns of hydrology and erosion or chemical contamination of groundwater or overland flows. By contrast, regional disruptions in the hydrosphere and atmosphere occur because of these spheres' fluid nature as currents, flows, and weather patterns transport disruptions from one area to another. In the biosphere, regional effects are due to the mobility of animal life and food chain contamination that allows the transfer of disruptions from one type of organism to another.

The overall ecological pattern of the magnitude of environmental disruptions indicates that the most acute impacts of war will manifest closest in terms of both scale and context to locations of wartime violence. In general, Tobler's Law helps explain the pattern of decreasing acuteness along the local-regional-global line in all three contexts. In terms of the rising and falling pattern along the preparation-war-post-war axis, this likely reflects several processes at play. First, the very nature of war as described by Clausewitz, being defined by the presence of intentional violence, means that acts of direct violence are more socially acceptable and therefore more frequent in this context (Clausewitz, 1993). In the preparation context, the more imminent a state of war seems can justify increasing levels of violence in anticipation of war, which governments often justify using frameworks of risk and security that override normal peacetime priorities and interests, especially in the case of socially marginalized minorities or indigenous peoples (O'Lear, 2018). In the post-war context, temporal proximity to a state of war can also increase the acuteness of disruption, likely reflecting the economic, political, and social disruptions wrought by the conflict, but also the changed ideological meaning of landscapes where wartime violence occurred. Prolonged periods of peace and the normal passage of time can usually mitigate both postwar conditions.

5. Discussion and Conclusions

The heuristic tool described above can act as a useful analytical framework to contextualize war-environment research or visualize the ecological impacts of a specific disruption or an overall conflict. It can also act as a predictive tool indicate the magnitude of disruptions that could be caused by a hypothetical future conflict, or to indicate where unstudied

disruptions may still be manifest in landscapes of past conflicts. Such a predictive tool might also be useful for governments seeking to prioritize remediation efforts or as a gauge of where relief aid might be most needed. In all these cases, however, studies should be well integrated with a thorough analysis of the military geography of the specific conflict in question. The heuristic can give an abstract indication of the magnitude of disruptions and their relationships to each other in terms of context and abstract scale, but it cannot by itself indicate *where* geographically disruptions are likely to have occurred or to occur in the future. This weakness highlights the importance of the taxonomy described in Chapter 4, which attempts to better integrate concepts from military geography with fields that seek to understand the environmental impacts of military actions.

Such an abstract tool as the one described above is, by necessity, imperfect. The magnitude grades of its scoring system are highly dependent upon the topology outlined in Table 6.1. Though this topology is based upon a broad reading of the conclusions of scientifically empirical war-environment research, its organization in terms of the categorization of disruptions within each sphere and the scoring for the magnitude of impact associated with specific types of disruptions are certainly disputable. Moreover, war is such a chaotic and unpredictable form of human activity that each specific conflict will defy in some ways the patterns that a generic application of the heuristic tool would predict. Nonetheless, this tool helps to answer three of the needs within the field of warfare ecology identified by Machlis and Hanson (2008). First, it has developed a theoretical framework to organize interdisciplinary advances within the disparate fields studying the environmental impacts of war. Second, the heuristic represents a method for both predicting and documenting the cascading effects of warfare for specific ecosystems.

Finally, the tool's scalability makes it a useful framework for case study research that can test and validate its underlying theory.

The next chapter of this project expands upon this third imperative by testing the heuristic tool within the context of three historical military conflicts. These case studies will help demonstrate the value of the tool as a framework for understanding the ecological impacts of specific, real-world conflicts, as opposed to the abstract hypothetical one analyzed above. The application of the heuristic within these case studies can also indicate where research gaps exist regarding the environmental impacts associated with the conflicts studied. Indeed, the tool can compensate for one of the greatest weaknesses in war-related environmental research, namely that the locations where war-related violence occurs are often inaccessible to researchers. Studies seeking to understand war's environmental impacts must often employ conceptual proxies or speculative analysis. The heuristic, with its emphasis on relationships between scales of impact, can act as a robust form to guide such analysis by placing it within an ecological framework, thus helping to fill the gaps between area where empirical studies of actual impacts are available.

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Chapter 7 - Falklands War Case Study

1. Introduction

The previous chapter described the structure and justification of a heuristic tool for systematically analyzing the ecological impacts of war and its related activities on the environment. It furthermore showcased applying the heuristic to visualize the ecological disruptions caused by a generic and hypothetical conflict in which every possible type of disruption (as identified in the topology of environmental disruptions developed in the previous chapter) would occur. This exercise was useful in showcasing the function and utility of the tool, but to fully demonstrate how it can increase understanding of a conflict's environmental impact, both in terms of existing empirical research and existing gaps in knowledge, requires examples of real conflicts as targets of analysis.

This chapter uses three case studies of modern military conflicts that occurred in Arctic or high latitude environments to test the heuristic tool's ability to provide a comprehensive visualization and contextualization of the environmental costs of war. In doing so, it follows one of the suggestions outlined by Machlis and Hanson (2008) to "use case studies to test developing theories" within the field of warfare ecology. The three conflicts, the Norwegian and Aleutians campaigns of the Second World War and the Falkland Islands War of 1982, were selected because of their similarity to one another in terms of the types of operations that they encompassed and the environment in which the actual combat occurred. They differ, however, in their operational scale and intensity. This allows further testing of the heuristic tool's ability to accommodate different scales of warfare.

This case study methodology also demonstrates the importance of integrating research from military geography, military art and science, and military history (among other disciplines) into studies of war-related environmental disruptions. The heuristic tool is useful for visualizing the relative acuteness of disruptions across scales and contexts and the relationships between disruptions, thus helping to answer questions related to the *what* and *how* of war-related environmental effects. However, it does not provide specific insight into questions of *where* and *why* these disruptions occur. Thus, pairing the already robust case study methods common in military geography with empirical studies of the effects of military activities via the framework of the heuristic tool can provide a more holistic understanding of a conflict's environmental impact in terms of its geography and acuteness.

2. Methods

Case study methodology is an appropriate way to approach the testing and validation of the heuristic tool. Case studies are the dominant form of research within military geography and theoretical justification exists for this approach within this field. Clausewitz (1993, 201) contended in his writings about the use and importance of military history that

“If, however, some historical event is being presented in order to demonstrate a general truth, care must be taken that every aspect bearing on the truth at issue is fully and circumstantially developed – carefully assembled, so to speak, before the reader's eyes.”

Furthermore, Clausewitz (1993, 203) noted that, “...where a new or debatable point of view is concerned, a single thoroughly detailed event is more instructive than ten that are only touched

on.” In one of his characteristically evocative uses of metaphor, Clausewitz (1993, 178) also contended, with regards to studying war in general, that

“War is not like a field of wheat, which, without regard to the individual stalk, may be mown more or less efficiently depending on the quality of the scythe; it is like a stand of mature trees in which the axe has to be used judiciously according to the characteristics and development of each individual trunk.”

As such, the chapter seeks to judiciously apply the axe of warfare ecology analysis to examine the environmental impact of three historical conflicts, each of which will be “fully and circumstantially developed” to the extent that available research allows, as described below.

Each case study analysis follows a four-step process. The first step involves an operational analysis of the campaign in question, which applies the tactical-operational-strategic framework of scale to understand where and why military violence occurred across the contexts of preparation for war, war, and postwar activities. In the second step, the operational analysis is combined with the topology outlined in Chapter 5 to identify which environmental disruptions are likely to have occurred during the conflict, and where their effects are most likely to be found. In the third step, empirical studies examining these disruptions are reviewed to determine the severity of the disruptions’ impact and to suggest where knowledge gaps exist about the conflict’s environmental legacy. As noted in Chapter 6, the “real” environmental effects of a conflict will theoretically always be less severe than the theoretical maximum effects of “absolute” war. In the final step, the heuristic tool is applied to the information gathered in the previous three steps to provide a visualization of the holistic ecological disruption caused by the conflict (Table 7.1).

Case Study Research Process	
Step 1	Operational analysis of the campaign
Step 2	Identification of likely types and locations of disruptions
Step 3	Review of existing empirical studies of disruptions, field and archival research
Step 4	Ecological analysis using heuristic tool

Table 7.1 Four step research process used in the three case studies covering the Norwegian and Aleutian campaigns of the Second World War and the Falkland Islands War of 1982.

All three historical conflicts occurred in vulnerable high-latitude environments, namely littoral areas on the Arctic, sub-Arctic, and sub-Antarctic regions of the world. However, they differed in terms of their temporal and geographic scope and the scale of their operations (Table 7.2). The Falklands War occurred over a period of weeks with the actual combat confined to the Falkland Islands, South Georgia Island, and the surrounding seas, with both sides employing forces numbering a few thousand individuals. The Aleutians campaign spanned thirteen months from June 1942 until August 1943 and encompassed action across several islands in the Aleutian and Kuril chains including Kiska, Attu, and Unalaska, and the mainland Alaskan littoral, as well as air and naval combat that stretched across the North Pacific Ocean, with forces numbering in the tens of thousands of individuals. The Norwegian theater in the Second World War was active starting prior to the German invasion of Norway in April 1940 and ended five years later with the German capitulation to the Allies in May 1945. The conflict spanned the length of the Norwegian littoral and the Kola Peninsula in the USSR, as well as the adjacent seas and islands. Over the course of the war, the theater drew in forces numbering hundreds of thousands and experienced large-scale ground, naval, and air warfare.

	Falklands War	Aleutian Campaign	Norwegian theater
Geographic scope of combat operations	Falkland Islands South Atlantic	Aleutian Islands Alaskan littoral North Pacific	Scandinavia, UK, & Finland North & Barents Seas North Atlantic
Time period	Weeks	Months	Years
Forces involved	1000s	Tens of 1000s	Hundreds of 1000s

Table 7.2 Geographic, temporal, and operational scale of the Falklands, Aleutians, and Norwegian case studies.

Throughout, these case study analyses rely heavily upon secondary source research, both to conduct the operational analyses of the campaigns and to understand the existing research regarding these conflict’s environmental impacts. However, in the case of one location, some original field and archival research contributed to the analysis. This location, Camp Hale, Colorado, was the site of training for American troops that participated in both the Norwegian and Aleutian campaigns of the Second World War, making it an interesting site to study the impacts military activities in the preparation for war context for both conflicts, as well as the importance of elements of social power for the fates of post-war landscapes. Field research included GPS marking of existing disruptions in the Camp Hale landscape, the results of which were then compared with archival research at the Denver Public Library and US Forest Service regarding the construction, operation, and demolition of Camp Hale to create a more thorough understanding of the existing disruptions and their origins, the rate at which disruptions are being mitigated through natural processes, and also the timeline of disruptions that have since disappeared from the landscape. This allowed an initial analysis of the overall condition of the

Camp Hale landscape using the heuristic tool as a framework, demonstrating the tool's value at different scales of analysis.

Altogether, this case study approach can begin to provide a more thorough understanding of the ecological consequences of the campaigns studied. Moreover, using the heuristic tool can show how the consequences of specific conflicts differ from the generic baseline established in the preceding chapter. Furthermore, combining the heuristic tool with both operational analyses and existing empirical research into the environmental consequences of military actions in these campaigns can highlight where gaps in research still exist, and can also help to contextualize the existing research.

A note here is appropriate about the selection of campaigns to serve as case studies in this chapter. The three case studies were selected for the similarity of the environments in which they occurred. While only one of these campaigns experienced large-scale combat operations that occurred above the Arctic Circle (the Norway Campaign), each case study's high latitude littoral setting provides landscapes and climates that are broadly like one another. As such, only the Norway campaign is properly "Arctic," if one defines the term as denoting anything north of the Arctic Circle. However, as Bennett (2014 & 2016) and Bennett *et al* (2016) have argued, the definition of what constitutes "the Arctic" is the subject of a fraught and contentious debate. Bennett (2014) advocates for a more networked understanding of the Arctic, a definition that incorporates not simply territory that exists north of the Arctic Circle, but also groups and organizations that possess economic, political, or cultural ties to the region. Additionally, one might consider the similarity of climate and terrain as a more cohesive way to unite a region than an abstract line of latitude. The chapter employs this approach, focusing on the environmental,

economic, and cultural similarities of the three regions rather than their absolute location on the globe to define their status as scenes of “Arctic” military conflict.

In the case of the Falklands conflict, the Falkland Islands and South Georgia island where all the combat occurred are entirely covered by a polar tundra (ET) climate according to the updated Köppen-Geiger climate classification system. (Peel *et al*, 2007) The islands of Kiska and Attu in the Aleutians are similarly within ET climate zones, while Unalaska Island further east and the remainder of the Alaskan littoral lie within temperate sub-polar oceanic (Cfc) and continental subarctic (Dfc) climate zones. The Norwegian theater contains the greatest climatic diversity, ranging from warm summer continental (Dfb) zones along Norway’s southern coastlines to ET climates in the high north (Peel *et al*, 2007). However, the most intense combat operation, the Petsamo-Kirkenes offensive of October 1944, occurred in Norway’s Arctic, entirely within ET and Dfc climate zones (Gebhardt, 1989; Dzwonczyk & Radunzel, 2020).

Culturally, the three case studies bear further similarities. Norway’s high north and the Aleutians both contain a European or Euro-American settler population interspersed with local indigenous communities, while the Falkland Islands population consists entirely of descendants of European colonists (Lantto, 2010; West *et al*, 2010; Lehtola, 2015; Blair, 2017). In all three cases combat operations occurred in areas of very low population density and low economic development. In general, the European and Euro-American populations of Norway and the Aleutians relied upon extractive industries such as mining, whaling, and commercial fishing for their livelihoods, while the indigenous populations practiced subsistence lifestyles such including fishing and reindeer herding at the time of the conflicts (West *et al*, 2010; Lehtola, 2015). The Falkland Islands population in 1982 was almost entirely devoted to sheep herding for commercial export (Hastings & Jenkins, 2012). In all three cases, the economic and political

fortunes of the local population are tied to distant urban areas, which serve as markets for extracted goods and decision-making centers that do not always place significant weight upon the local populations' desires or interests.

Both environmentally and culturally, the areas selected for this research are especially vulnerable to outside disruption, military or otherwise. As Dalby (2003) contends, Arctic lands are uniquely sensitive, both environmentally and culturally, to disruptions associated with modernity, where the effects of such disruptions are the most obvious and, in many cases, the most long-lasting. The reasons for this are both environmental and cultural. Environmentally, the colder climates of high latitude regions slow chemical reactions, and thus also the natural breakdown of pollutants and litter (Wängberg & Björk, 2021). Moreover, the low level of economic development in many of these areas and their political dependence upon distant urban centers for resources can mean that the post-war recovery of these landscapes occurs more slowly (if at all) than in more economically developed or politically influential areas (Dalby, 2003). Overall, then, war-related disruptions in Arctic or high-latitude landscapes are likely to persist longer than similar disruptions in warmer or more developed areas, making these areas attractive targets for analyzing the ecological consequences of historical conflicts.

3. Falklands War Introduction

The Falkland Islands War of 1982 between the United Kingdom and Argentina is the most recent of the three conflicts examined in this chapter. It is also the shortest in terms of duration and the smallest in terms of the size of the forces involved. Nonetheless, the conflict resulted in significant destruction, both for the military forces involved and for the local

landscape. The violence of the conflict is best summarized by the losses incurred (Hastings & Jenkins, 2012). Both sides suffered hundreds of fatalities among their military forces, with thousands more wounded or captured (Friedman, 2005b). Both sides lost dozens of aircraft, both to enemy action and to non-combat crashes (Chant & Rolfe, 2001). Both sides also suffered the loss of numerous naval vessels to enemy action, including major ones (Hampshire & Turner, 2012). Furthermore, even though the conflict lasted for barely nine weeks, with actual combat occurring over a far shorter period, the environmental effects of this war remain obvious in the landscape of the Falkland Islands and South Georgia Island to this day.

4. Step 1: Operational Analysis of the Falklands War

In broad overview, Argentinian forces invaded and occupied the Falkland Islands and South Georgia in April 1982 (Hastings & Jenkins, 2012). The British government quickly dispatched a naval and amphibious task force, including two small but vital aircraft carriers and two brigades of infantry, to recapture the islands. After initial naval and air skirmishing that resulted in the sinking of the Argentinian cruiser *ARA Admiral Belgrano* and the British destroyer *HMS Sheffield*, as well as a special forces operation in which the British recaptured South Georgia and destroyed the submarine *ARA Sant Fe* there, the British successfully landed at San Carlos inlet on the western coast of East Falkland (Hastings & Jenkins, 2012).

Argentinian air attacks intensified after the landing, resulting in the sinking and damaging of several more Royal Navy vessels in both coastal and deep waters around the islands (Hampshire & Turner, 2021). Subsequently, British ground forces advanced, largely by foot, across East Falkland, engaging Argentinian ground forces in sharp battles at Goose Green and then the

network of hills west of Port Stanley (Gardiner, 2012; van der Blij & Thompson, 2015). With these hills under British control the Argentinian position at Port Stanley became untenable, and the Argentinians surrendered their forces in the Falklands to the British, effectively ending the conflict.

4.1 Strategic Level Analysis of the Falklands War

Strategically, the policy roots of the Falklands War centered on whether the government of Argentina or that of the United Kingdom held rightful sovereignty over the Falkland Islands. The islands had been a Crown Colony of Great Britain since 1841, while Argentina asserted (and continues to assert) that the Malvinas (the Argentine name for the islands) have long been Argentine territory (Freedman, 2005a). Ironically, the British government viewed the islands as an economic and political liability and was amenable to transferring sovereignty to Argentina, especially after the United Nations in 1965 called upon the two governments to work towards a resolution of the conflict (Hastings & Jenkins, 2012). However, the Falkland islanders considered themselves to be British and were hostile to the idea of Argentine sovereignty. They waged a lobbying campaign directed at the government in London that effectively stalled efforts to transfer the islands to Argentina (Hastings & Jenkins, 2012). Nonetheless, negotiations continued slowly, with the British government trying various means to convince the local Falklands population to accept Argentine sovereignty (Hastings & Jenkins, 2012).

The dispute might have remained peaceful but for the economic and political turmoil that roiled Argentina in the 1970s and early 1980. A military junta had been governing Argentina since 1976, and its leaders, including General Leopoldo Galtieri and Admiral Jorge Anaya,

reasoned that a successful military operation that presented the surprised British with a *fait accompli* and resulted in a resolution of the sovereignty dispute in Argentina's favor would help to diffuse domestic tensions in the country (Freedman, 2005a). In a surprise invasion, Argentine forces landed by sea in the Falklands and South Georgia on 2 April 1982 (Hastings & Jenkins, 2012). After a brief but fierce firefight, the local British Royal Marine garrison surrendered, and the Argentinian forces proceeded to occupy and fortify the islands.

Due to the sudden onset of the crisis and its relatively short duration, neither the British nor the Argentinians conducted any significant mobilization for the conflict. Instead, both sides employed forces that were already in existence, rather than raising and forming new units. British units destined for the Falklands did conduct some pre-deployment training in Scotland prior to embarkations, and other units conducted training at Ascension Island in the central Atlantic specifically in preparation for action on the Falklands, but in general British forces, like their Argentinian opponents, went to war prepared only by their normal "peacetime" training regimes (Hastings & Jenkins, 2012; Gardiner, 2012; White, 2020). The Royal Navy did press into service several civilian vessels to help transport their forces to the South Atlantic, including the passenger liner SS *Canberra* and the cargo freighter SS *Atlantic Conveyor*, but neither side significantly altered their industrial production of weapons or other war-related materiel in response to the conflict, choosing instead to try to buy weapons from other countries to make up any shortfalls (Hastings & Jenkins, 2012; Privratsky & Thompson, 2016; White, 2020). Thus, other than some added training exercises, the preparation for war phase of the conflict did not produce any significant deviations in military activity from the normal steady state.

The leaders of the Argentinian junta had underestimated both the British will and military ability to respond to the invasion. The British government led by Margaret Thatcher viewed the

Argentinian invasion as an unacceptable aggression against British sovereignty and national pride, and decided to retake the islands, by force if necessary (Freedman, 2005a). Moreover, the Argentinean government had also overestimated the international support they would receive, even from other South and Central American countries, in the aftermath of their aggression. The British quickly scored a diplomatic coup in the passage of UN Resolution 502, which demanded the withdrawal of Argentinian military forces from the Falklands (Hastings & Jenkins, 2012). Efforts by the United States Secretary of State to broker a peace deal failed as British forces gathered and sailed for the South Atlantic, and the British commenced combat operations on 21 April with a landing on South Georgia that forced the Argentinian garrison there to surrender four days later. Fierce air, naval, and sea engagements continued for the next month until the main British amphibious landing on East Falkland Island on 21 May (Chant & Rolfe, 2001). Thereafter, despite fierce Argentinian air attacks against the beachhead, the British were able to build up their landing forces and then attack across the island, defeating the Argentinian ground forces in a series of infantry battles that eventually forced the surrender of all Argentinian forces in the islands, which marked the effective end of the war (Hastings & Jenkins, 2012).

In the war's aftermath, the Argentinian junta collapsed, and the country conducted democratic elections in 1983 (Hastings & Jenkins, 2012). Despite this, Argentina continues to maintain its claims to sovereignty over the Falkland Islands, and the British government continues to dispute their claims (Clare, 2024). Victory in the war strengthened the political position of the ruling Conservative government in the UK, and in general the British turned decisively away from any willingness to concede sovereignty over the islands to Argentina. To guard against a future invasion, the British elected to fortify the Falklands in the aftermath of the war, establishing a permanent military garrison and constructing a military airfield (Hastings &

Jenkins, 2012). The British government also invested resources in the Falkland Islands economy, improving the quality of life for the island's residents (Blair, 2017).

The most significant environmental disruptions associated with the strategic level of the Falklands War occurred in the post-war context in the Falkland Islands themselves in the form of changed patterns of land-use and a changed economic pattern that generally benefitted the local residents (Blair, 2017). Because of the suddenness of the conflict, neither Argentina nor the UK significantly altered their strategic posture prior to the outbreak of hostilities in the preparation context, and the war's short duration meant that neither side significantly altered their economic or military base during the wartime context either. Thus, the enduring local-scale disruptions of the strategic level of war consist almost exclusively of the military infrastructure that the UK constructed in the Falklands after the war's conclusion.

4.2 Operational Level Analysis of the Falklands War

The remoteness, environment, and low level of economic development of the Falkland Islands created severe military challenges at the operational level of war for both sides in the conflict. The islands lie more than 400 miles from southern Argentina and more than 8,000 miles from Britain (Figure 7.1). Moreover, the infrastructure of the islands at the time of the conflict posed further challenges. Only one port, Port Stanley, could handle large ships, and only three airfields existed on the islands, none of which were long enough to accommodate high performance military aircraft (Privratsky & Thompson, 2016). Thus, both sides were forced to stage most of their naval and air power from bases outside of the Falklands. For the British, the closest such staging base was Ascension Island in the central Atlantic, while the Argentinians

used bases in southern Argentina and Patagonia, including Puerto Belgrano, Trelew, and Ushuaia. This meant that whichever side was able to dominate the sea and airspace around the Falkland Islands would effectively be able to cut the other side off from their bases of supply and support.



Figure 7.1 Strategic and operational level naval and air activities of the 1982 Falklands War.

In terms of forces involved, the British redeployed naval units from the Caribbean, Mediterranean, and North Seas to form the Task Force that sailed for the Falklands (Chant & Rolfe, 2001). This force included two small aircraft carriers capable of operating the Sea Harrier jump jets that would form the only source of persistent air cover for the British forces (White, 2020). The rest of the naval force included several destroyers and numerous smaller frigates, as well as the Royal Navy's amphibious assault ships and various logistical vessels. Finally, the British also used the converted passenger liner *Canberra* as a vital troop transport and the cargo vessel *Atlantic Conveyor* as an improvised aircraft carrier to move additional Harriers and heavy lift Chinook helicopters to the South Atlantic (Hastings & Jenkins, 2012). The naval force also carried many smaller helicopters of various types (Chant & Rolfe, 2001). Other than the shipborne aircraft, the only other significant air assets available to the British in the Falklands were long-range aircraft flying from Ascension Island, which included several Vulcan heavy bombers, tanker aircraft, and electronic warfare aircraft (Bird & Tooby, 2023).

UK ground forces included two infantry brigades, both based in Britain, though at least one battalion had been deployed to southeast Asia for training at the conflict's outset (Gardiner, 2012). These ground forces possessed little mechanization besides a few light tanks and over-snow tracked vehicles designed for operations in Norway. The British anticipated using helicopters to maneuver their ground forces once they were ashore on East Falkland (Hastings & Jenkins, 2012). However, the Argentinians succeeded in sinking *Atlantic Conveyor* before the British could offload the transport helicopters the ship was carrying, thus forcing the British ground forces to maneuver largely by foot (Gardiner, 2012). Lacking a port, British ground forces had to rely upon ship-to-shore landing craft and smaller helicopters to deliver supplies

from the naval Task Force to units ashore after their successful landing at San Carlos on the west side of East Falkland (Privratsky & Thompson, 2016).

Argentina possessed a large and relatively modern navy at the time of the conflict, which included one aircraft carrier and the Second World War-era cruiser *Admiral Belgrano* (ex-USS *Phoenix*), purchased from the United States (Chant & Rolfe, 2001). The Argentinian Navy operated from bases along the country's southern coast. However, after the sinking of the *Admiral Belgrano* by the British nuclear-powered submarine HMS *Conqueror* on 2 May 1982, the majority of the Argentinian Navy returned to port and did not participate meaningfully in the remainder of the conflict (Hastings & Jenkins, 2012). This left air power as the primary means of support for the Argentinian ground forces on the Falklands. A British air raid damaged the Port Stanley Airport runway on 1 May, further constricting its utility as a logistics entrepôt for the Argentinians, and British Harriers later managed to shoot down several transports inbound to the islands, prompting the Argentinians to largely suspend resupply operations (Hastings & Jenkins, 2012). Thus, at the operational level of war, once the opposing ground forces were deployed on East Falkland Island, both were heavily constrained in terms of logistics. The British were limited by what they were able to move by sea from the northern hemisphere and by how quickly they were able to transfer supplies from ship to shore, and the Argentinian forces were dependent upon the supplies they had been able to move to the Falklands prior to the arrival of the British naval Task Force.

Overall, then, few areas that enabled the operational maneuver of the opposing forces in the Falklands War experienced disruption that was significantly different from peacetime activity. One exception includes Ascension Island, where UK forces staged prior to sailing south. The military airfield and port there experienced far higher volumes of air and sea traffic during

the conflict, while British forces conducted training exercises on the island in areas that had not previously acted as reserves for military training activities (Gardiner, 2012). Two more exceptions include Port Stanley, where the airport and port facilities likewise experience far higher levels of through traffic, and the inlet at San Carlos Water, where the British forces landed. Finally, the waters around the Falklands and the southern coast of South America represented the operational maneuver area for both fleets, with related naval activity causing disruptions that will be discussed in the analysis of the tactical level of war below.

4.3 Tactical Level Analysis of the Falklands War

The tactics employed by both sides reflected both the relative strengths and weaknesses of the forces involved and the constraints of the terrain and situation of the conflict zone. Both sides were relatively well-equipped with modern weapons and supplies for their sea, air, and land forces (Gardiner, 2012). However, the remoteness of the islands and the terrain's ruggedness meant neither side could employ massed firepower with heavy weapons in a decisive way, due to difficulties in moving and stockpiling ammunition (Martin & Thompson, 2018). At sea, the boldness of the Royal Navy rapidly gained the British dominance in the air and sea around the Falklands, though the naval Task Force was too small to totally prevent the Argentinians from reinforcing and resupplying their forces (Chant & Rolfe, 2001). In the air, the British Sea Harrier jets performed beyond expectations as air-to-air fighters but were too few to decisively defeat incoming Argentinian raids (White, 2020). Similarly, the distance from Argentina to the Falklands meant that the Argentinians were never able to decisively mass their air attacks against the British naval units due to fuel and range constraints (Hampshire & Turner, 2021). On land,

the rugged terrain and lack of supplies for both sides meant that heavy weapons such as mortars and artillery could not be used by either side to decisively destroy their enemies, resulting in battles that were often decided by small arms fire between infantry forces (Privratsky & Thompson, 2016).

In the naval battle, the British forces used tactics designed to both cut off Argentinian naval forces from the Falkland Islands and protect the mission vital ships of the Royal Navy fleet, namely the two aircraft carriers and the amphibious assault ships and troop transports (Chant & Rolfe, 2001). The Royal Navy forces employed a layered approach to achieving these two objectives. The outer layer consisted of a group of nuclear-powered submarines that established a screen between the south American mainland and the Falklands to provide reconnaissance of Argentine naval movements and to engage Argentine naval units before they could threaten the British Task Force. The most significant engagement that occurred in this zone was the sinking of *Admiral Belgrano* by HMS *Conqueror*. This engagement included the torpedoing of the Argentine cruiser by the British submarine, as well as an attempted counterattack by escorting Argentine frigates using active sonar sensors and depth charges (Sciaroni, 2019). *Admiral Belgrano* sank in deep water west of the southern tip of South America, where the wreck remains today.

The next layer of the British tactical concept for isolating the Falklands consisted of establishing a total exclusion zone around the islands, in which any Argentinian ships or aircraft would be attacked without warning (Hastings & Jenkins, 2012). British aircraft and helicopters sank several small Argentinian craft in coastal waters around the islands during the war, but no major Argentinian naval units chose to challenge the British after the sinking of *Admiral Belgrano* (Chant & Rolfe, 2001).

The final layer of the British tactical construct was the actual defense of the Task Force ships. These defenses consisted first of the Sea Harrier jets aboard the two British aircraft carriers, which patrolled with missiles and cannon to shoot down threatening enemy aircraft (White, 2020). Enemy strikers that penetrated the Sea Harriers were to be engaged by long- and short-range surface-to-air missiles (SAMs) from the Task Force's ships and, later, from land-based batteries that were established around San Carlos after the British landings (Hastings & Jenkins, 2012). Finally, attacking aircraft were to be engaged by gunfire from the ships as a final defense.

The attempts by the Argentinian air force to penetrate this defensive scheme and destroy the British Task Force represented the climactic struggle of the Falklands War. Both sides suffered heavy losses both before and after the British landings at San Carlos. The Argentinians possessed a small number of French-manufactured Exocet anti-ship missiles, which they used to sink the destroyer HMS *Sheffield* and the container ship *Atlantic Conveyor*, both in deep water (Hastings & Jenkins, 2012). Argentinian aircraft also attacked British ships from very low altitude with unguided bombs and cannon fire, especially in the waters of San Carlos inlet and Falkland Sound, and at the subsequent British landing site at Fitzroy on the southern coast of East Falkland. These attacks resulted in the sinking of two Royal Navy frigates in Falkland Sound, the destruction of the beached landing ship *Sir Galahad* at Fitzroy, and the sinking of the destroyer HMS *Coventry* north of Falkland Sound (Hastings & Jenkins, 2012). Up to one hundred Argentinian aircraft were destroyed in these attacks, and other operations, during the war along with several dozen British jets and helicopters, all of which crashed into the waters around the Falklands or on the islands themselves.

The land combat component of the Falklands War was largely a light infantry affair supported by light artillery, naval gunfire, and aircraft-delivered bombs and rockets (Gardiner, 2012). Neither side possessed significant numbers of vehicles on the islands, nor was the terrain particularly amenable to cross-country movement by vehicles (Privratsky & Thompson, 2016). Thus, once the British successfully landed at San Carlos water, the fighting consisted mostly of the British forces moving by foot overland to attack largely static Argentinian defensive positions around the Island's major settlements (Gardiner, 2012). Both sides attempted to use helicopters to ferry troops to points of action, but the loss of most of the British heavy-lift helicopters aboard *Atlantic Conveyor* and the loss of control of the air over the islands by the Argentinians to the British Sea Harriers meant that very few personnel and little equipment moved by air after the British landings (Hastings & Jenkins, 2012).

The initial British land operations on the Falkland Islands consisted of special forces attacks to recapture South Georgia and to destroy Argentinian attack aircraft at an improvised airfield on Pebble Island off the northern coast of West Falkland (Hastings & Jenkins, 2012; McKay & Cooksey, 2017). Both operations, though not especially deadly, were still destructive with regards to equipment losses for both sides. Between 21 and 25 April, the British conducted several insertions of Special Boat Service (SBS) commandos onto South Georgia. During these insertions, the British lost two helicopters in crashes on the island due to weather, though these did not cause any casualties (Hastings & Jenkins, 2012). At the same time, the Argentinian submarine *ARA Santa Fe* was resupplying the garrison at the whaling settlement at Grytviken, which had fortified the area with some minor obstacles including landmines. British helicopters attacked the submarine and damaged it sufficiently that the crew were forced to ground the vessel at the Grytviken pier and then join the garrison. An *ad hoc* invasion force of Special Air

Service (SAS) and SBS commandos then landed by helicopter near Grytviken and, aided by naval artillery fire, forced the Argentinians to surrender (Hastings & Jenkins, 2012). The only fatality from this action was a single Argentinian sailor from the Santa Fe, who was killed in a misunderstanding after having surrendered.

Unlike the situation at South Georgia, the British raid on the improvised Argentinian airfield at Pebble Island was intended to destroy light attack aircraft that the Argentinian Air Force had stationed there after seizing the Falklands (McKay & Cooksey, 2017). In this action, a force of British SAS commandos landed by helicopter on the night of 14-15 May 1982 and proceeded to attack the parked aircraft with incendiaries, explosives, and gunfire, damaging or destroying all eleven Argentinian aircraft at the air strip. As the commandos withdrew, the British used naval gunfire to destroy the strip's ammunition and fuel dumps as well. One Argentinian marine was killed in the action and one British commando was wounded.

The decisive phase of the British operation to recapture the Falkland Islands began with the amphibious landing of 3 Commando Brigade, composed of British Para and Royal Marine Battalions, at San Carlos on the western coast of East Falkland, facing Falkland Sound, on the night of 21 May 1982 (Hastings & Jenkins, 2012). The British forces landed against only token opposition and quickly fortified the heights surrounding the inlet by digging fortifications and the establishing supply dumps (Gardiner, 2012). British units, including the ground forces and ships in the inlet and Falkland Sound, weathered heavy Argentinian air attacks over the next several days. In addition to the naval losses already mentioned, these attacks resulted in the destruction of at least one British fuel and ammunition dump, as well as the loss of at least two British helicopters to enemy fire (Hastings & Jenkins, 2012; Gardiner, 2012) (Figure 7.2).

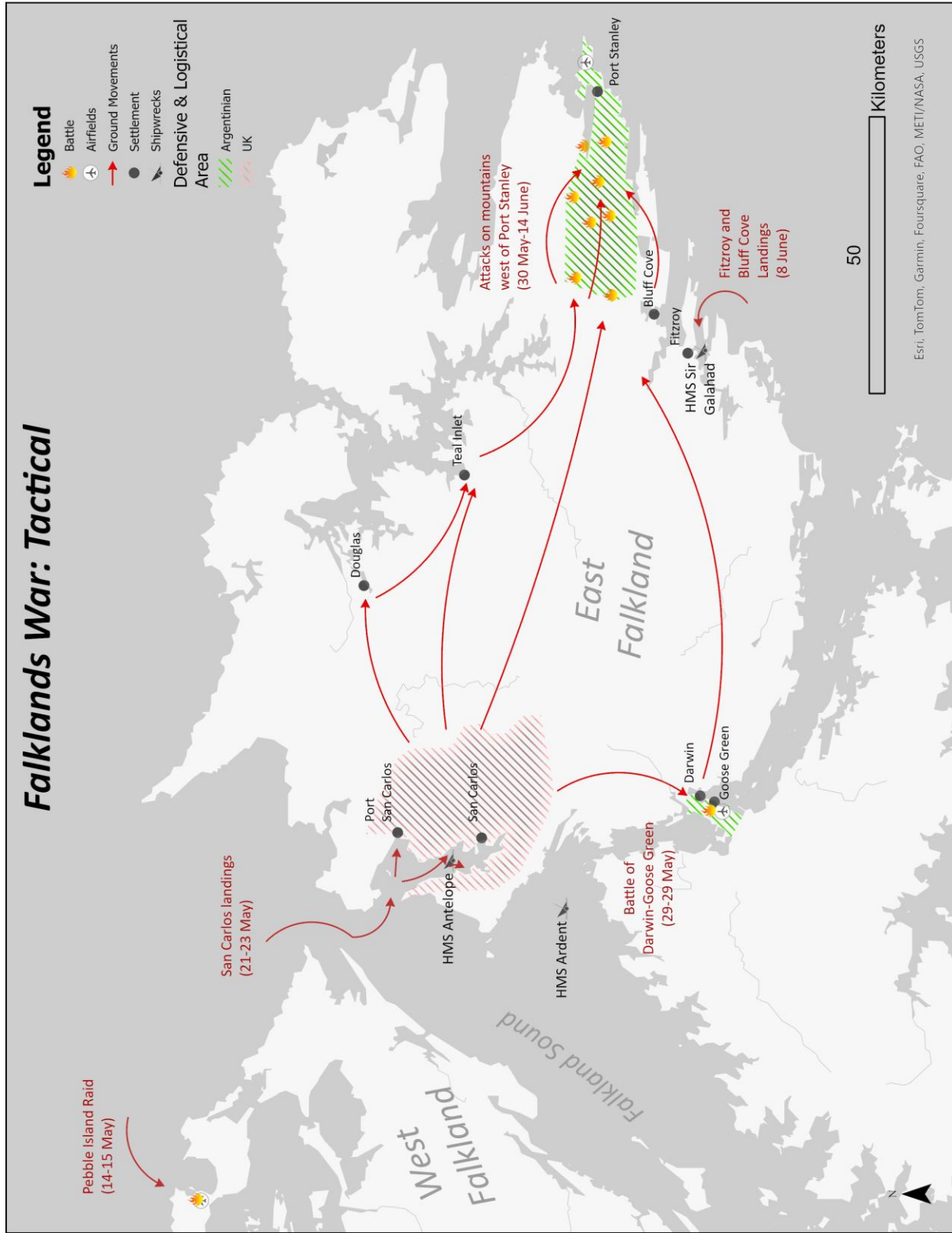


Figure 7.2 Tactical level ground activities of the 1982 Falklands War

Once the British forces had built up sufficient strength at San Carlos, a battalion moved south by foot to attack the Argentinian garrison at the settlements of Darwin and Goose Green in what would be one of the sharpest land battles of the war (Adkin, 2017). The Argentinian forces defending the settlements and the small airfield that serviced them had constructed bunkers and fighting positions for their heavy weapons and had also laid minefields along likely landward avenues of approach and to protect against seaborne landings (Adkin, 2017). The British forces attacked on the night of 28-29 May 1982 with artillery support from 105-millimeter howitzers, mortars, and naval gunfire. The Argentinian forces resisted, supported by fire from their own 105-millimeter howitzers and from anti-aircraft guns stationed at the airstrip. After intense fighting with relatively heavy casualties on both sides, including the commander of the attacking British battalion and the sinking of the frigate HMS *Ardent* by air attack, British Sea Harriers tipped the battle in their side's favor by silencing the Argentinian support fire with cluster munitions dropped on the enemy heavy weapons positions (Hastings & Jenkins, 2012). The surviving Argentinian forces subsequently surrendered.

Thereafter the British forces at San Carlos and Darwin-Goose Green proceeded to move, mostly by foot, cross-country across central and southern East Falkland against minimal opposition (Gardiner, 2012). The small, mechanized portion of the ground force consisted of a detachment of light tanks and a few over-snow vehicles used to transport supplies. The British conducted at least one amphibious operation to move their troops towards Port Stanley more rapidly, landing elements of 5 Infantry Brigade at Bluff Cove (Hastings & Jenkins, 2012). However, this ended in disaster when Argentinian aircraft attacked the beachhead, destroying the landing ship HMS *Sir Galahad* on the beach and killing forty-eight sailors and soldiers in the process.

The opposing Argentinian forces had fortified the hills to the west of Port Stanley to defend the islands' key settlement by constructing rudimentary bunkers with native rock and other material (Pollard, 2022). Digging was difficult in the hills, due to the rocky soil, but the Argentinians did deploy extensive minefields along likely avenues of approach and planned to support their defending infantry with artillery around Port Stanley, including some heavier 155-millimeter guns (van der Blij & Thompson, 2015). The British infantry sequentially attacked these hilltop defensive positions during the first two weeks of June 1982, supported by mortars, 105-millimeter howitzers, and naval gunfire. Once the British forces gained control of these heights overlooking Port Stanley, the Argentinian commander determined that his military position on the Falklands had become untenable and elected to surrender his forces, effectively ending the tactical portion of the war except for the subsequent occupation of Port Stanley by British troops (Hastings & Jenkins, 2012).

5. Step 2: Identification and Location of Likely Environmental Impacts of the Falklands War

Despite its relatively small size and short duration, (April-June 1982) the Falklands War produced numerous long-lasting disruptions in the local landscape and surrounding seas, as well as a few potential disruptions further afield. Table 7.3 highlights the probable disruptions that military action created during the conflict in the preparation, war, and postwar contexts of the conflict based on the operational analysis. The pairing of an operational analysis of military operations conducted during the Falklands War with the taxonomic classification of the likely disruptions caused by these operations illustrates the value that both forms of examination bring

to creating a more holistic understanding of the environmental consequences of the conflict, as will be more fully described below.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 7.3 Likely environmental disruptions caused by the Falklands War (highlighted in gray)

In the lithosphere, the Falkland War produced incidents of all forms of mechanical and biological disruption, and three of the four forms of chemical disruption. Indeed, the only mechanical disruptions that the Falklands War did not produce are those associated with chemical and nuclear or radiological weapons, which only the British possessed and whose use was never considered.

Neither side conducted significant construction and excavation activity in the preparation context. In the context of wartime operations, Argentinian forces dug and built fortifications for their forces on East Falkland at three primary locations: Darwin-Goose Green, the hill systems west of Port Stanley, and around Port Stanley proper. The British forces only dug significant defensive works in one location, covering their beachheads around San Carlos water. In the postwar context, the British government financed the construction of a new military airfield, named RAF Mount Pleasant, on the southern side of East Falkland. This base is serviced by a newly built Royal Navy anchorage on the island's southern coast at Mare Harbour.

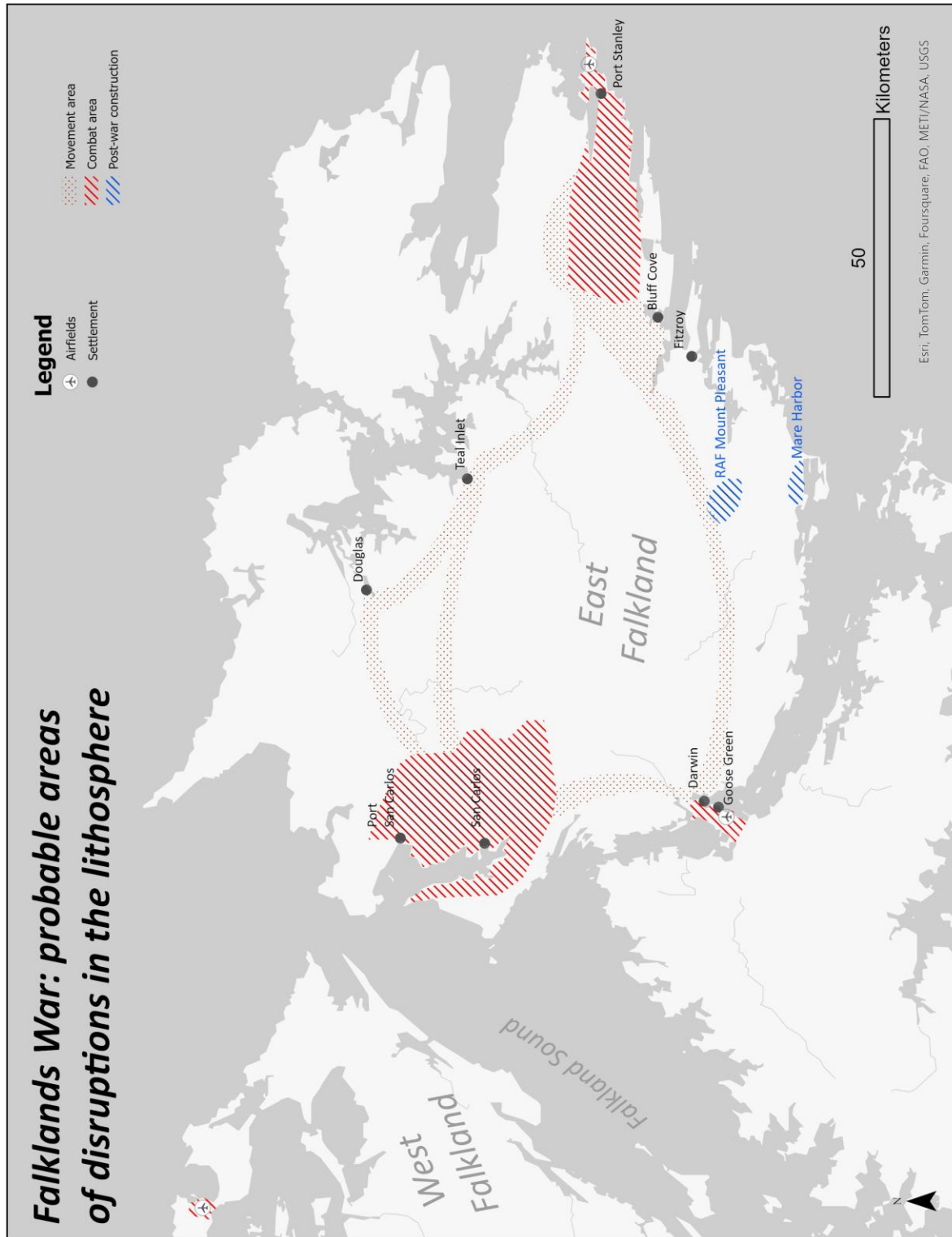


Figure 7.3 Areas of likely major environmental disruption in the lithosphere associated with the Falklands War. Combat areas are likely locations of construction and excavation-related disruptions, as well as deposition and chemical spills. Movement areas are likely locations for deposition and soil compaction.

Areas that became important defensive and logistical areas, and thus areas where combat occurred during the conflict, experienced several other forms of disruption, including the deposition of landmines and other detritus of war (Figure 7.3). Indeed, the Argentinian forces employed landmines extensively to protect their defensive positions, while British forces employed air-delivered cluster munitions at the Battle of Darwin-Goose-Green and elsewhere. These areas are also likely locations for whatever cratering occurred due to artillery fire or aerial bombs, though the small caliber of artillery employed, and the soft ground likely limited the size and longevity of any craters. Finally, the areas of the Falkland Islands where combat occurred are also the most likely to have experienced the slow violence effects of petroleum spills, explosive residue, and heavy metal contamination. Indeed, Argentinian air attacks destroyed at least one fuel and ammunition dump at the San Carlos beachhead, while British attacks struck numerous Argentinian supply nodes around Darwin-Goose Green and Port Stanley, causing uncontrolled spills and detonations of these materials.

Areas through which ground forces moved on East Falkland likely experienced a different mix of disruptions. British forces marched generally around the northern and southern edges of the island, avoiding cross-country movement through the rugged interior. These corridors are likely areas where the footfalls of thousands of soldiers and dozens of tracked vehicles caused compaction of the soil. Moreover, the process of maintaining several thousand soldiers in an austere environment may have resulted in further acts of deposition as soldiers cast off trash from used ration containers and other items.

The postwar fate of the Falklands terrestrial landscape presents an interesting example of the importance of the ideological and political meaning that governments can ascribe to a

conflict's outcome. As noted, prior to the war the British government viewed the Falklands and their inhabitants as an economic and diplomatic liability. After the British victory in the conflict, which developed a narrative of having halted the UK's national decline in the post-Second World War period, the Falklands became an emblem of military prowess and national boldness. The British government invested funds in the Falklands economy, both for post-war recovery and to improve the general economic conditions for the local Falklanders. The land mine clearance issue illustrates this commitment. After Argentinian forces sowed the Falklands landscape with thousands of anti-personnel landmines, the local Falklands government advocated simply abandoning the areas affected by this disruption, noting that clearing these hazards would be far more expensive than the recovered landscapes were worth (McAdam, 2013; Rein et al, ND). The government in London, however, due to its ideological and political commitment to both the recovery of the Falklands and to its responsibilities under the UN's Land Mine treaty, devoted resources to clearing all mines by 2019. In 2020, the effort concluded with the ceremonial detonation of the last landmine on the Falklands (Sandle, 2020, November 10). This result contrasts many other conflicts and landscapes, where the comprehensive clearing of deposited explosive hazards is deemed too expensive to remediate, illustrating the importance of ideological forms of social power to the recovery of post-war landscapes.

The hydrosphere also experienced significant mechanical and chemical disruption during the Falklands War, especially the ocean and coastal waters around the islands. These may have created long-lasting conditions of slow violence in the biosphere, especially near the numerous shipwrecks resulting from the conflict. This illustrates the inherently amphibious and expeditionary nature of the Falklands War specifically and warfare in high latitudes more generally. The amount of naval activity and the scale of naval losses was large given the

relatively short duration and overall scale of the conflict, creating correspondingly large disruptions where naval forces operated.

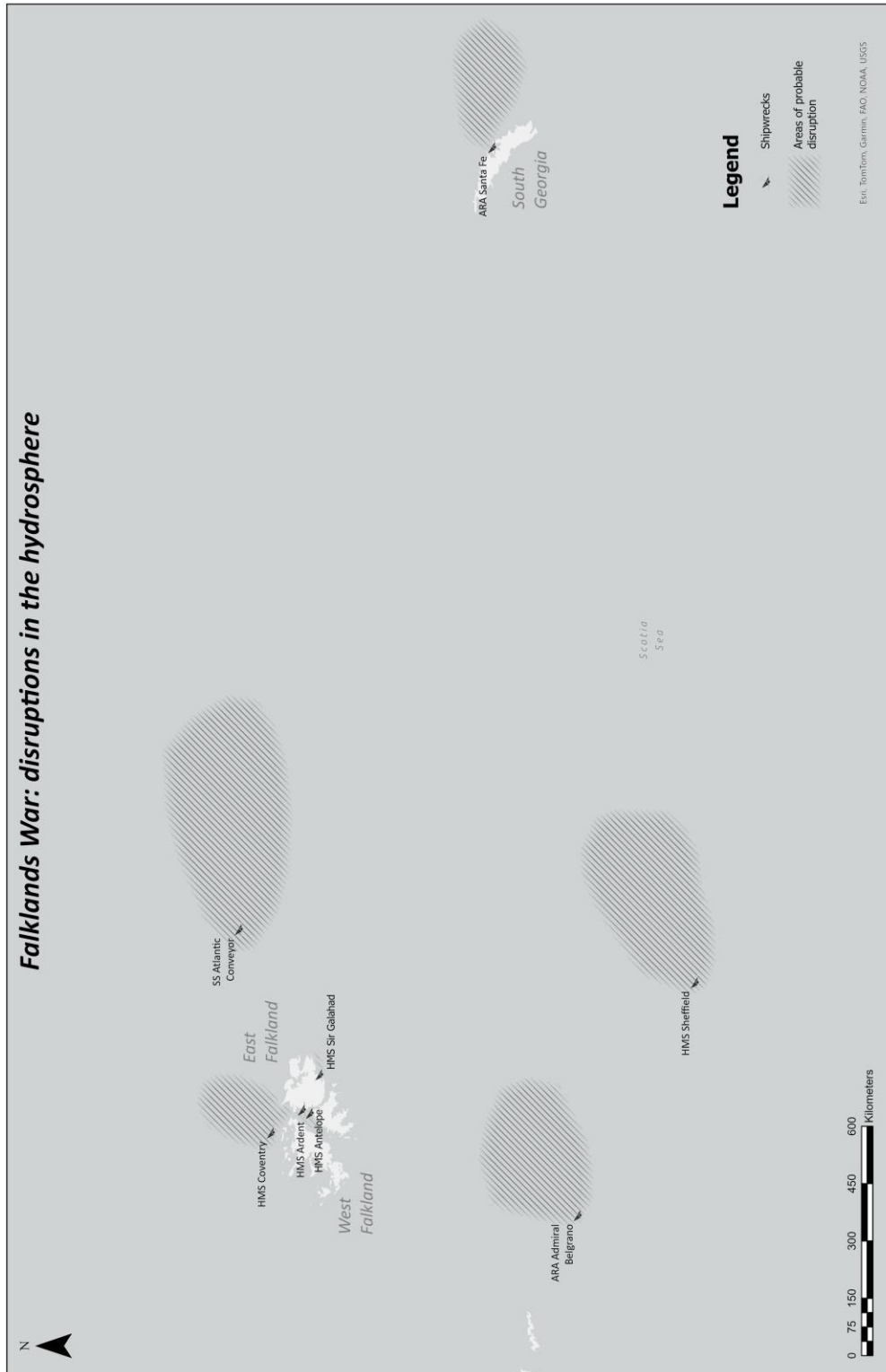


Figure 7.4. Likely areas of chemical contamination in the waters around the Falklands islands considering the location of military shipwrecks and dominant ocean currents.

Noise and blast energy in the hydrosphere are the first forms of disruption caused by the conflict, though also probably the most transitory. Both sides employed modern ships and submarines equipped with active sonar sensors, augmented by active sonar sensors carried by both fleet's anti-submarine warfare (ASW) helicopters. Both sides used these sensors extensively to locate and prosecute enemy submarines (Sciaroni, 2019). Similarly, both sides employed ordnance that detonated in the water, including torpedoes, depth charges, missiles, and aerial bombs. Indeed, given that the Argentinian air force employed mostly unguided bombs to attack British ships, far more of these weapons struck the surface of the ocean as opposed to their targets. However, as many histories of the conflict have noted, many if not most of the Argentinian bombs failed to detonate (Hastings & Jenkins, 2012).

The more long-lasting disruptions in the hydrosphere ecological habitat caused by this conflict include the deposition of numerous shipwrecks onto the ocean floor and their likely chemical contamination of the surrounding seascape. Eight large ships, as well as several smaller vessels, were sunk during the war. Of these, four sank in shallow coastal waters near the Falklands and South Georgia, while five went down in the deeper waters of the Southern Ocean. Six of the eight shipwrecks sank with all their stores, including fuel, ammunition, and other reactive materials (Chant & Rolfe, 2001). Two, ARA *Santa Fe* and HMS *Sir Galahad*, were destroyed in waters too shallow to submerge them. In the post-war context, these were eventually stripped of their toxic materials before being towed into deeper waters and scuttled. Furthermore, Royal Navy divers retrieved some of the more advanced ordnance and equipment from the two British frigates that sank in Falkland sound to prevent their technology from falling into the hands of third parties (Hoare, 2022, June 13). Overall, however, as with modern military

shipwrecks around the world, the Falkland War losses represent point sources for the slow seepage of hydrocarbons, explosive residue, and heavy metals into the ocean, to be carried far from their source by the local currents (Figure 7.4).

Disruptions in the atmosphere during the Falklands War included the noise and blast energy created by the sea, land, and air battles that occurred during the conflict, as well as toxic fumes created by the burning of military equipment and supplies. The second type of disruption is the more concerning because it bears the greater potential for creating conditions of slow violence in other spheres. As already noted, attacks that resulted in toxic burning of military equipment occurred in the San Carlos beachhead area, Darwin-Goose Green, and around Port Stanley, as well as the Pebble Island airstrip and the site of the destruction of HMS *Sir Galahad*. The sites of individual aircraft crashes around East Falkland also represent potential point sources of toxic burning. Overall, however, the small scale of the Falklands conflict and the logistical challenges experienced by both sides meant that the actual amount of material available to be burned was relatively small, and the short duration of the conflict meant that such violence was more localized than widespread.

Finally, the Falklands War resulted in important changes to the biosphere both during and after the conflict. Perhaps the most striking of these is the way the war temporarily expanded the human population of the Falkland Islands. The peacetime population of the Falklands in 1982 was approximately 3,000 individuals (Hastings & Jenkins, 2012). At the height of the battle for East Falkland, both sides had deployed a combined total of approximately 25,000 military personnel. Prior to the war, the British had maintained only a small contingent of a few dozen Royal Marines at Port Stanley. Afterwards, the British established a much larger garrison to deter future Argentinian aggression. This force consists of a permanent rotating force of several

hundred military personnel, which represents a significant proportional increase in the islands' permanent population (McAdam, 2013). This garrison, as well as the already-mentioned investments made by the British government in the Falklands' post-war economy, represent changes from the pre-war context that have altered local economic patterns (Blair, 2017).

Chemical disruptions to the biosphere include consequences of the contamination already mentioned in the lithosphere and the hydrosphere. These may have resulted in degraded food chains for the local fauna. Indeed, as will be discussed in the next section, some species of local wildlife appear to have suffered significant population reduction since 1982, a trend likely due in part to the widespread chemical disruption of the biosphere caused by the war (Bingham, 2002; Panel & Pietri, 2022). Finally, the war also resulted in the killing of at least a few large animals, as both sides reported mistaking whales for enemy submarines at various points during the conflict (Chant & Rolfe, 2001).

6. Current Research Examining Falklands War Disruptions

Several research projects since 1982 have examined various aspects of the Falklands War's environmental legacy. Table 7.4 highlights which potential disruptions identified in the preceding section have been the subject, either directly or indirectly, of empirical scientific studies since the war's conclusion. As this table shows, numerous gaps still exist in the literature examining the environmental impacts of the conflict, highlighting the value of the heuristic for both directing inquiries towards these areas and estimating the impacts of unstudied disruptions.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 7.4 Reproduction of the taxonomy outlined in Chapter 4. Disruptions caused by the Falklands War featured in scientific studies are highlighted in green, while probable disruptions that have yet to be studied are highlighted in gray.

Regarding disruptions in the lithosphere, studies have originated from two primary sources. The first include extensive battlefield archeology studies, which have documented much of the still-existing mechanical disruptions in the Falklands landscape (Pollard, 2016 & 2022; Clack & Pollard, 2023). These studies mapped the locations of trench and fortification systems associated with the war and the location of craters and detritus from the conflict. The second source represents studies about the removal of landmines from the Falklands landscape since 1982. These help to provide a picture of the geographic distribution of this form of deposition in the lithosphere, as well as the effects of landscape abandonment in the conflict's aftermath over the past four decades (McAdam, 2013; Rein *et al*, ND). The archeological research shows that

even the very basic fortifications constructed by both sides in the Falklands remain evident more than forty years after abandonment. However, nothing in these studies indicates that these disruptions represent anything more than a difference in the landscape, as opposed to any form of ecological damage. The fate of landmines and unexploded ordnance on the islands was different, however. As noted, the British government devoted resources to clearing the Falklands landscape of depositional hazards, though this remediation took nearly forty years to complete.

Another long-lasting form of mechanical disruption in the lithosphere of the Falklands is the fate of the bodies of soldiers who died there. During the war, fallen soldiers' bodies were interred in hasty graves near where they died. Postwar, these bodies were exhumed. The fate of these remains is illustrative of how ideological and political forms of social power can affect the fates of postwar landscapes. The British established a military cemetery, the Blue Beach Cemetery, near the San Carlos beachhead (Atlas Obscura, ND). However, after the war, most families of the fallen British soldiers elected to have their loved ones' remains transported back to Britain for final interment, reflecting the Falkland Islands' enduring status as a distant colonial possession of the UK's metropole. As such, only fourteen British service members are buried at Blue Beach, including one who died in an accident years after the conclusion of hostilities. The Argentinians, by contrast, refused a British offer to return the bodies of their fallen soldiers to Argentina, stating explicitly in their justification that the Malvinas *are* Argentina. Thus, the Argentinian Military Cemetery near Darwin holds the remains of 236 fallen soldiers (Bellot, 2021). Both cemeteries contain memorials to the fallen and are maintained by local residents who are paid by the British and Argentinian governments for their services.

In the hydrosphere, studies about the ecological consequences of chemical disruptions originate from a source studying impacts tangential to the Falklands conflict. Recent oil

exploration in Falklands waters has prompted studies examining hydrocarbon pollution. None, however, attempt to distinguish the polluting effects of oil spills from Falklands War shipwrecks (Hopkins & Ollevent, 2002). This highlights one possible broad conclusion from the study of the ecological effects of war in general; while the disruptions of war can be severe and long-lasting, they can pale in comparison to the those caused by peacetime economic activities, which often occur at a greater scale and over longer periods than war-related actions.

Studies of the ecological health of the biosphere around the Falkland Islands provides one possible proxy for the post-war health of the lithosphere and hydrosphere. Blair (2017 & 2022) and Panel and Pietri (2022) both noted that the population of King penguins around the Falklands has declined significantly since 1982. These studies all attribute this decline to the effects of oil leaking from Falklands War shipwrecks that have contaminated the penguins' food web. However, in an earlier study, Bingham (2002) cited increased commercial fishing and commercial oil spills from offshore drilling as the likely culprit for this decline. None of these studies contain a spatial analysis of the relative locations of shipwrecks, oil exploration sites, and commercial fishing grounds as compared to the habitat and feeding areas for the penguin population, making it difficult to assess which factor may be most detrimental to the hydrological ecology of waters around the Falklands. This highlights the need for further analysis that considers not just the location of military shipwrecks, but also the probable dispersal of pollutants.

Overall, then, the longest lasting environmental disruptions associated with the Falklands War are evident in the lithosphere, hydrosphere, and biosphere around the islands, with those in the linked hydrosphere and biosphere being apparently the most damaging ecologically. Many research gaps persist, however. Many of the significant impacts of the war, including petroleum

spills and other forms of chemical contamination in the lithosphere, remain unstudied.

Furthermore, the link between chemical contamination in the hydrosphere and its effects on the marine biosphere remains poorly understood.

7. Step 4: Applying the Heuristic

The first step in using the heuristic tool to analyze the Falklands War is to grade the acuteness of disruptions that occurred according to its established topology and grading schemes. This is challenging in at least two ways. First, as noted above, many of the potential impacts identified by the taxonomic analysis of the conflict (Table 7.4) have yet to be the subject of any meaningful scientific inquiry. For the sake of this analysis, these impacts will receive the “maximum” grade of destructiveness. Alternatively, an attempt could be made to approximate the actual impacts of these disruptions based on circumstantial evidence and educated guesswork which might, in the end, provide a more accurate assessment of acuteness. However, using the maximum possible acuteness based on a broad analysis of empirical evidence seems a more appropriate method. Secondly, the fact that the conflict occurred little more than four decades ago makes the timescale for analyzing the duration of slow violence in the environment problematic. Here again, the effects of a particular disruption, including those that have received scientific attention since 1982, will be assumed to last for their maximum possible duration unless an existing study has documented that the effects of the disruption have disappeared or reasoned evidence can reliably predict that the disruption will disappear sooner than the worst-case scenario. Table 7.5 then indicates the resulting grading for the environmental disruptions associated with the Falklands War.

Earth sphere	Mechanism	Direct violence	Context of direct violence	Slow violence (spatial)	Slow violence (timescale)	Slow violence (severity)	Slow violence (acuteness)	
Lithosphere	Mechanical	Construction and excavation	War, post-war	Local	Decades	Difference	1 (Minimal)	
		Deposition	War, post-war	Local	Decades	Disturbance	2 (Moderate)	
		Cratering	War	Local	Decades	Difference	0 (No impact)	
	Biological	Soil compaction	War	Local, regional	Local, regional	Decades	Disturbance	1 (Minimal)
		Explosive residue	War	Local	Local	Decades	Disturbance	1 (Minimal)
		Metal residue	War	Local, regional	Local, regional	Centuries	Disturbance	2 (Moderate)
		Petroleum product spills	War	Local, regional	Local, regional	Decades	Degradation	2 (Moderate)
		Habitat destruction	War	Local, regional	Local, regional	Decades	Disturbance	1 (Minimal)
		Landscape abandonment	Post-war	Local, regional	Local, regional	Decades	Disturbance	1 (Minimal)
		Noise and blast energy	War	Local, regional	Local, regional	Years	Disturbance	0 (No impact)
Hydrosphere	Mechanical	Deposition	War	Local, regional	Millennia	Difference	2 (Moderate)	
		Hydrocarbon spills	War, post-war	Local, regional	Decades	Degradation	2 (Moderate)	
	Chemical	Explosive residue	War	Local	Decades	Disturbance	1 (Minimal)	
		Metal residue	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	
	Biological	Habitat disruption	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	
		Noise and blast energy	War	Local	Years	Disturbance	0 (No impact)	
		Burning of toxic materials	War	Local, regional	Weeks	Degradation	1 (Minimal)	
		Military deployments	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)	
		New economic patterns	Post-war	Local, regional, global	Centuries	Disturbance	2 (Moderate)	
		Chemical/metal poisoning	War, post-war	Local	Decades	Degradation	2 (Moderate)	
Biosphere	Chemical	Food chain contamination	War, post-war	Local, regional	Decades	Degradation	2 (Moderate)	
		Burning	War	Local, regional	Years	Disturbance	0 (No impact)	
	Biological	Habitat alteration	War, post-war	Local, regional	Years	Disturbance	0 (No impact)	
		Killing	War	Local, regional	Decades	Disturbance	2 (Moderate)	

Table 7.5 Grading of the acuteness of the environmental impacts of the Falklands War.

This analysis then supplies the data needed to generate the visualizations illustrating the results of the heuristic model through an additive compilation of the identified disruptions (Table 7.6). The resulting “real war” composite grades within each sphere are then divided by the “absolute war” theoretical maximums to provide a ratio of how destructive the Falklands War was in comparison to a theoretical absolute war. The ratio is then multiplied by 10 to cosmetically place the ration on a grading scale of 0-10, with 0 being no impact and 10 being the maximum theoretical impact as identified in Table 6.6. These scores then feed visualizations (Figure 7.5) that provide a quick reference for the relative acuteness of impacts within each sphere and for the conflict overall.

		Mechanical			Chemical			Radiological			Biological			Composite ratio		
		Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global
Lithosphere (.34)	Postwar	4	0	0	0	0	0	0	0	0	0	0	0	3.64	0.00	0.00
	War	5	1	0	5	4	0	0	0	0	2	2	0	5.45	4.67	0.00
	Preparation	0	0	0	0	0	0	0	0	0	2	2	0	1.00	1.33	0.00
Hydrosphere (.33)	Postwar	0	0	0	3	3	0	0	0	0	1	1	0	3.64	3.64	0.00
	War	2	2	0	4	3	0	0	0	0	1	1	0	3.18	3.53	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Atmosphere (.06)	Postwar	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	War	0	0	0	1	1	0	0	0	0	0	0	0	3.33	3.33	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Biosphere (.27)	Postwar	1	1	0	4	2	0	0	0	0	2	2	1	6.36	6.25	5.00
	War	1	1	0	5	3	0	0	0	0	4	4	0	6.67	8.89	-
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	-
Overall	Postwar	5	1	0	7	5	0	0	0	0	3	3	1	4.41	3.21	0.63
	War	8	4	0	15	11	0	0	0	0	7	7	0	4.84	5.00	0.00
	Preparation	0	0	0	0	0	0	0	0	0	2	2	0	0.43	0.61	0.00

Table 7.6 Grading of the additive acuteness of environmental impacts of the Falkland War across spheres and mechanisms. The far right columns represent the ratio between the cumulative scores of the “real war” Falkland conflict and the “absolute war” theoretical maximums derived in Chapter 6 (Table 6.6).

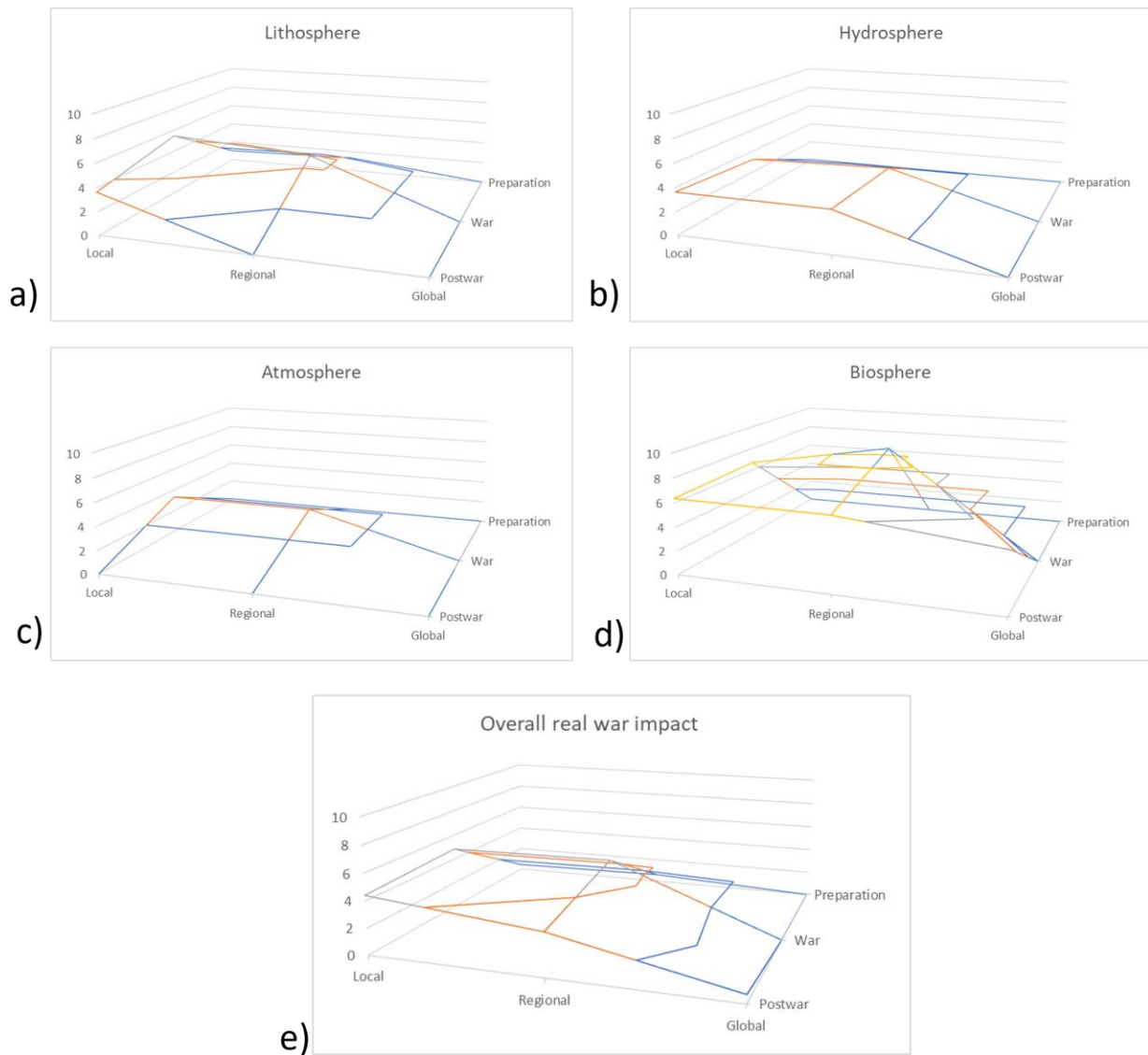


Figure 7.5 Visualization of the overall potential worst-case magnitude of acuteness of the disruptions in the lithosphere (a), hydrosphere (b), atmosphere (c), and biosphere (d) and overall ecology (e) of the Falklands environment

Analysis of the heuristic tool's output reveals several patterns about the environmental legacy of the Falklands War. First, because neither side conducted any significant preparation for the conflict, this context yielded no measurable impacts. In the lithosphere, the wartime disruptions produced long-lasting conditions of slow violence, especially the landscape abandonment caused by the extensive use of landmines, though the duration of these impacts

was mitigated by the British government's decision to resource the remediation of the Falklands landscape. Postwar, the interment of war dead in the Falklands landscape produced relatively benign but nonetheless long-lasting changes to local landscapes.

As expected, disruptions in the hydrosphere, especially chemical ones, appear to have spread further and lasted longer than those in the lithosphere. Indeed, evidence exists that the ongoing pollution caused by the numerous Falklands War shipwrecks continue to exert a negative influence on the health of the marine habitat around the islands, though some studies have attributed this to other factors. Regardless, more study appears necessary to fully understand the impact of the conflict's naval operations on the ecological health of the South Atlantic region.

Potential disruptions in the atmosphere are entirely attributable to the toxic burning of military equipment and supplies. While this may have produced short-term adverse health effects, contaminants are unlikely to have remained in the atmosphere for more than a few hours or days, thus limiting the acuteness of disruption in this sphere.

Finally, disruptions in the biosphere are largely due to the habitat disruption apparently caused by chemical pollution of the marine environment. Researchers have noted significant declines in the population of certain species of local penguins which they attributed to the pollution caused by military shipwrecks. However, other researchers have provided alternate explanations for these issues, illustrating the need for further research that incorporates the relative location of the shipwrecks with oil exploration infrastructure and commercial fishing activities.

Overall, despite the relatively small scale and short duration of the Falklands War, the conflict appears to have produced long-lasting detrimental environmental impacts at both the

local and regional scales. These impacts are due almost entirely to direct violence that occurred in the wartime context, as well as the decision by both sides not to remediate the shipwreck sites after the war. Otherwise, the postwar context in many ways has mitigated the postwar slow violence of the conflict, as exemplified by the British government's decision to adhere to international agreements concerning landmines and devote resources to removing landmines from the Falklands landscape.

8. Discussion and Cconclusions

The operational analysis of the Falklands War described above provides a much-needed spatial representation of *where* the likely disruptions of the Falklands War occurred, something that has been entirely missing from studies of war-related disruptions in the Falklands hydrosphere. While studies of disruptions in the lithosphere, by contrast, have devoted significant space to mapping the disruptions on East Falkland, these lack much of the context of *why* certain types of violence occurred where they did, a perspective that military geography and history can help to provide. Indeed, an analysis of where war-related disruptions occurred appears vital to disentangling their effects from those of peacetime civilian activities such as tourism, oil exploration, and commercial fishing.

The heuristic tool's visualization also highlights the importance of interdisciplinary collaboration in creating a holistic understanding of the Falklands War's environmental legacy. To date, much of the existing literature examining this legacy comes from a variety of disciplinary perspectives including marine biology, environmental assessments of oil exploration risks, battlefield archeology, and critical studies of the islands' colonial legacy. Even so, broad

gaps remain in the study of this issue, gaps that will require specialists from many other fields to adequately address. This demonstrates that a broad-based project to examine the ecological consequences of even a relatively minor war cannot rely on just one or two disciplines for a deep and holistic analysis but will need to bring together experts from across physical and social science disciplines.

Finally, the legacy of the Falklands War highlights the importance of ideological and political power in shaping the postwar activities and landscapes of a conflict area. The war altered the status of the Falkland Islands' residents in the eyes of their distant government in London. Before the war the government generally treated the islands and their residents as an unwelcome and expensive legacy of the UK's colonial past. The British government actually devoted resources and effort to convincing the Falklanders that they would be better off as Argentinian citizens. After the British victory, however, the Falklanders became an emblem of the UK's military and geopolitical prowess, and the views and preferences of the islanders as British subjects worth dying for became of paramount importance in London (Dodds, 2007). This fact led to a permanent postwar British military presence in the Falklands. Ironically, one of the war's most enduring effects has been to enhance the political power of the islands' local population and to improve their economic and military security.

The Argentinian government's continued political and ideological commitment to their right to sovereignty over the islands also shaped the postwar landscape. The Buenos Aires government's ongoing contention that the Malvinas are rightfully Argentinian led to their decision to bury their war dead there instead of returning the bodies to mainland South America, a symbolic but still powerful statement of their country's long-standing commitment to this cause.

Moreover, the UK government's broader commitment to its international arms control agreements prompted the London government to devote significant resources to remediate the Falklands landscape in the form of landmine and unexploded ordnance clearance. These activities occurred even after the local Falklands government expressed their opinion that such activities were more effort than they were worth, and that simple abandonment of hazardous locations was the more economically feasible option. Again, the irony of the conflict is that those who benefitted most from the war appear to be the civilians who lived in and around its battlefield landscapes. This goes to illustrate the importance of elements of social power in shaping a war's environmental legacy.

This case study of the environmental impacts of the Falklands War illustrates both the advantage of better integrating military geography into such studies and the value of the heuristic tool in organizing and contextualizing the conflicts disruptions, their acuteness, and their relationships with one another. More broadly, it shows the importance of an interdisciplinary approach for providing a comprehensive analysis of the ecological consequences of a specific conflict. Finally, this analysis of the Falklands War highlights the importance of the various forms of social power in shaping the recovery of the post-war landscape.

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Chapter 8 - Aleutians Campaign Case Study

Introduction

The second case study of this project examines the campaign waged during the Second World War over the control of the Aleutian Islands between forces of Imperial Japan on one side and those of the United States and Canada on the other. This campaign lasted for more than a year, starting with the Japanese occupation of the islands of Kiska and Attu in June 1942 and ending with the Japanese withdrawal from the island chain and their subsequent reoccupation by US and Canadian forces in May and August 1943. The Aleutians campaign was an expeditionary operation, with forces from both sides deploying from distant bases in their metropolises to fight in the North Pacific littoral. Both sides mobilized significant new forces to fight and sustain the campaign and constructed infrastructure both within the local area and farther afield to support their operations, much of which was abandoned after the war. Combat activities included naval, air, amphibious, and ground operations resulting in thousands of casualties on both sides, as well as numerous military shipwrecks and hundreds of destroyed aircraft. Moreover, the conflict was disastrous for the indigenous Unangax communities in the Aleutians. Both the Japanese and American governments forcibly removed the islands' residents to poorly resourced internment camps, where many died. After the war, when the Unangax were allowed to return home, they returned to devastated landscapes that bore the marks of the severe environmental damage wrought by modern war.

1. Step 1: Operational Analysis of the Aleutians Campaign

The Aleutians campaign was an ancillary part of the broader Pacific War of 1941-1945 (Garfield, 1969). In many ways, the campaign lacked a cohesive military logic, as neither side possessed pressing material reasons for disputing each other's possession of the Aleutian Islands (Polhamus, 2015). Nevertheless, political and ideological factors prompted both sides to deploy large forces to this theater, resulting in costly combat operations that left enduring marks on the local environment. Even so, the campaign remains largely unremembered in comparison to more famous Pacific War battles that occurred in the Central and Southwest Pacific theaters (Palka, 2012). Thus, in the aftermath of the struggle, the landscapes on which the Aleutians battles raged were mostly abandoned by the US government, and the plight of the indigenous Unangan population largely ignored (Hudson & Mason, 2015). In other cases, the geopolitical changes wrought by the Second World War more broadly led the US government to militarize places in the Aleutians for decades as bases from which to contest the Soviet Union in the Cold War (Clemens & Lewis, 2008).

1.1 Strategic Level Analysis of the Aleutians campaign

The roots of the Japanese decision to occupy Kiska and Attu in the Aleutian Islands lie in the Imperial Japanese military's strategy for achieving its government's policy objectives in Asia and the South Pacific. The Japanese elected to go to war with the United States, as well as the British Empire and the Netherlands, to secure access to vital oil and other material resources in the Dutch East Indies (present-day Indonesia) and Southeast Asia (Garfield, 1969). This access

had been threatened by US embargoes related to the ongoing Japanese war against China. The Japanese understood they were severely outmatched by American industrial might and military capacity to wage war. Thus, they opted for a strategy that they believed would erode the US government's political will to enforce its policy goals upon the Japanese (Polhamus, 2015). This strategy involved a breathtakingly rapid advance by Japanese military forces across the vast reaches of the Pacific Ocean to establish successive perimeters of island fortresses. The logic behind this strategy was a calculation that the US government would not possess be willing to invest the resources and incur the casualties necessary to fight through these island perimeters and, instead, be open to a negotiated settlement that would secure Japanese access to strategic resources (Garfield, 1969).

The Japanese did not initially consider the Aleutian Islands are part of their defensive scheme to slow an American military advance into the Western Pacific (Garfield, 1969). They considered the archipelago to be too remote and the environmental conditions too harsh for the islands to serve as a realistic base for American attacks. However, this view changed in April 1942 after the daring and unconventional "Doolittle" Raid. In this attack, American medium bombers, led by American aviator and US Army Air Forces (USAAF) Lieutenant Colonel James Doolittle, launched from the aircraft carrier USS *Hornet* and bombed Tokyo and several other Japanese cities before continuing to land at airfields in China (Polhamus, 2015). The raid was almost entirely a symbolic gesture, with little military value. However, it produced major changes in Japanese strategy.

Because of the unconventional nature of the Doolittle Raid (launching medium bombers from an aircraft carrier was thought to be impossible by the Japanese, as well as by most Americans), the Japanese were left unsure as to the origin of the aircraft that had unexpectedly

attacked into the heart of the Japanese Home Islands (Polhamus, 2015). Some Japanese strategists speculated that the raiders might have flown from a secret US base in the Aleutians, which was just one of several theories. In the end, the Japanese determined that they needed to expand their defensive perimeter in the North Pacific to prevent the possibility of further raids against the Japanese Home Islands. Thus, the Japanese decided to occupy Midway Atoll at the western end of the Hawaiian archipelago, as well as Kiska, Attu, and Adak islands in the Aleutians (McManus, 2021). After occupying the islands, the Japanese would fortify them, build airfields, and defend them against any American counterattacks.

Japanese forces failed to occupy Midway due to the decisive defeat at the naval battle of the same name, but their attack in the Aleutians proved more successful (Garfield, 1969). Japanese ground forces occupied Kiska and Attu, though poor weather prevented their landings on Adak. These forces then dug fortifications and built primitive air and port facilities to sustain their occupation. They also forcibly evacuated the entire indigenous population of Attu to an internment camp on Hokkaido in the Japanese Home Islands (Madden, 1993).

The Japanese presence in the Aleutians presented little real threat to American military strategy and defending the Aleutians and Alaska was in many a distraction from the US government's overall strategy for victory against Japan (Polhamus, 2015). In broad terms, American strategy envisioned powerful thrusts through the Japanese island perimeters in the Central and South Pacific that would eventually allow them to invade (or at least blockade and bombard) the Japanese Home Islands, forcing the Japanese government to surrender unconditionally (McManus, 2021). Agreeing with the Japanese assessment, the Americans also did not consider the Aleutians or the North Pacific in general to be a promising staging area for attacks against Japan (Garfield, 1969). However, Japan's dramatic victories in the early months

of their war against the US, along with the political and ideological repercussions of Japanese forces occupying American territory, forced an adjustment in American military priorities.

The rapid advance of Japanese military forces across the vast reaches of the Pacific and into Southeast Asia from December 1941 through May 1942 resulted in panicked reactions among many American communities, particularly those on the West Coast of North America (McManus, 2020). To many Americans, the Japanese invasions in the Aleutians seemed to be the first step in a broader campaign that could carry the Japanese down the Alaskan and British Columbian littoral to threaten Seattle. While better-informed American strategists understood these fears to be baseless, they nonetheless placed enormous political pressure on the US government in Washington to eliminate the Japanese threat from this direction (Garfield, 1969). Moreover, and perhaps more importantly, the fact that Japanese forces occupied American territory added an ideological dimension to the American imperative to reclaim Kiska and Attu. The Japanese military presence on American territory was framed as a direct affront to American national prestige which needed to be removed as rapidly as possible (McManus, 2021). In response, the Americans (and eventually their Canadian allies) diverted military resources from their main campaigns to the south to accomplish this removal. Many of these resources included newly formed units from the contiguous United States that were mobilizing to fight Japan in the Pacific War (Palka, 2012). Furthermore, the perceived threat of further Japanese advances led the US government to force the evacuation of the indigenous population of the Aleutian and Pribelof Islands, which resulted in the internment of hundreds of Unanga people in poorly resourced camps on the Alaskan mainland, ostensibly to protect them from the violence of military actions in the area (Hudson & Mason, 2015).

Both the United States and Japan needed to mobilize new ground, naval, and air forces to prosecute their respective strategies in the Pacific. In the US, this mobilization entailed a massive reworking of civilian industry to produce war material, as well as the induction of more than 12 million men and women into the armed forces (McManus, 2020). Dissecting the proportion of this massive effort that is attributable to the needs of the Aleutians campaign would be nearly impossible, and not particularly useful, as the changing strategies and operational imperatives of the war often meant that the military units created with one purpose in mind were often actually used in entirely different theaters than had been envisioned. However, in one case, directly tying mobilization activities in the US metropole with combat operations along the Alaskan littoral is possible. This is the case of the 87th Infantry Regiment of the US 10th Mountain Division which formed and trained at Camp Hale in the Colorado Rockies explicitly as a cold-weather specialist unit before deploying to participate in the landing on Kiska in August 1943 (Whitlock & Miller, 2023). This example, featuring Camp Hale, illustrates how far from actual battlefields preparation activities can occur and reshape landscapes in modern warfare.

Once the Japanese presence had been removed, the North Pacific receded once again into a backwater status (McManus, 2021). The military logic that graded the Aleutians as poor bases for offensive operations against Japan once again came to the fore, leading both sides to redeploy most of their forces in the North Pacific to more important theaters, leading to the eventual abandonment of much of the infrastructure that had supported the Aleutian campaign (Sackett, 2007). After the war ended, however, the resulting new geopolitical context of the Cold War once again shifted the military status of the Aleutians (Clemens & Lewis, 2007). American fears of being the victims of another surprise attack, such as what had occurred at Pearl Harbor, along with the Aleutian Islands' proximity to Soviet territory, prompted the US military to repurpose

some of the Aleutians' wartime infrastructure to support military surveillance of the Soviet Union.

1.2 Operational Level Analysis of the Aleutians Campaign

Prior to the outbreak of hostilities, the US government had anticipated that Alaska might come under threat in a potential war with Japan. In 1939, the US military began an extensive building campaign across Alaska and into the Aleutians to provide infrastructure that could support the deployment of large naval, air, and ground forces (Guzman, 2022). Naval infrastructure developed during this time included Naval Operating Bases at Sitka, Kodiak, and Dutch Harbor. Major airfields were constructed at Cold Bay near the tip of the Alaskan Peninsula, Fort Glenn on Umnak Island, and fields near Anchorage and Fairbanks on the Alaskan mainland (National Park Service, ND). These were all protected by bases and fortifications constructed to house ground forces who could defend these sites, such as Fort Mears at Dutch Harbor and Fort Greely on Kodiak Island. They were also supported by a network of radio navigation stations and smaller airfield and port facilities that arched along the southern coast of Alaska and extended into the Aleutian archipelago (Kraus, 2021). The combined purpose of this infrastructure was to facilitate the movement by air and sea of supplies from the contiguous United States up the western coast of North America to the Alaskan mainland and into the Aleutians.

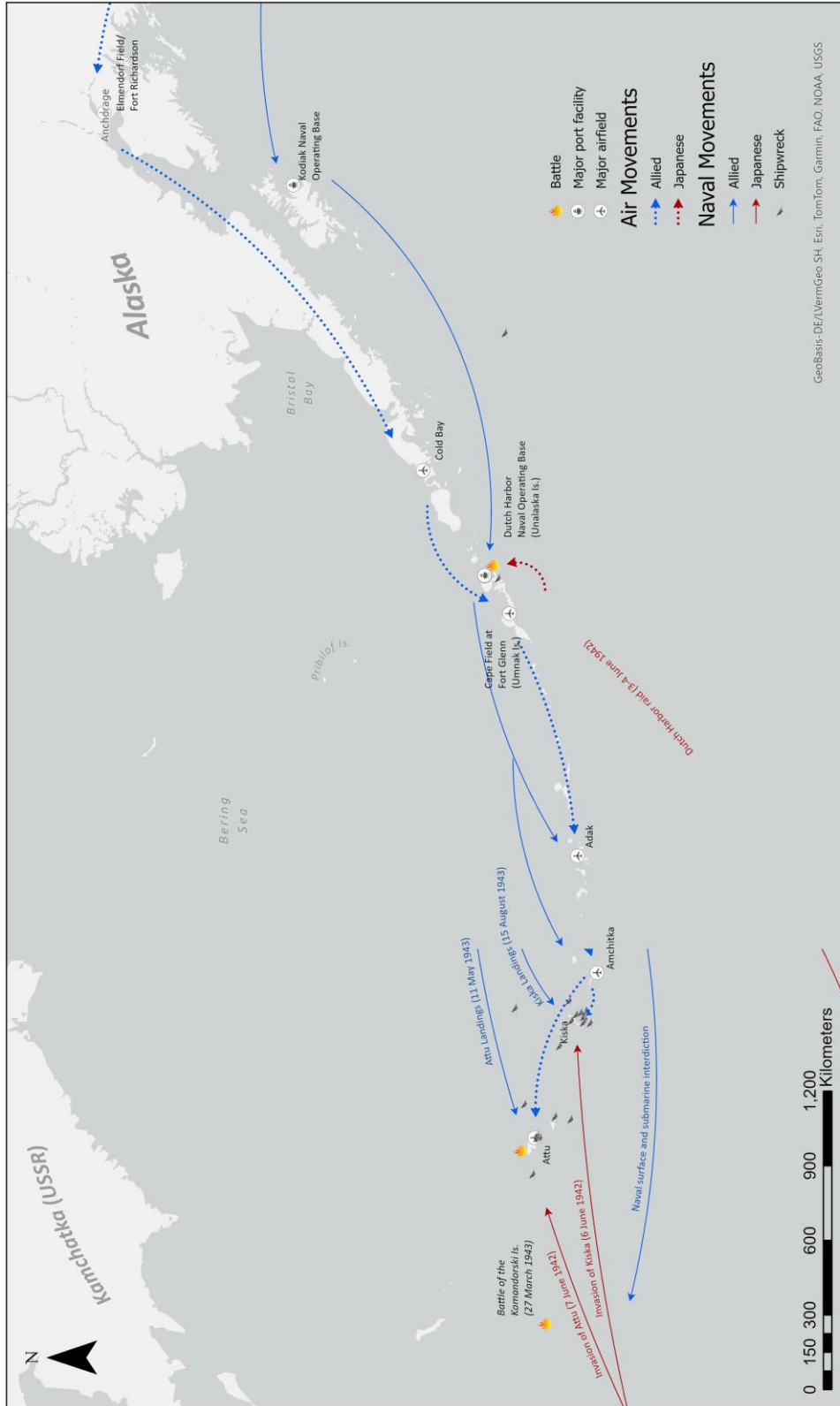


Figure 8.1 Operational level activities of the Aleutians campaign.

Construction accelerated after the Japanese seizure of Kiska and Attu. American engineers built more naval and air bases further west along the Aleutian archipelago to support recapture of the islands, including on Adak and Amchitka, and eventually on Shemya and Attu after the recapture of that island (Kraus, 2021). Moreover, preparation for war also accelerated the construction of the Alaska Highway, a road that linked the contiguous United States to Fairbanks in central Alaska, allowing the transfer of material by ground to the Alaskan mainland (Connor, 2005).

The Japanese also constructed infrastructure to support their operations in the Aleutians, though on a far smaller scale than the Americans. Japanese naval forces could take advantage of existing port facilities on Hokkaido and Sakhalin Island to project their forces into the Aleutian theater (Garfield, 1969). However, once in possession of territory in the Aleutians, the Japanese needed to build airfields and rudimentary port facilities to support their forces there. The importance of airfields was heightened by the fact that, given the Aleutians status as a backwater theater for both sides, neither the US Navy nor the Imperial Japanese Navy (IJN) were willing to commit significant aircraft carrier forces to operations there after the initial Japanese invasions (McManus, 2021).

The Japanese naval and amphibious operation to seize footholds in the Aleutians was a component of, and in many ways a distraction from, the much larger Japanese thrust to seize Midway Atoll in the Central Pacific (Parshall & Tully, 2005)). The core striking component of the Midway invasion force was the *Kido Butai* (Mobile Strike Force) of the IJN. The *Kido Butai* consisted of the six largest aircraft carriers in the IJN along with their escorting warships and represented the largest concentration of carrier-borne airpower in the world. This was the force

that had attacked Pearl Harbor on December 7th, 1941, to initiate the war against the United States, and had since ranged across the Pacific and Indian Oceans to smash allied naval forces and infrastructure. However, for the Midway operation the IJN elected to split the *Kido Butai* into two groups, detaching two of the force's aircraft carriers to support the Aleutians invasions while the remaining four sought to challenge the US carrier force around Midway (Garfield, 1969).

At Midway, a force of three American aircraft carriers, aided by the US military's ability to intercept and decipher Japanese naval communications, was able to ambush the IJN carrier force and destroy all four carriers in exchange for the loss of just one American carrier. This was a major strategic reversal, as it eliminated the IJN's main offensive potential and shifted the initiative in the Pacific to the US Navy (Parshall & Tully, 2005). The Japanese attack on the Aleutians, however, was more successful. In the North Pacific, only relatively weak US land-based air forces and naval surface forces were present to contest the IJN. On 3-4 June 1942, Japanese carrier-borne aircraft raided Dutch Harbor, destroying the port's oils storage facilities and several grounded aircraft, as well as damaging ships in the harbor (Garfield, 1969). Following the raids on Dutch Harbor, Japanese ground forces conducted unopposed amphibious landings at Kiska on 6 June and Attu on 7 June. The Japanese forces fortified the islands in anticipation of using them as patrol bases to monitor US naval and air operations and to prevent a US advance along the island chain towards Japan (Funk et al, 2020).

In the aftermath of the Japanese invasions, both sides engaged in skirmishing around the Aleutians chain as US forces sought to gain naval and air superiority to isolate the Japanese garrisons from their bases of supply in the Home Islands (Garfield, 1969). These engagements included repeated raids by US aircraft against Japanese facilities on Kiska and Attu, which

destroyed several Japanese aircraft on the ground and sank a submarine and several transports in the harbor at Kiska. The largest naval engagement was the Battle of the Komandorski Islands in which a patrolling force of US warships attempted to intercept a Japanese resupply convoy destined for the Aleutians, though this fight did not result in any warships lost for either side (Garfield, 1969). More destructive were the engagements between both sides' submarines and anti-submarine escorts. The IJN lost three destroyers and several freighters sunk by American torpedoes as they tried to sustain their ground forces in the Aleutians in 1942 and 1943, while Japanese counterattacks sank two American submarines in the same period (Donihue et al, 2023; Heersink, 2023). As the American blockade of the islands tightened in early 1943 the Japanese started to use submarines to resupply their ground forces, resulting in the loss of three more vessels to American patrols. Finally, one American destroyer, the USS *Worden*, sank in shallow water at Adak Island during a storm.

In May 1943, a large US ground force landed on Attu Island to reclaim it from the Japanese control. In heavy fighting over the next three weeks, the Americans suffered over 3,000 casualties with more than half of caused by sickness and exposure, while the Japanese garrison of over 2,500 troops was annihilated (Palka, 2012). This defeat prompted the Japanese to abandon the Aleutian campaign and they secretly evacuated their garrison from Kiska on 28 July (Funk et al, 2020). Unaware of the Japanese withdrawal, US and Canadian forces conducted an amphibious landing on Kiska on 15-16 August. Despite no opposition during the operation, the allied forces suffered hundreds of casualties to fratricide, booby traps left by the Japanese, accidents, exposure, and disease (McManus, 2021). The Kiska landing effectively marked the close of the Aleutians campaign, as both the Allied and the Japanese redeployed most of their forces in this area to other, more strategically important theaters.

1.3 *Tactical Level Analysis of the Aleutians Campaign*

The remoteness and hostile environment of the Aleutians placed major constraints on the size and types of military forces that could be effectively employed and supported there (Guzman, 2022). This constraint led both sides to attempt attacks on one another's sea and air lines of communication, though the Japanese lacked much capacity to do so after their initial raids on Dutch Harbor's port facilities (Garfield, 1969). American air and naval attacks focused on destroying Japanese resupply convoys and their airfield and port facilities on Kiska and Attu to weaken the garrisons prior to mounting their amphibious landings. Poor weather also limited when and how frequently combat operations could occur, a constraint that was especially acute when employing air power (Palka, 2012; Wilder, 2014). Both sides lost more aircraft due to poor weather or poor maintenance than to enemy action (Garfield, 1969). This limited the value of air power in the campaign, leading both sides to rely more heavily upon submarines and surface warships to contest lines of communication.

On land, the lack of any real road system on either Kiska or Attu meant that once ashore, most movement by ground forces was by foot (Palka, 2012). This, along with the rugged volcanic landscape of the islands, slowed the pace of land operations and limited the Americans' ability to employ their superior artillery firepower due to the difficulty of moving heavy guns and ammunition. The exception to this was naval gunfire, which the Americans applied in abundance in both of their amphibious landings and during the prolonged fighting on Attu. Both sides constructed fortifications and entrenchments to protect themselves from enemy firepower. In the case of the American forces on Unalaska and Kodiak, these fortifications included

concrete bunkers (Clemens & Lewis, 2007). More common, however, were earthen entrenchments, sometimes reinforced with wooden supports or local rock (Funk et al, 2020). The Japanese also sowed landmines and booby traps on land and sea mines at sea to reinforce their defensive obstacles and limit American mobility (Rutherford, 2022).

The only major land battle of the campaign occurred when a US force of 15,000 soldiers landed to recapture Attu in May 1943 (Operation Landcrab). The American landing forces, consisting mostly of the US 7th Infantry Division, could hardly have been more inappropriately trained for the environmental conditions they would encounter (Palka, 2012). This unit was first mobilized as a motorized formation and conducted intensive training in southern California and the Mojave Desert in anticipation of deploying to North Africa (McManus, 2021). Instead, when the need to recapture the Aleutians arose, the 7th Infantry was tapped to execute the landings. The unit's soldiers lacked cold weather training and equipment, a deficiency that would lead to many non-battle casualties during the fighting on Attu (Palka, 2012). A small, better equipped unit of reconnaissance troops recruited from the local Alaskan population, including some Unangan men who had been forcibly evacuated from the Aleutians, also landed and supported the 7th Division soldiers (Garfield, 1969).

The Americans landed on both the northern and southern coasts of the island, then advanced up through several rugged valleys to dislodge Japanese forces entrenched on the ridgelines before both landing forces pivoted eastwards to attack the core Japanese positions around Chichagof Bay and Attu settlement (Palka, 2012). The difficult terrain that limited the Americans' ability to employ their superior artillery firepower meant that the advance into the island's interior was slow and costly. However, by 29 May they had pushed the Japanese forces into a small perimeter near Attu settlement (Garfield, 1969). At this point, in what would become

a pattern on other Pacific battlefields, the Japanese forces abandoned their defensive tactics and assumed the tactical offensive, launching a massive *banzai* bayonet charge with the entire remaining garrison on the night of 29-30 May (McManus, 2021). Though this attack penetrated deep into the US lines and caused heavy US casualties, it also resulted in the effective annihilation of the remaining Japanese troops on the island due to superior American firepower, ending the battle more quickly than would have occurred if the Japanese had maintained their defensive tactics.

The loss of Attu prompted the Japanese to evacuate their garrison on Kiska, which they accomplished on 29 July, leaving their fortifications intact (Garfield, 1969). On 15-16 August, a joint American and Canadian force of nearly 40,000 troops (including the US 87th Infantry Regiment, the 7th Infantry Division, and the Canadian 13th Infantry Brigade) landed on Kiska (Operation Cottage) and advanced inland up the mountainous valleys, as they had at Attu (McManus, 2021). During this advance, US and Canadian soldiers mistook one another for Japanese defenders, resulting in a heavy firefight that caused dozens of casualties in both country's units. Other soldiers were lost to booby traps left behind by the Japanese and to vehicle accidents as troops attempted to maneuver in the rugged terrain (Rutherford, 2022). At sea, an American destroyer was badly damaged after striking a Japanese sea mine, resulting in heavy loss of life (Garfield, 1969).

2. Step 2: Identification and location of Likely Environmental Impacts of the Aleutians Campaign

War-related disruptions in the Aleutians affected all four earth spheres (Table 8.1). The intensely localized combat and related supporting activities that characterized the Aleutians campaign resulted in intensely scarred landscapes as well as also numerous conditions of slow violence that have spread regionally and persisted temporally. The remoteness of the theater, as well as the duration of the campaign and its status as a minor part of a much larger war, meant that the belligerents devoted significant resources to constructing infrastructure to support the campaign both in the preparation context and during wartime. Moreover, the speed at which this infrastructure was developed and then in many cases abandoned after the end of the campaign may have contributed to disruptions in the biosphere that persists today. Finally, the fate of the indigenous people of the Aleutians illustrates how elements of social power can help explain how and why wealthy metropolises often abandon disrupted landscapes after a conflict, leaving the economically impoverished local population to make what remediations than can in their environment.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 8.1 Likely types of environmental disruptions (highlighted in gray) that occurred during the Aleutians campaign

In the lithosphere, US forces began constructing both support infrastructure and fortifications in the Aleutian theater before the start of hostilities with Japan and accelerated this construction during wartime (Figure 2). This infrastructure included naval port facilities at Dutch Harbor, Kodiak, and Sitka, which included fuel and ammunition storage facilities besides berthing spaces for warships (National Park Service, ND). The US military constructed fortifications to protect these facilities, including coastal artillery emplacements, barracks, and other facilities at Fort Mears near Dutch Harbor and Fort Greely on Kodiak Island. Other newly built facilities supporting the build-up of US and allied forces in the Aleutian theater included Fort Richardson near Anchorage, Fort Wainwright near Fairbanks, and Fort Glenn on Umnak

Island (Clemens & Lewis, 2008). All these locations included barracks and life support facilities to maintain garrisons of several thousand up to tens of thousands of soldiers in relative comfort for extended periods. New infrastructure to support air operations were even more far-flung, with US engineers creating major airfields stretching from Alaska's southeast all the way to Attu at the western end of the Aleutian Archipelago and stretching also deep into the Alaskan interior (Kraus, 2021). These facilities included fuel storage and maintenance facilities and life support facilities for the aircraft and ground crews. Moreover, airfields were supported by dozens of dispersal and staging airstrips both in the Aleutians and mainland Alaska intended to provide flexibility and extend the range of the US air forces operating from the main bases, as well as radio beacon stations to assist air crews with navigation.

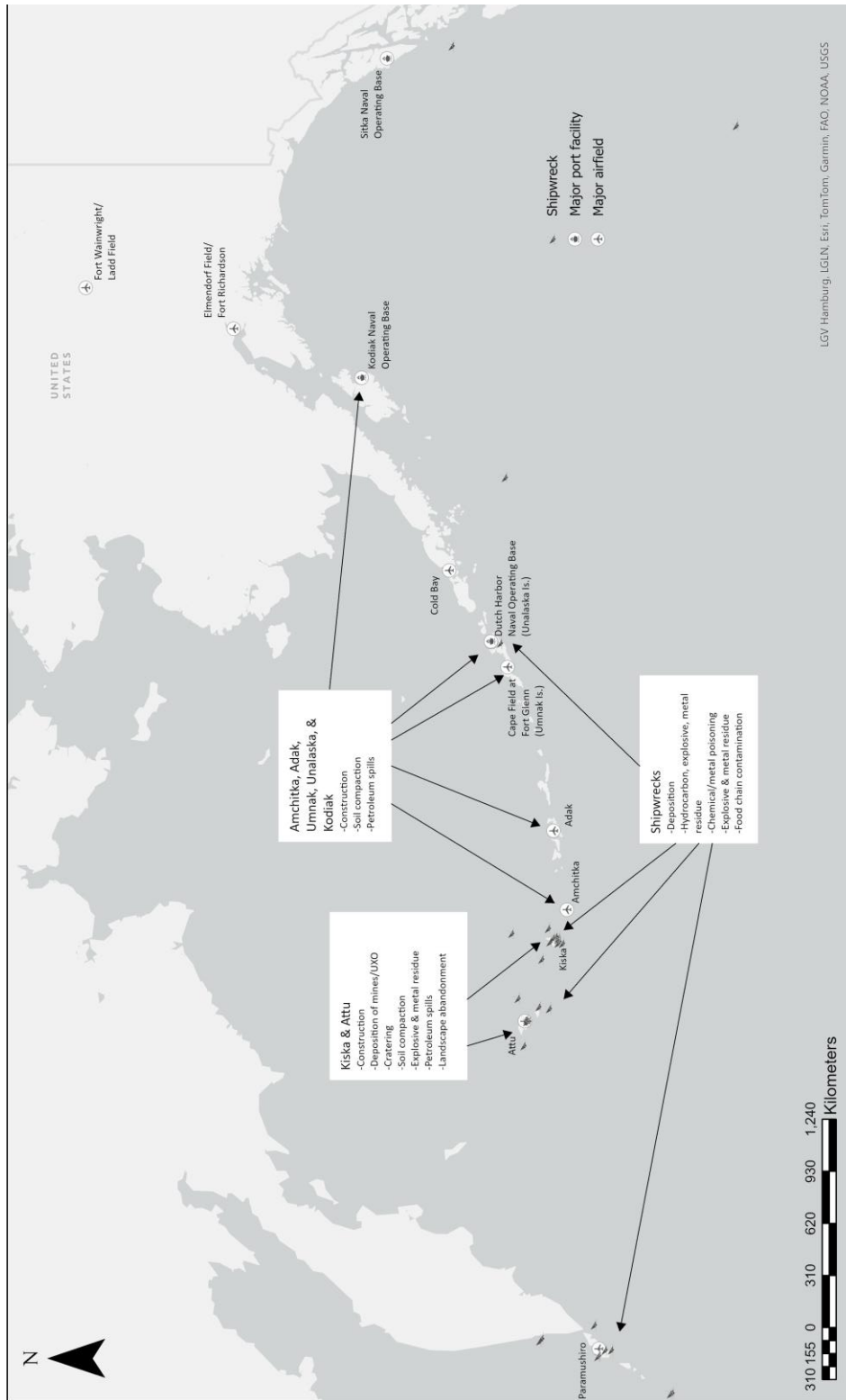


Figure 8.2 Location and types of important environmental disruptions due to military activity related to the Aleutians campaign.

The Japanese also constructed infrastructure to support their operations in the Aleutians, mostly in the Kuril Islands but also on Kiska and Attu (Garfield, 1969). The largest concentration of these facilities was a naval port, a cluster of airfields, and ground forces support infrastructure on Paramushiro in the northern Kuriles. The Japanese also constructed living quarters and support buildings for their garrisons in the Aleutians (Funk et al, 2020). They also build primitive airstrips on both Kiska and Attu, as well as minor facilities to support the unloading of ships and the operation of seaplanes. Moreover, the Japanese dug extensive defensive fortifications into the tundra on both islands they occupied, reinforcing these trenchworks and foxholes with imported lumber, metal, and other materials. In the postwar context, some of the above-described infrastructure was abandoned as the focus of combat operations shifted elsewhere (McManus, 2021). However, the changed geopolitics of the post-war world meant that the US military maintained and even expanded many of these wartime facilities (Sackett, 2008). Forts Wainwright and Richardson became major permanent posts housing thousands of US Army troops to this day, while Elmendorf Field expanded to become Elmendorf Air Force Base, which continues to support most US Air Force operations in Alaska and the North Pacific. The facilities at Kodiak persist as a US Coast Guard operating base (Clemens & Lewis, 2008). Other facilities, such as those on Adak Island, remained in operation through the Cold War. Much of the remaining infrastructure, especially the extensive network of airstrips and radio beacons, transitioned to civilian use to support Alaska's growing aviation industry as well as trans-Pacific air travel (Kraus, 2021). However, other built infrastructure and especially fortifications, including those at Attu, Kiska, and Amchitka, were quickly abandoned

after the end of hostilities, leaving these sites as silent markers of the violence that engulfed the North Pacific during the Second World War (Hudson & Mason, 2015).

The actual combat of the campaign also left its mark on Aleutian landscapes. The need of the allied ground forces to rely upon naval artillery to dislodge their Japanese foes resulted in extensive cratering of certain areas of Kiska and Attu. Second World War-era naval artillery was generally of larger caliber than land-based field artillery, meaning that the larger shells were likely to produce both larger and longer-lasting craters. Indeed, the allied landing forces were supported by at least one battleship firing 15-inch guns that threw shells weighing nearly a ton (Garfield, 1969). Aerial bombs from the years-long bombing campaign that supported the ground and naval operations would also have cratered the landscape around targeted facilities.

Dud rounds, as well as landmines and booby traps laid by the defending Japanese, represent a source of depositional disruptions on Kiska and Attu (Rutherford, 2022). Another depositional disruption is detritus of broken or abandoned military equipment cast off, or intentionally abandoned, by the soldiers on both sides such as derelict aircraft left to rust by the Japanese at their airfield on Attu (Funk et al, 2020). Finally, the movement of thousands of troops along the confined valleys and narrow ridgelines of the Aleutian battlefields would have contributed to soil compaction in these areas. Additionally, all but 28 of the nearly 2,500 Japanese soldiers defending Attu died on the island and were buried in several mass graves (Rosen, 2007, 9 August). In the 1970s, the US government exhumed about 200 of these remains and moved them to Fort Richardson, Alaska, where they were cremated. However, most Japanese human remains are still interred on Attu.

The following activities are possible sources of chemical disruption in the lithosphere. The effects of explosive residue are probably the most minor, as the actual fighting on Kiska and

Attu was relatively brief with low densities of shelling compared to other theaters in the Second World War. Petroleum and heavy metal contamination are likely a far larger issue, with sources ranging from abandoned infrastructure across the archipelago, temporary dumps in combat and staging areas, and destroyed and abandoned equipment including aircraft crashes.

Finally, the violence of the Aleutians campaign also resulted in the forced abandonment by the Unangax of several settlements in the archipelago, including Attu and areas of Adak (Hudson & Mason, 2015). While the Unangan nation were able to reclaim some of their lost territory by occupying the US military facilities at Adak after that base's closure in the 1990s, Attu remains uninhabited by humans to this day. US government authorities deemed the island, with its minefields and other types of unexploded ordnance, to be too dangerous for civilian occupation and has so far failed to devote resources needed to clear these hazards to allow for the eventual return of the indigenous population (Rutherford, 2022).

Sources of disruption in the hydrosphere during the Aleutians campaign included naval combat and shore-based facilities supporting both sides' naval forces. Both sides employed depth charges, torpedoes, and explosive shells and bombs to attack one another's ships, as well as active sonar to locate submarines, representing brief but frequent incidents of noise and blast disruption (Morrison, 2001). Engagements involving these sorts of weapons occurred mostly around the western end of the archipelago, where US and Japanese naval forces contested the sea lanes leading to Kiska and Attu. These engagements also resulted in shipwrecks of both warships and Japanese freighters resupplying their garrisons, which sank with fuel in their bunkers and high explosive ammunition in their magazines, creating point sources for long-term chemical pollution of the surrounding marine environment (Carter et al, 2023; Heersink, 2023). Many of

these shipwrecks lie in the shallow waters around Kiska, Attu, and Amchitka, while others sank in the deeper waters of the Bering Sea and North Pacific.

The conflict also resulted in the brief abandonment of several traditional fisheries as the Unangan population, who fished the waters around the Aleutians both for subsistence and commercially, were removed to Japan and mainland Alaska. However, this abandonment did not persist long in every case, as many of the Unangan men were allowed to return to their fisheries to support the US war effort, specifically around the Pribilof Islands (National Park Service, ND). The abandonment of the Unangan settlement at Attu, however, meant that fishing activity at the western end of the Aleutians became less frequent, at least in the immediate post-war period (Hudson & Mason, 2015).

The ground fighting on Attu and the landings on Kiska, though brief, were accompanied by the detonation of large amounts of high explosive ordnance. These engagements, as well as the frequent aerial bombing raids launched mostly by the US forces, would have been the source of noise and blast energy in the atmosphere that may have affected the avian population that represents much of the fauna of the Aleutian Islands. Moreover, the destruction and burning of military stores and equipment that accompanied nearly every naval, ground, or aerial engagement would have, at least briefly, emitted toxic elements into the atmosphere to be carried elsewhere by the local winds. However, the admittedly brief effects in this sphere are probably most impactful in their ability to transfer pollutants rather than to retain them.

The effects of the Aleutians campaign on the biosphere were far-ranging. All three contexts of the conflict saw the deployment of large numbers of military personnel into environments that before had supported only very sparse human populations, if any at all. For example, the pre-war population of Attu consisted of 42 Unangan permanent residents (Hudson

& Mason, 2015). The arrival of the Japanese invasion force increased the human population of the island to nearly 3,000 individuals who lived there for nearly a year. The arrival of the American landing force swelled these numbers by a further 15,000 people (Palka, 2012). Though most of these occupants' tenure on the island was brief, lasting perhaps a few weeks, they nonetheless represent an increase in the area's population that can be measured in orders of magnitude. Similarly, at the time of the Japanese landings on Kiska, the island's only occupants were a US Navy weather detachment. Nearly 5,000 Japanese lived on the island for more than a year from 1942-1943, while the US-Canadian landings to recapture Kiska swelled its population briefly to more than 45,000 (McManus, 2021). All of these forces included animals among their ranks, especially dogs but some others as well.

The Aleutian campaign also caused refugee flows, most notably with the forced evacuation of the indigenous populations of the Aleutian and Pribilof Islands. The members of these communities were removed to cramped and squalid camps on the Alaskan mainland, where more than 10% of them perished due to disease and malnutrition (Madden, 1993). Mortality disproportionately affected the very young and the very old, with the loss of the latter representing a further loss of local knowledge and experience for the broader community.

The economic patterns of the Aleutians and Alaska changed significantly after the war. The military aviation infrastructure proved to be a boon to the local aviation industry, while the built-up port infrastructure facilitated increased commercial fishing activities (Kraus, 2021; Clemens & Lewis, 2008; Sackett, 2008). However, the war was also economically devastating for the Unangan communities of the islands. Not only had they been removed from their settlements for years, but in many cases their homes and communities had been intentionally demolished, either to prevent a feared Japanese invasion from using them as shelter, or to make

way for military infrastructure (Madden, 1993). In other cases, US and Japanese forces moved in to occupy the settlements' buildings and appropriated their owners' property. In all cases, the civilian population of the islands returned to communities that had been significantly damaged or entirely destroyed by the campaign. Not until 1987 did the US government recognize the suffering caused by the combined evacuation of the Unangan population and destruction of their property. The US Congress voted to provide survivors reparations of \$12,000 each (Civil Liberties Act, 1987). This amount was hardly sufficient to compensate the survivors for their losses, and moreover many of the survivors were no longer living to receive this payment more than four decades after the fact.

The extensive military infrastructure building campaign initiated by the US before the war also may have accelerated post-war oil exploration and exploitation in Alaska and its surrounding waters. The Alaska Highway facilitated pipeline construction in Alaska's interior, while maritime and airfield infrastructure supported offshore drilling in Cook Inlet and elsewhere (Sokolski, 1979; Robertson & Campbell, 2020). While such activities would almost certainly have still occurred in the absence of military action, the facilities constructed to support the conflict no doubt accelerated the development of infrastructure that eased the path of the oil industry into Alaska in the post-war years.

Many of the above-described disruptions would likely have created disturbances in the food chain of the biota which make their home in the Aleutians and its surrounding waters. Perhaps the most important source of this type of disruption are the chemical pollutants added to the environment by the presence of military shipwrecks. Hydrocarbon and heavy metal contamination from these point sources represent a threat to the health of the organisms that live in their proximity. Moreover, higher order predators such as seabirds can concentrate these

pollutants at the top of the food chain, with negative effects for the broader health of species' populations (Burger et al, 2007; Anthony et al, 2007; Burger et al, 2009).

Finally, the Aleutian campaign also helped to introduce invasive species to the isolated islands of the Aleutian chain. Invading soldiers were not the only ones to splash ashore on the Attu, Kiska, and other of the Aleutian Islands. With them came Norway rats from the holds of the ships that carried them there (Renner et al, 2017). These rodents remain endemic to the islands where they were introduced in the 1940s, where they prey on seabird eggs and other local animals, with negative effects on the overall health of these species' populations.

3. Step 3: Current Research Examining Aleutians Campaign Environmental Disruptions

Numerous studies from at least four disciplinary approaches have examined aspects of the environmental legacy of the Aleutians campaign, though many gaps in knowledge still exist (Table 8.2). First, anthropological and battlefield archeology research has focused on mapping the abandoned infrastructure left behind by both Japanese and US military forces after the end of the Second World War. Second, post-war oil exploration in Alaskan waters prompted numerous studies examining the effects of oil spills on the hydrosphere, though these often fail to consider wartime disruptions as a possible source of contamination. Third, marine biologists have conducted numerous studies to gage the level of chemical contamination present in the region's aquatic and avian lifeforms. These studies often make explicit geographical connections between the locations of past military infrastructure and higher levels of contamination. Finally, numerous

studies have examined the historical marginalization of the Unangan population of the Aleutians in the aftermath of their forced displacement from their homes in the 1940s.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 8.2 Likely environmental disruptions caused by the Aleutians campaign. Those that have been the subject of published research are highlighted in green, while those that have not been the subject of published research are highlighted in gray.

Several research projects have documented the changes that military construction created in the regional landscape of Alaska prior to, during, and after the Aleutians campaign. Sackett (2008) and Clemens and Lewis (2008) have provided an anthropological perspective on the legacy of the Second World War US military infrastructure in Alaska. They show how the context in which the military construction occurred can be an important factor in its post-war fate. Sackett (2008) demonstrates that pre-war infrastructure projects, such as Fort Richardson

near Anchorage and the Dutch Harbor naval facilities, were envisioned as permanent facilities in the less hurried context of pre-war preparations and these structures were more often fashioned from concrete. In contrast, wartime construction was understood to be temporary and was generally composed of wooden or earthen structures. Clemens and Lewis (2008) note that much of this temporary construction disappeared beneath more permanent military infrastructure in the post-war context, as the US military's preparation activities during the Cold War caused them to maintain a permanent presence in many of the more remote reaches of Alaska and the Aleutians.

Japanese military construction in the Aleutians has also received attention from anthropologists. Funk *et al* (2020) documented the location and condition of abandoned Japanese entrenchments, tunnels, and structures on Kiska, showing that many of these fortifications remain largely intact more than 80 years later. Funk *et al* (2020) also show that much of the Japanese fortification system, as well as the craters from the heavy naval artillery bombardment that attempted to destroy them prior to the unopposed allied landings on Kiska, remain readily apparent in aerial and satellite imagery of the island. This is commendable in that it combines a thorough analysis of the Japanese tactical defensive scheme for the island with an on-site search for the archeological remains of the occupation. This demonstrates the value that military geography can bring to understanding the environmental legacy of wartime actions. However, Funk *et al* (2020) do not address the possible changes to Kiska's hydrology that the Japanese fortifications may have caused, though some of their study's figures provide indications that this may have occurred. Moreover, Funk *et al* (2020), as well as Rutherford (2022) have explored the legacy of military deposition on Kiska and Attu, noting that a hazardous amount of unexploded ordnance remains in the islands' soil, causing the US government to restrict access to these landscapes.

Historic military infrastructure and battlefield landscapes are an area where various elements of social power combine to contest the meaning of these places in a way that has often extended their presence. In 1996, the US Congress designated numerous sites within the Aleutians theater as the Aleutian World War II National Historic Area. The indigenous Unalashka Corporation manages this extension of the US National Park system with financial and other support from the US National Park service (National Park Service, ND). This collaboration has allowed the indigenous people of the Aleutians to preserve the memory of their suffering and marginalization both during and after the Second World War while also highlighting their status as patriotic American citizens who nonetheless contributed materially to the defense of the Aleutians against Japanese aggression. Thus, both local and federal political, economic, and ideological interests have aligned to preserve many of the built features of the Aleutians militarized landscape, even as the US government has neglected to devote any resources to clearing the more remote reaches of the National Historic Area of hazards.

Other studies of the environmental legacy of the Second World War have focused on the chemical contamination of the marine environment around Alaska and the Aleutians. Many of these studies have been focused on understanding the environmental cost of post-war oil exploration in Alaska, but several make direct connections to the contamination originating from military infrastructure and sites. These studies have focused heavily on measuring the contamination of the marine biosphere due to various contaminants. Miles et al (2009) showed that the concentration of polychlorinated biphenyls (PCBs) in various species of fish was significantly higher in samples collected near sites of Second World War military infrastructure than at sites distant from such facilities. Similarly, Anthony et al (2007), Burger et al (2007), and Burger et al (2009) showed that avian life on remote Aleutian Islands where heavy military

activity had occurred during the Second World War exhibited measurable levels of heavy metal contamination in their feathers and eggs, which the studies attribute to the lingering effects of abandoned military infrastructure and equipment in the region. Moreover, Rocque and Winker (2004) have documented contaminants in the Aleutians food web and observed that, though identifying the exact point sources of many of these contaminants is a complex problem, the region's remoteness from heavy industrial activity leaves the military legacy as a likely major source of pollution.

Other biologists have studied the legacy of invasive species introduced to the Aleutians during the Second World War. Specifically, Renner et al (2017) studied populations of Norway rats on several Aleutian Islands to understand the risks this species posed to local bird life and to assess possibilities for eradication. They hypothesized that many of the rat populations originated from civilian shipwrecks from the Bering Sea fishing industry, but also noted that many of the more remote islands, such as Attu and Kiska, were only infrequently visited by fishing vessels, leaving the brief military presence on the island as a likely source for the introduction of these invasive rodents. They also note that these two islands, due to their remoteness, represent attractive targets for attempts to eradicate the rat population to restore the pre-war ecological balance, though no such remediation has apparently been attempted.

Finally, the indigenous Unangax have leveraged their stewardship over the Aleutian World War II National Historic Area to document the indigenous experience during the war through a series of books, articles, and documentaries available on the National Historic Area's official web site (Hudson & Mason, 2009). These resources document many of the cultural but also environmental effects caused by the forced abandonment by the Unangax of their villages during the conflict, several of which remain uninhabited to this day.

Overall, while each study is important and useful for compiling an overall understanding of the environmental legacy of the Aleutians campaign, they often neglect to make connections between initial acts of direct violence and subsequent conditions of slow violence. For example, archeological studies of Japanese fortifications on Kiska have extensively documented the location of abandoned Japanese fortifications and major sites of various kinds of deposition. However, they do not pursue the slow violence implications of these disruptions to question whether they may have caused altered patterns of erosion or chemical contamination in the soil. The observation is not a criticism of these individual studies, but rather highlights the need for an ecological framework that can guide other researchers to pursue the slow violence implications of a certain disruption, or alternately seek out the actual source of observed conditions of slow violence.

4. Applying the Heuristic

As with the previous case study, the topological grades for the acuteness of environmental impacts were assessed based on the available empirical studies for each disruption (where such studies were available) and according to the potential worst-case scenario for disruptions in the Aleutians that have not been the subject of direct scientific inquiry (Table 8.3). This led to the overall disruption acuteness results shown in Table 8.4, feeding the visualization output of the heuristic tool (Figure 8.3).

Earth sphere	Mechanism	Direct violence	Context of direct violence	Slow violence (spatial)	Slow violence (timescale)	Slow violence (severity)	Slow violence (acuteness)	
Lithosphere	Mechanical	Construction and excavation	Preparation, war, post-war	Local	Decades	Disturbance	2 (Minimal)	
		Deposition	War, post-war	Local	Decades	Disturbance	2 (Moderate)	
	Chemical	Cratering	War	Local	Decades	Decades	Disturbance	1 (Minimal)
		Soil compaction	Preparation, war, post-war	Local, regional	Decades	Decades	Disturbance	1 (Minimal)
	Biological	Explosive residue	War	Local	Decades	Decades	Disturbance	1 (Minimal)
		Metal residue	War	Local, regional	Centuries	Centuries	Disturbance	2 (Moderate)
		Petroleum product spills	War	Local, regional	Decades	Decades	Degradation	2 (Moderate)
		Habitat destruction	War	Local, regional	Decades	Decades	Disturbance	1 (Minimal)
	Hydrosphere	Mechanical	Landscape abandonment	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)
			Noise and blast energy	War	Local, regional	Years	Disturbance	0 (No impact)
Chemical		Deposition	War	Local, regional	Millennia	Difference	2 (Moderate)	
		Hydrocarbon spills	War, post-war	Local, regional	Decades	Degradation	2 (Moderate)	
Biological		Explosive residue	War	Local	Decades	Decades	Disturbance	1 (Minimal)
		Metal residue	War, post-war	Local, regional	Decades	Decades	Disturbance	1 (Minimal)
		Habitat disruption	Preparation, war, post-war	Local, regional	Decades	Decades	Disturbance	1 (Minimal)
		Fishery abandonment	War	Local, regional	Years	Years	Disturbance	1 (Minimal)
Atmosphere		Mechanical	Noise and blast energy	War	Local	Years	Disturbance	0 (No impact)
			Burning of toxic materials	War	Local, regional	Weeks	Degradation	1 (Minimal)
	Chemical	Military deployments	Preparation, war, postwar	Local, regional	Decades	Disturbance	1 (Minimal)	
		Movement of animals	Preparation, war, postwar	Local, regional	Years	Disturbance	0 (No impact)	
		Refugee flows	War, postwar	Local, regional	Decades	Decades	Disturbance	1 (Minimal)
		New economic patterns	Postwar	Local, regional, global	Centuries	Centuries	Disturbance	2 (Moderate)
	Biological	Chemical/metal poisoning	War, post-war	Local	Decades	Decades	Degradation	2 (Moderate)
		Food chain contamination	War, post-war	Local, regional	Decades	Decades	Degradation	2 (Moderate)
	Biosphere	Mechanical	Burning	War	Local, regional	Years	Disturbance	0 (No impact)
			Habitat alteration	Preparation, war, post-war	Local, regional	Decades	Degradation	2 (Moderate)
Biological		Invasive species	War, post-war	Local, regional	Centuries	Centuries	Degradation	3 (Significant)
		Killing	War	Local, regional	Decades	Decades	Disturbance	2 (Moderate)

Table 8.3 Topology of likely environmental disruptions caused by the Aleutians campaign.

		Mechanical			Chemical			Radiological			Biological			Composite ratio		
		Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global
Lithosphere (.34)	Postwar	5	1	0	0	0	0	0	0	0	1	1	0	5.45	2.50	0.00
	War	6	1	0	5	4	0	0	0	0	2	2	0	5.91	4.67	0.00
	Preparation	3	1	0	0	0	0	0	0	0	0	0	0	1.50	0.67	0.00
Hydrosphere (.33)	Postwar	0	0	0	3	3	0	0	0	0	1	1	0	3.64	3.64	0.00
	War	2	2	0	4	3	0	0	0	0	2	2	0	3.64	4.12	0.00
	Preparation	0	0	0	0	0	0	0	0	0	1	1	0	0.63	0.91	0.00
Atmosphere (.06)	Postwar	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	War	0	0	0	1	1	0	0	0	0	0	0	0	3.33	3.33	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Biosphere (.27)	Postwar	3	3	1	4	2	0	0	0	0	3	3	0	9.09	10.00	5.00
	War	1	2	0	4	2	0	0	0	0	5	5	0	6.67	10.00	-
	Preparation	1	1	0	0	0	0	0	0	0	2	2	0	3.33	6.00	-
Overall	Postwar	8	4	1	7	5	0	0	0	0	5	5	0	5.88	5.00	0.63
	War	9	5	0	14	10	0	0	0	0	9	9	0	5.16	5.45	0.00
	Preparation	4	2	0	0	0	0	0	0	0	3	3	0	1.49	1.52	0.00

Table 8.4 Cumulative grades of the acuteness of likely disruptions caused by the Aleutians campaign according to the topology outlined in Table 8.3.

Overall, in contrast to the Falklands War, the preparation context of the Aleutians campaign contributed significantly to environmental conditions of slow violence both on local landscapes and regionally in the form of pre-war military infrastructure. The wartime and post-war impacts of refugee flows and invasive species also differentiate the environmental legacy of this conflict. Another minor difference is attributable to the types of weapons employed; In the Falklands, all sides employed only relatively light calibers of both ground and naval artillery, a fact that limited the size and effects of cratering in the landscape. In the Aleutians, however,

much heavier calibers of artillery resulted in large craters on Kiska and Attu that remain part of the landscape today, illustrating the importance of military technology in shaping militarized landscapes.

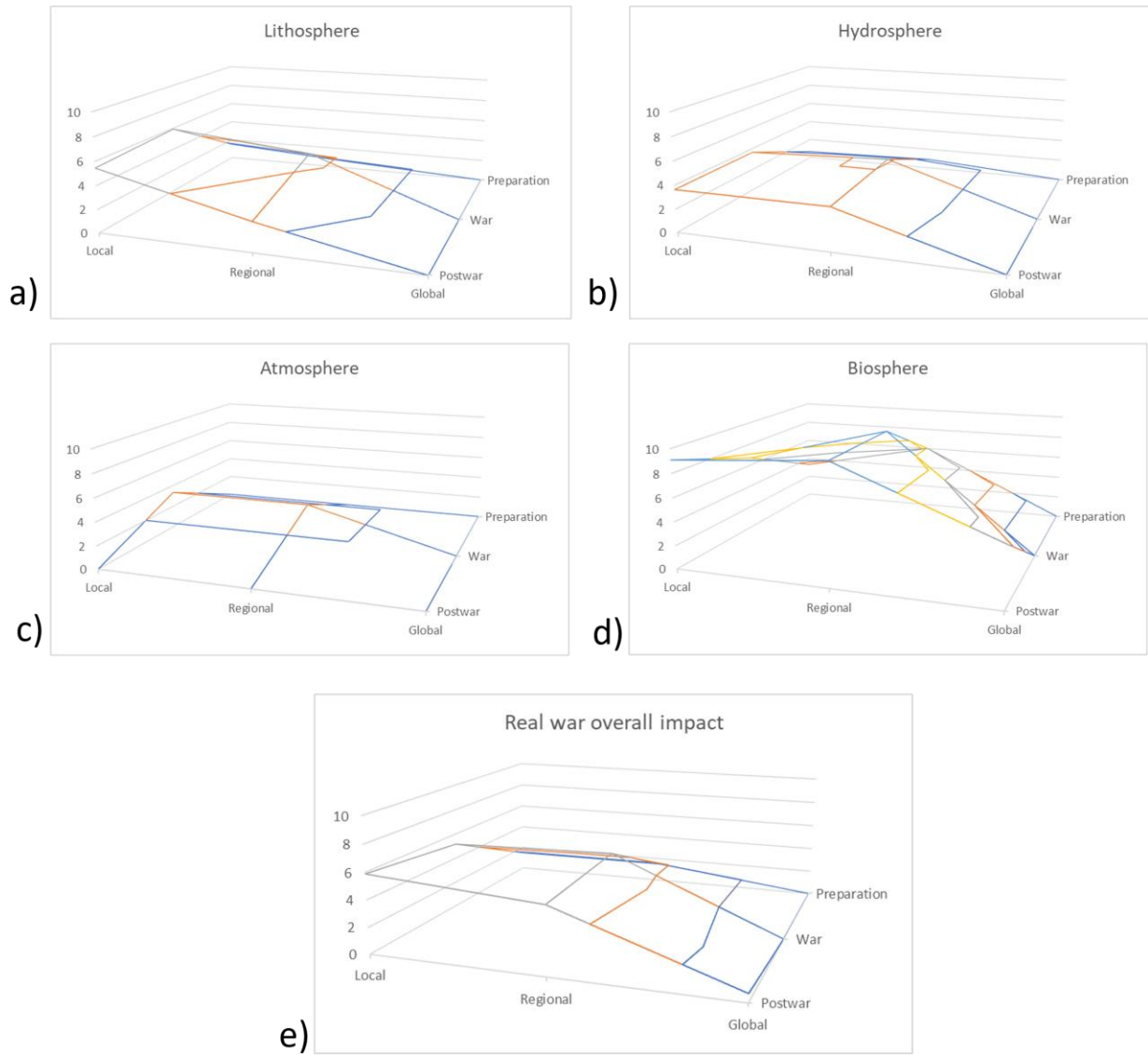


Figure 8.3 Visualization of the overall potential magnitude of acuteness of the disruptions in the lithosphere (a), hydrosphere (b), atmosphere (c), and biosphere (d) and overall ecology (e) of the Aleutians environment.

5. Discussion and Conclusions

The postwar legacy of the Aleutians campaign illustrates, in a different way from that of the Falklands, how elements of social power can affect the fate of post-war militarized landscapes. In contrast to the Falklands War, the Aleutians theater of the Second World War became a largely forgotten backwater of the war even before it ended. The units that served there were largely redeployed from the Aleutians to fight other battles in the Pacific and Europe that have created a more lasting hold on the American public's imagination (McManus, 2021). The almost forgotten status of the theater meant that Aleutian landscapes did not assume the type of political and ideological post-war importance in the US metropole that Falklands did in the UK. The Aleutians remained important military outposts throughout the Cold War, prompting further military investment and construction, but little effort was devoted to the remediation of damaged areas such as Kiska and Attu (Clemens and Lewis, 2008; Rutherford, 2022). Many of these areas remain abandoned today. Facilitating the return of the local population to their destroyed and abandoned homes was not deemed sufficiently important, in most cases, to justify the economic investment necessary to make such a return safe. An interesting byproduct of this marginalization is that the indigenous population of the Aleutians has taken on the role of preserving the militarized landscapes of the Archipelagos as a means of educating the broader population about the legacy of the war and its effect on them. The Ounalashka Corporation's management of the Aleutian World War II National Historic Area represents an interesting example of how the ideological meaning of sites of past violence can be leveraged even by marginalized actors to advocate for their interests.

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Chapter 9 - Norway Theater Case Study

Introduction

The Norwegian theater in the Second World War was a strategically important subsidiary of the broader struggle in Europe between Nazi Germany and the Allied powers. From before the German invasion in 1940 until Norway's final liberation after the Nazi regime's capitulation in 1945, the theater drew in a large number of forces and significant resources from Germany, Britain, France, and the Soviet Union, besides the native Norwegian military and paramilitary forces that participated in the conflict. Moreover, Norway's strategic position relative to the sea lines of communication for both the United Kingdom and the USSR meant that it never truly became a military backwater as some other theaters did after their conquest by the Nazis.

The Norwegian theater, which stretched from southern Norway to the country's High North near the border with the USSR, was the scene of large-scale ground, naval, air, and amphibious combat. The intensity of combat operations ebbed and flowed with the fortunes of the various belligerent powers over the five years of the conflict, while the places that would be scenes of direct military violence also shifted with the changing imperatives of the theater. In the end, war-related activity in this theater left an enduring environmental and cultural legacy that created conditions of slow violence on landscapes near and far from the battlefields.

1. Step 1: Operational Analysis of the Norwegian theater

Despite its subsidiary status to the broader struggle consuming Europe, the Norwegian theater drew in forces and interest from many belligerent militaries, including Germany, the

United Kingdom, France, Poland, the USSR, Sweden, and the United States, besides the native Norwegian regular and partisan forces that fought in the conflict (Mann & Jørgensen, 2003). As the fortunes of the Second World War altered the geostrategic context of the conflict, so too did the way these forces perceive the theater's geography and their relationship to it. Both the German and Allied sides considered themselves at various junctures to be engaged in both offensive and defensive actions at all three levels of war. Understanding the offensive/defensive frame that the belligerents were employing at various points during the war, a concept that Clausewitz (1993) expounded upon at length, is a vital component in any analysis of where and why certain types of military activity occurred. German forces went on the offensive in Norway first, launching a daring amphibious and airborne invasion of the country in April 1940 (Lunde, 2008; Haarr, 2009).

After successfully overcoming Norwegian and Allied resistance to conquer the country, German forces in Norway adopted a defensive posture as Norwegian territory became a base for sea and air raids against Britain and Allied naval assets (Claasen, 2001). In 1941, northern Norway also became a base for ground attacks into the Soviet Union as part of Operation Barbarossa (Holtmark, 2021). However, by 1944 German forces were entirely on the defensive, as threats of Allied amphibious landings along the German coast and a large counteroffensive by the Red Army in the Norwegian Arctic threatened the German strategic position in this theater (Gebhardt, 1989). Throughout, the strategic, operational, and tactical levels of war interacted in complex ways to shape when and where direct military violence would affect local landscapes.

1.1 Strategic Level Analysis of the Norwegian Theater

The Norwegian government's primary policy objective before, during, and after the Second World War was to maintain their country's independence from their more powerful neighbors (Græger & Leira, 2005; Græger, 2007). The strategies they employed to achieve this objective varied depending upon the actions of those neighbors. Norway had won its independence from neighboring Sweden when the latter agreed to a bloodless dissolution of the centuries-old union between the two Scandinavian countries in 1905 (Lunde, 2008). The government of Norway had built up significant military resources prior to the dissolution in anticipation of military conflict with Sweden, including ground and naval fortifications around Oslo. Though no fighting broke out over Norwegian independence, this strong military potential allowed Norway to maintain a firm neutrality during the Great War. By the eve of the Second World War, however, the Norwegian government had allowed their country's military strength to stagnate, compromising their ability to credibly deter their neighbors from violating Norway's status as a neutral power (Lunde, 2008). This was unfortunate for Norway, as several of their neighbors had compelling policy imperatives to violate Norway's neutrality or even curtail the country's independence.

The first of Norway's neighbors to seriously consider using military force to compel the country's government to abandon its neutrality was not Germany, but rather the United Kingdom, and this for two divergent reasons (Churchill, 1948). The first of these was Britain's policy of maintaining a distant blockade of the German economy, as they had done in the Great War. The second reason that the British government seriously considered using military force to compel Norwegian compliance was a desire to assist Finnish forces after the Soviet invasion of Finland in December 1939. In the end, fear of the tightening British blockade led the German

government to decide to invade Norway to secure access to Scandinavian resources, particularly iron ore from the High North, before the Allies could act decisively to cut them off from these vital materials (Haarr, 2009).

Germany invaded Poland in September 1939, followed closely by the Soviet Union, who both quickly overran all military Polish resistance (Churchill, 1948). Britain and France declared war on Germany in response, but what followed this declaration was months of “phony war” in which little actual combat occurred other than naval skirmishing as the Royal Navy sought to secure global sea trade against German raiders (Folly, 2004). At the same time, the Royal Navy attempted to repeat its successful strategy from the Great War of cutting Germany off from all sea trade via a distant blockade of the English Channel and North Sea. Norway and Sweden were important exporters of iron ore to Germany and interdicting these supplies became an important strategy objective for the Allies (Lunde, 2008; Haarr, 2009). To accomplish this, the British proposed to emplace belts of sea mines in Norwegian territorial waters to sink German blockade runners that were taking advantage of Norway’s rugged coastline and sovereign territory to avoid British warships (Churchill, 1948). Indeed, the British had already begun to lay these minefields without the Norwegian government’s knowledge or consent in the hours prior to the German invasion. The British also made plans to land ground forces around Narvik in the north of the country to physically secure the main entrepot for the Scandinavian ore resources (Churchill, 1948).

The second impetus pushing Britain to violate Norway’s neutrality was the Soviet invasion of Finland. The Molotov-Ribbentrop Pact that divided Poland between Nazi Germany and the USSR had effectively made the two countries unlikely allies, if only briefly (Churchill, 1948). The USSR’s aggression against Finland set within the context of the phony war against

Germany prompted the Allies to consider ways in which they could support this latest victim of totalitarian military aggression (Edwards, 2008). One plan was to dispatch troops to fight alongside the Finns. These would need to land at Narvik and make their way across northern Sweden to reach Finland. This far-fetched plan was eventually abandoned by the Allies, but it added further weight to the scales in favor of violating Norwegian territory and neutrality (Churchill, 1948).

The German government was aware of the British intentions to interdict Scandinavia ore shipments and decided to physically secure these resources before the Allies could move (Lunde, 2009). Fearing British naval superiority, the Germans elected to launch an audacious surprise amphibious and airborne invasion of both Denmark and Norway to forestall the tightening of the British blockade (Figure 9.1). Denmark, whose military position was self-evidently hopeless, capitulated to the German invasion within hours, but the Norwegian government elected to resist, even to the point of going into exile in Great Britain after the country was occupied by German forces, as a means of maintaining its independence (Riste, 1987).

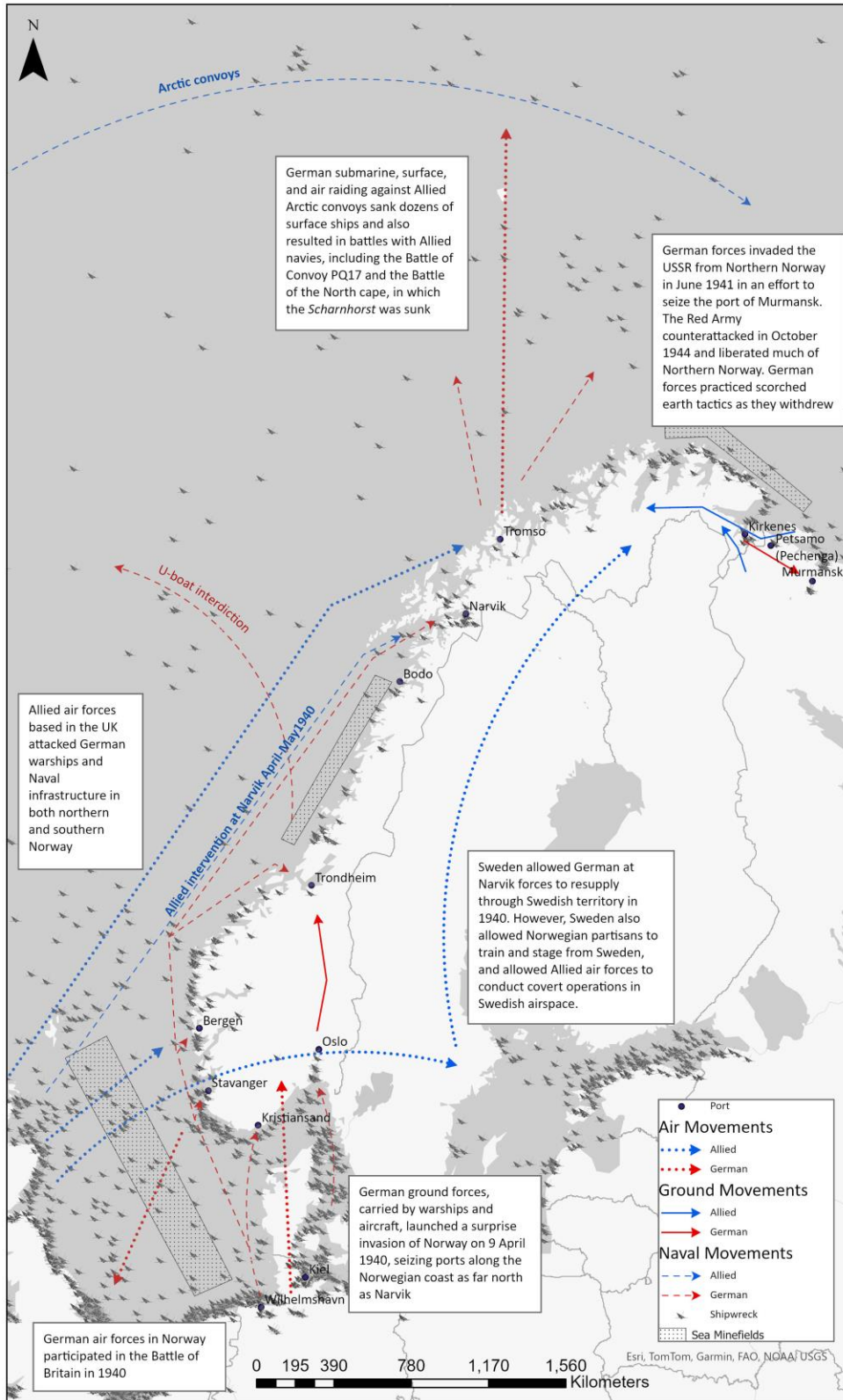


Figure 9.1 Strategic and operational aspects of the Norwegian theater in the Second World War.

After assuming the strategic offensive in their invasion of Norway, the Germans were able to extend their offensive reach after their successful conquest and occupation of the country by using Norway as a base (Figure 9.1) (Claasen, 2001). However, this also required them to defend their conquests in Norway from Allied attacks. Assisted by fascist Norwegian collaborators like Vidkun Quisling, who acted as the head of a Norwegian puppet government under Nazi control, the Germans sought to suppress Norwegian partisan resistance while also using Norwegian territory as a base for attacks elsewhere, first against Great Britain and later against the USSR (Hetland et al, 2021). The German military constructed airfields in southern and central Norway to allow bombing attacks against the UK during the Battle of Britain (Claasen, 2001). They also built naval infrastructure, including ports and submarine pens, to support German naval surface and submarine interdiction of sea lanes of communication in the North Atlantic and, later, the Barents Sea (Showell, 2017). Finally, northern Norway became the base for the northernmost prong of Nazi Germany's massive ground invasion of the Soviet Union in June 1941. To protect these assets, the German military also constructed an extensive system of coastal fortifications to deter and defend against a potential Allied invasion to liberate Norway (Zaloga, 2011).

The Allied strategic imperative to maintain the sea routes to Great Britain and the Soviet Union invited counterattacks from Allied forces (Cherry, 2016). British air and naval forces throughout the war sought to attack German naval units that were using Norwegian coastal waters as a refuge, with varying success (Claasen, 2001). Norwegian partisans, assisted by British commandos, also launched attacks against important resources in Norway to deny them to the Germans (Mann, 2009). Sweden, fearful of losing its independence to German military domination, surreptitiously assisted the Norwegian partisan movement, allowing tens of

thousands of Norwegians to train in Sweden and opening Swedish airspace to covert Allied movement and resupply of these forces (Chaisson, 2014). Finally, the Soviet Union launched a massive ground invasion of northern Norway in October 1944 to push German forces back from the important Soviet port at Murmansk, which was an important entrepôt for Allied military aid to the USSR (Gebhardt, 1989; Holtmark, 2021). German forces, unable to maintain their position in northern Norway but still intent upon keeping their grip on the rest of the country, executed a scorched earth retreat from the Soviet frontier to the Lyngen Alps, devastating Norway's Arctic communities and causing a large movement of refugees, composed disproportionately of Norwegian Sami indigenous persons, to flee into southern Norway and Sweden, many of whom never returned to their homelands (Weinstock, 2013; Hunt, 2014; Johnson, ND)

Post-war, the Norwegian government abandoned its policy of neutrality. Norway became a founding member of the NATO alliance in the changed geopolitics of the emerging Cold War, making it, along with Turkey, one of only two NATO member states to share a border with the USSR (Græger & Leira, 2005). As part of the alliance, Norway constructed new military infrastructure to prepare for a possible war with the Soviet Union, including fortifications, airfields, and surveillance sites, many of which remain in operation today (Crocker, 1984; Efstad, 2017).

Thus, strategic-level considerations shaped where and when military activity occurred in the Norwegian theater. Southern Norway's proximity to both Germany and Great Britain and its status as the host to most of the country's population and government infrastructure meant that this area became the scene of early ground combat as the Germans sought to rapidly force the Norwegian government to capitulate. However, as the conquest of Norway was only a means for

the Germans to secure access to vital resources, which their enemies were also seeking to deny them, the bulk of all subsequent ground combat occurred in northern Norway, initially around the vital ore entrepot of Narvik and then even further north into the areas around the Soviet frontier as Norway became a base for German attacks against Murmansk (Lunde, 2008; Gebhardt, 1989). Air combat tended to occur in southern and central Norway as Allied air raids attempted to attack German U-boat infrastructure and naval units, while naval and amphibious combat (after the initial invasion) occurred largely in the High North as German naval strength attempted to interdict Allied sea lanes of communication (Claasen, 2001).

1.2 Operational Level Analysis of the Norwegian Theater

Norway's rugged terrain and the remote location of many of the battles that occurred in this theater initially limited the size of the forces fielded by the belligerents. Even so, combat in the early weeks of the German invasion was fierce, with especially heavy naval losses incurred by both sides (Lunde, 2008). The Germans, unable to directly contest the vastly superior naval strength of the Royal Navy, needed to rely upon surprise and audacity in their initial invasion. By sortieing nearly their entire surface fleet from Wilhelmshaven and Kiel loaded with invasion troops on 9 April, the Germans were able to avoid British detection and put ashore ground forces nearly simultaneously along the Norwegian coast at Oslo, Kristiansand, Bergen, Stavanger, Trondheim, Narvik, and several smaller ports, supported by airborne landings around Oslo and Stavanger (Haarr, 2009). Two German ships were sunk before unloading, including the troop ship *SS Rio de Janeiro* by a Polish submarine off southern Norway and the cruiser *Blucher* by a Norwegian shore torpedo battery in the Oslofjorden (Lunde, 2008). Moreover, the British

destroyer HMS *Glowworm* was sunk in the North Sea after the ship stumbled upon a superior German force headed for Trondheim. Despite these losses, the Germans were able to land most of their forces intact and seize all their initial objectives.

The Allied response, while ineffective on land, was devastating for the *Kriegsmarine* at sea (Cherry, 2016). The German navy lost at least 13 warships during the invasion, including 10 destroyers and three cruisers, most of which were lost around Narvik (Lunde, 2008). These losses crippled the German surface fleet for the remainder of the war. Allied naval losses during the invasion were heavy as well, with a total of 15 British, French, and Polish warships sunk including the Royal Navy aircraft carrier HMS *Glorious* (Cherry, 2016). However, the much larger Allied naval forces were better able to absorb these losses than were the Germans. The resulting naval imbalance prompted the Germans to rely even more heavily on submarine raiding, and to hold their remaining surface warships as a fleet in being and for raiding near Norwegian waters, rather than trying to challenge the Allied fleets directly (Engvig, 2016).

The conquest of both Denmark and southern Norway secured German lines of communication across the Baltic Sea, allowing them to maintain an occupying force of around 400,000 troops in the theater (Lunde, 2008). Norwegian ports, especially Bergen and Trondheim, became major bases for German U-boat operations into the North Atlantic and Arctic Ocean while German surface ships were also able to hide in the steep-sided fjords of Norway's long coastline, then sally out to attack Allied convoys sailing for northern Russia, resulting in several sharp and costly naval engagements (Showell, 2017). However, this long coastline was also difficult to defend without major effort. Thus, even after northern Norway became a base for the German invasion of Karelia, the bulk of German ground forces in Norway remained farther south, securing the country against partisan activity and the coastline against invasion and air

attack (Zaloga, 2011). The latter mission required the construction of hundreds of coastal forts to defend against possible allied landing sites at part of the broader Atlantic Wall fortification scheme.

Moreover, the remoteness of Norway's High North meant that the Germans had to rely on supplies passing initially through Sweden and later through Finland to support their northern offensive at Narvik and later into the Soviets Union (Lunde, 2008; Gebhardt, 1989). The German victory at Narvik was a very near run affair where German forces were nearly forced to surrender before the Allies elected to withdraw (Cherry, 2016). Without supplies passing by rail through Sweden, the German position at Narvik in April and May 1940 would have been an impossible one (Lunde, 2008). Later, even with Finnish support, the Germans were unable to commit sufficient forces to northern Norway to seize their objective of Murmansk (Gebhardt, 1989). These logistical issues were amplified by the German need to maintain such large defensive forces further south to protect against threats from Great Britain. When Finland submitted to the Allies in late 1944 and joined the USSR in ejecting German forces from the region, the German position became even more difficult logistically, making their subsequent defense of the Norwegian Arctic a losing venture (Gebhardt, 1989).

In October of 1944, the Red Army launched an offensive to push German forces back from the outskirts of Murmansk and liberate northern Norway. The Soviets were able to field a force of over 130,000 soldiers for this operation, against a defending German force less than a third that size (Gebhardt, 1989; Dzwonczyk & Radunzel, 2020). The Soviet forces were well-equipped but the challenging terrain and difficult logistical conditions in the Arctic limited their ability to bring overwhelming force against the German defenses. The Soviets ultimately liberated much of Norway's Arctic coast but were unable to destroy the defending German units

(Gebhardt, 1989). These German forces ultimately retreated to the mountainous Lyngen Alps, where they constructed field fortifications in anticipation of further Soviet advances (Murray, 2019). In doing so, they employed a scorched earth policy of demolishing towns and infrastructure to deny these to the advancing Soviets, with tragic consequences for the local population (Hunt, 2014). Soviet forces, assisted by a force of nearly 1,500 Norwegian ski troops covertly flown by American aircraft into northern Norway from Sweden, worked hard to meet the humanitarian needs of the destitute population, generating long-lasting goodwill between Norway and the USSR that persisted beyond the end of the Cold War (Hunt, 2014).

After the end of hostilities, British, American, and exiled Norwegian forces landed in southern Norway to help intern German forces and reestablish Norwegian government control of the country (Mann, 2012). Soviet forces withdrew from Norway relatively quickly, cultivating the legacy of friendliness between the two countries already seeded by the Red Army's actions in northern Norway in 1944 (Gebhardt, 1989). Even so, the Norwegian government's fear of another invasion, this time from the Soviet Union, led them to join the NATO alliance and host NATO surveillance and military infrastructure on their territory (Græger & Leira, 2005). The surveillance infrastructure was mostly constructed in the High North near the border with Soviet Union and included such sites as the radar facility at the North Cape. Other military infrastructure included military airfields and coastal fortifications.

At the operational level of war all sides struggled to support sufficiently large ground forces in Norway's Arctic to achieve overwhelming military superiority. This emphasized the importance of naval and air forces to bypass ground defenses to enhance offensive mobility. Even when one side could commit large forces to an offensive, as occurred with the German invasion of Karelia and the Soviet counteroffensive into northern Norway, the rugged terrain and

long logistical tail meant that these forces' mobility was limited, preventing deep and decisive offensive operations (Dzwonczyk & Radunzel, 2020). This fact enhanced the importance of defensive fortifications that could amplify the advantages of Norway's rugged terrain, as demonstrated by the effort and resources that the German military devoted to fortifying the Norwegian coast and the Lyngen Alps (Murray, 2019). The vulnerability of maritime supply lines in the High North also emphasized the importance of sea mobility and naval raiding, prompting the Germans to devote significant resources to developing naval infrastructure in Norway and the Allies to make major efforts to destroy this infrastructure. The German's use of Norway as a base for naval raiding also meant that naval engagements continued to occur in Norwegian waters throughout the conflict.

1.3 Tactical level Analysis of the Norwegian Theater

The operational constraints imposed by the ruggedness and remoteness of the Norwegian theater shaped the tactics employed by the ground, naval, and air forces of all belligerents. On the ground, the difficulty of sustaining large, well-equipped forces meant that all sides struggled to employ heavy firepower, meaning that combat emphasized infantry engagements and the importance of fortifications (Dzwonczyk & Radunzel, 2020). The long distances in the theater also limited the impact of air power, though individual air raids could still be devastating (Claasen, 2001). This fact created carry-over effects in naval operations, where the lack of persistent air cover and the difficulty of operating aircraft and aircraft carriers in the Arctic environment meant that surface ships and submarines assumed a greater importance in this theater than in many others.

The inability of any side to sustain heavy, mechanized forces at the point of combat limited the firepower of the forces engaged. This, in turn, meant that the quality of the infantry engaged, or the strength of the defenders' defensive works, was often a decisive factor in the outcome of a battle (Lunde, 2008). The German infantry units that initially invaded Norway were of generally higher training and quality as compared to the Norwegian and British units that opposed them (Chruchill, 1948). This allowed the German forces in southern Norway, though lightly equipped, to repeatedly turn Allied defenders out of their defensive positions, even when these were sited in rugged terrain that favored the defenders (Lunde, 2008). Especially effective were the division of German mountain troops (*Gebirgsjägers*) and paratroopers (*Fallshirmjägers*) who defeated a numerically superior Norwegian-British-French-Polish force at Narvik (Lunde, 2008). Indeed, the effectiveness of the *Gebirgsjägers* in Norway was such that their reputation produced effects as far away as the United States, where the American military elected to train its own specialized mountain troops to match this German capability (Rottman, 2012). This contributed to the formation of the US 10th Mountain Division at Camp Hale, Colorado. Some of these specialist US troops would eventually deploy to Norway, though not until after the German surrender in 1945.

The importance of infantry specially trained for cold weather combat led several of the belligerents, including the USSR, Finland, and Norway, to seek such soldiers within their indigenous Sami minority populations in the Arctic (Johnson, ND). These indigenous soldiers provided valuable service to all three countries against the Germans at various points in the war, belying fears within their national governments that they might prove disloyal to the broader polity (Poyer, 2017).

The reliance on infantry meant that combat tended to be relatively localized in Norway. Even in large operations, such as the Soviet liberation of northern Norway, advances were often limited by how far infantry forces could walk and be sustained cross-country, with heavy weapons and mechanized assets confined to the few existing roads (Dzwonczyk & Radunzel, 2020). Coastal areas provided opportunities to enhance this mobility, as infantry forces could use small ships to conduct amphibious operations to outflank defenses, as the Red Army did on several occasions during their offensive. This dearth of heavy weapons hampered infantry forces in reducing fortifications, meaning that battles could become long and drawn out (Gebhardt, 1989).

The importance of the sparse civilian infrastructure in Norway's High North made these features targets for military violence. As the Germans retreated to the Lyngen Alps after the Soviet offensive into northern Norway, they intentionally destroyed towns, transportation infrastructure, and even set fire to forests and reindeer grazing areas to deny these resources to the advancing Soviets (Hunt, 2014; Johnson, ND). This created great hardship for the local civilian population, though the consequences were not consistent across ethnicities. Many ethnic Norwegians opted to remain in their ruined settlements, where they were eventually cared for by the liberating Red Army (Hunt, 2014). However, thousands of refugees departed for southern Norway and Sweden. These were composed disproportionately of indigenous Sami people, many of whom did not return and were instead absorbed into the larger population centers of the Norwegian metropole (Weinstock, 2013).

The importance in this theater of fortifications meant that the German forces defending Norway invested huge resources in their construction. Along the coast of southern and central Norway, where the Germans prepared extensively for a possible Allied landing, these

fortifications consisted of hundreds of forts and artillery emplacements constructed of earth and concrete (Zaloga, 2011). In the High North, where combat operations were more fluid, German and Soviet forces dug earthen entrenchments into the tundra, often reinforced by imported lumber (Gebhardt, 1989). When the Germans withdrew to the Lyngen Alps, they fortified their positions by constructing bunkers from the native rock of the surrounding country (Hunt, 2014; Murray, 2019). The Germans supported all these fortifications with fields of landmines. Examples of all three types of fortifications—concrete, trenches, and rock bunkers—remain in landscapes around Norway to this day, many of which have become tourist attractions (Visit Norway, ND). The fate of deposited landmines was far shorter-lived and darker. In the immediate aftermath of the war, the Allies forced surrendered German soldiers to clear the minefields the Nazi armies had sown across Europe, resulting in hundreds of injuries and deaths among these soldiers (MacKenzie, 1994). However, it also successfully removed this threat from the landscape less than a year after the conflict ended.

Partisan activity was also an important factor on the Norwegian front, as Norwegian insurgents, supported by British and American commandos and air forces, sought to attack key infrastructure within occupied Norway (Chaisson, 2014). One of the most dramatic events to occur in the Norwegian theater is illustrative and hints at types of environmental disruptions that while not actually a factor in the Norwegian campaign, will certainly be important in similar conflicts in the future. This was the operation launched by Norwegian partisans and British commandos to damage the Venmork power plant in southern Norway and to interrupt the supply of deuterium (also called heavy water) that this facility was producing as part of the German government's effort to develop an atomic bomb (Sørensen, 2018). Norwegian saboteurs were able to infiltrate the power plant and use explosives to destroy the equipment used to

manufacture the heavy water. They then planted bombs on the ferry craft *Hydro* that was moving the remaining supplies of heavy water down Lake Tinn below the power station, sinking the ship in the deep waters of the glacial valley lake. Deuterium is neither toxic nor radioactive, but this incident highlights how nuclear resources can become targets of military action during wartime, with the potential to produce radiological disruptions under other circumstances.

The tactics of the naval war around Norway were shaped by operational considerations as well. The rugged fjords constituting the terrain of the entire Norwegian littoral provided ample opportunity for ships to conceal themselves from both surface and aerial observation (Engvig, 2016). This was, in part, the reason the British government elected to start mining Norwegian coastal waters even before the German invasion to restrict enemy maritime mobility (Churchill, 1948). After the invasion, due to the heavy losses suffered by the German surface fleet around Norway and elsewhere, the *Kriegsmarine* decided to employ submarine raiding to attack distant sea lanes, such as those in the North Atlantic (Engvig, 2016). The Germans elected to keep many of their remaining surface warships, including the battleship *Tirpitz* and the battlecruiser *Scharnhorst*, close to Norwegian waters, where they could launch surprise raids against Allied convoys transiting the Barents Sea to Russia, raids that were often supported by aircraft and submarine attacks. Attacks by Norway-based German submarines and surface warships sank considerable numbers Allied merchant ships from 1940 to the end of the war. Raids by the German surface fleet could also be devastating, as demonstrated by the Battle of Convoy PQ17, in which German warships led by *Tirpitz* sank 24 of the 35 merchant ships in the convoy (Engvig, 2016).

The threat of German raids against Allied shipping prompted frequent Allied counterattacks, both against the German ships' bases in Norway and in the surrounding seas

(Engvig, 2016). British bombing raids launched from Great Britain were a near constant threat to German ships and naval infrastructure, especially in southern Norway where areas around the port city of Bergen became some of the most war-ravaged landscapes in Norway (Claasen, 2001). These attacks prompted the Germans to construct massive concrete submarine pens at both Bergen and Trondheim to protect U-boats based there, activity which attracted further Allied air attacks against these facilities (Showell, 2002). The Germans also employed camouflage to protect their ships from attack, cutting down local vegetation to and placing it onboard to disguise the vessel (Engvig, 2016). The Germans also employed smoke screens to mask their ships, burning chlorosulfuric acid to create an artificial mist and prevent enemy observation and targeting during attacks. Even so, Allied air attacks could be effective. British bombers, using huge 12,000lb (about 5443.1 kg) “Tallboy” bombs severely damaged the German submarine pens at Bergen and sank the *Tirpitz* near the port of Tromsø in late 1944 (Claasen, 2001). The Allies also escorted Arctic convoys with powerful forces of surface warships that could engage German raiders. In one such engagement, British warships sank the battlecruiser *Scharnhorst* in the Barents Sea during the Battle of the North Cape as the Germans attempted to attack Convoy JW55B (Woodman, 2018).

In the post-war context, some of the shipwrecks in coastal waters, such as the *Tirpitz*, were salvaged for scrap, while those in deeper water like the *Scharnhorst* and British aircraft carrier *Glorious*, along with the dozens of merchant ships sunk along the convoy routes, remain where they sank (Grossman, 2018). Sea mines remain an ongoing hazard in Norwegian waters, which the Norwegian military usually disposes of by detonating where they are located (Lott, 2022). Much of the German naval infrastructure constructed in Norway became incorporated

into the civilian infrastructure of the growing Norwegian maritime trade industry, such as the massive submarine pens in Trondheim that now serve as dockside warehouses (Showell, 2002).

2. Step 2: Identification and Location of Likely Environmental Impacts in the Norwegian Theater

The imperatives of the tactical, operational, and strategic levels of war shaped how and where both sides interacted with the geography and landscapes of the Norwegian theater (Table 9.1). German forces modified the landscapes of areas they intended to defend by building extensive fortifications and infrastructure. Ground combat on battlefields across the length of Norway represent potential areas of various kinds of contamination. Naval combat resulted in dozens of shipwrecks that continue to contaminate the ocean around Norway today, while naval forces continue to locate and destroy sea mines along the country's coast. Burning military equipment spewed chemical pollution into the atmosphere, later to be absorbed by nearby flora and fauna. Finally, the conflict changed the Norwegian government's strategy for maintaining the country's independence, creating ripple effects that changed Norway's military and environmental landscape. Finally, the fate of Norway's Sami minority in the High North accelerated economic changes in that region that continue to affect its landscape today.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 9.1 Likely types of environmental disruptions (highlighted in gray) that occurred during the Norwegian theater

In the lithosphere, construction and excavation activities occurred at sites where German forces sought to fortify their conquests from Allied counterattacks. This included the belt of coastal forts and artillery batteries that stretched from Oslo to Norway's Arctic, but was most dense in southern Norway. Field fortifications including trenches and bunkers constructed of wood and rock were created in the tundra and Alpine terrain in the High North, including near the Soviet frontier, in the Lyngen Alps, and the major islands off Norway's Arctic coast (Zaloga, 2011; Murray, 2019). Construction also occurred in Norway's port cities, where German forces developed infrastructure to support their naval forces operating from the country (Showell, 2002 & 2012).

Cratering and soil compaction occurred at sites of actual combat in the Norwegian theater. However, their effects are likely to have been relatively minor due to the inability of any belligerent's ground forces to sustain large, mechanized forces in the Norwegian environment (Dzwonczyk). Even so, the Allies employed heavy naval artillery during the Battle of Narvik in 1940, while Soviet forces tried to sustain a large artillery force during their attack into northern Norway, though the difficult terrain hampered this effort (Lunde, 2008; Gebhardt, 1989). More likely to have left lasting craters were the aerial bombing attacks launched by both sides during the war. The German *Luftwaffe* launched devastating aerial attacks against Narvik in 1940, while British bombers repeatedly attacked German ships and naval facilities, sometimes with bombs of tremendous size (Claasen, 2001). Many of these bombs fell into the waters of the fjords in which their targets were anchored, but many others might have struck the coastline, altering the topography and drainage patterns of the local landscape. Similarly, solid compaction would have occurred in areas of frequent or heavy troop movement, such as around the sites of the major battles in southern Norway, at Narvik, and near the Soviet border. However, the inability of any side to effectively operate heavy mechanized forces in this theater means that these effects would largely be due to heavy foot traffic, rather than to the movement of vehicles in most cases.

Explosive and metal residue are another likely effect of World War II conflict in the Norwegian lithosphere, though the relatively low density of the actual combat on any single landscape means that such effects are likely very minor. Furthermore, the Norwegian government forced the large numbers of German prisoners who were in Norway after the German capitulation to remediate many of the landscapes that had been most affected by the deposition of war residue, including landmines (MacKenzie, 1994). The low regard in which Norwegians held the occupying forces of the Nazi regime led to them using these troops as a

cheap and ready labor force to rapidly erase many of the environmental disruptions in the lithosphere that might otherwise have led to the abandonment of some Norwegian landscapes, or at least a slower remediation process.

Finally, the spillage of petroleum products into the lithosphere would most likely have occurred on the battlefields in the High North, where the Red Army attempted to field a highly mechanized force for their attack into northern Norway (Gebhardt, 1989). Though Soviet vehicles remained largely road bound, their units' logistical areas would likely have become sites of contamination as Soviet soldiers attempted to maintain the momentum of their attacks across the tundra.

The hydrosphere is the most likely location of the longest-lasting effects of slow violence originating from the Norwegian theater of the Second World War due to the hundreds of shipwrecks that the conflict produced (Carter et al, 2023; Heersink, 2023). These shipwrecks, which included large and small warships, merchant ships, troop transports, oil tankers, and fishing vessels, are a major potential source of hydrocarbon, metal, and high explosive contamination of the waters around Norway, representing as they do hundreds of thousands of tons of reactive metal, thousands of tons of fuel, and hundreds of tons of explosives deposited on the ocean floor. Adding to this, the large numbers of sea mines emplaced by both sides continue to wash ashore on the Norwegian coastline in the 21st century, where they are destroyed in controlled detonations (Lott, 2022).

The noise and blast energy, originating from both explosives and sonar sensors, associated with the hundreds of engagements that produced the above-mentioned shipwrecks is also a source of possible disruption in the hydrosphere, as these forms of direct violence may have injured or killed aquatic life in the area, especially in the confined waters of Norwegian

fjords, though direct study of the effects of this type of violence is likely impossible so long after the fact (Holm, 2012; Lott, 2022). However, in the post-war context, Norwegian scientists have raised concerns about the practice of using explosives in the confined waters of Norwegian fjords to destroy sea mines that wash ashore, siting concerns about the effects these blasts can produce on aquatic life in the local area (Lott, 2012).

Finally, the direct violence of the Second World War in Norway may have produced some benign or even beneficial disruption in the lithosphere. These include the potential for the hundreds of shipwrecks in the area to provide new habitats for marine life, and also the reprieve provided to aquatic populations from the pressures of commercial fishing as such activities were largely suspended in the dangerous wartime waters of the North, Norwegian, and Barents Seas during the five years that the conflict raged (Holm, 2012).

In the atmosphere, the direct violence of noise and blast energy near ground, naval, and air engagements might have produced negative effects on nearby organisms. These effects would likely have been worse in areas of heavy fighting, especially where such fighting was sustained, such as around Narvik or along the Soviet border. Likely more destructive was the toxic burning that occurred as part of many engagements. Intentional and unintentional burning of equipment and structures as a byproduct of combat, but also the intentional creation of smoke as a means of obscuration, as practiced by the German *Kriegsmarine* to mask their ships from aerial observation and attack (Hartl, 2019). While such fumes would not remain in the atmosphere for long, they nonetheless could be transported in the atmosphere to nearby landscapes, where they could affect the local biota.

The fighting in and around Norway in the Second World War carried the potential for important disruptions in the region's biosphere. Norway's civilian population at the time of the

German invasion was approximately 3 million persons (Lunde, 2008). The German occupation force of 400,000 individuals represented an increase in this population more than 13% for the five years that the war lasted. Moreover, military deployments could alter local populations even more dramatically, particularly in the sparsely populated High North. The relatively brief Battle of Narvik swelled the human population of that northern town by nearly 30,000 individuals during the two months of fighting there, while a combined 200,000 Soviet and German soldiers lived and fought in the even more sparsely populated areas around the Soviet frontier in October of 1944 (Lunde, 2008; Gebhardt, 1989). The German and Soviet armies also relied upon thousands of horses and mules as pack and draft animals (the Soviets also employed local reindeer for this purpose), swelling the large animal populations of certain landscapes as well (Gebhardt, 1989).

The chemical contamination of biota and food chains because of military action in the Norwegian theater is likely far more pronounced among marine life as opposed to organisms on land. The long-term threat of hundreds of shipwrecks leaking oil, fuel, and other toxic materials has the potential to contaminate the entire region's maritime food chain, and by extension that of animals, including humans, who rely on ocean life for food. While similar processes may be at work on land as well, the difficulty of operating large, mechanized forces away from the coasts in this difficult terrain and environmental conditions of this theater means that these terrestrial effects may be muted. The effects of burning on landscapes, while accompanying many engagements on land, were also most likely mitigated by the region's cool, humid climate. More important, but harder to assess, are the short and long-term effects of the killing of both plant and animal life that occurred during the conflict. This occurred both unintentionally, such as the killing of aquatic life at sea because of the detonation of ordnance, and intentionally, as when

German forces cut down trees and other local vegetation along the coastlines of the fjords where they hid their warships. Moreover, about 9,000 Norwegian civilians died violently during the war, with these casualties disproportionately occurring in the sparsely populated High North. The movement of refugees to areas further south changed the ethnic makeup of northern Norway, reducing the proportion of indigenous Sami and in many cases causing these refugees' indigenous identities to disappear into the broader Norwegian cultural identity (Berg-Nordlie, 2021). This also caused a decline in the region of this minority population's traditional industries, including coastal fishing, farming, and reindeer herding, and accelerated the growth of extractive industries (Weinstock, 2013). Though the Norwegian government altered its national policy after the war to value multiculturalism over the prior policies of integrating national minorities into “Norwegian” culture, much of the damage to Sami society wrought by the war proved to be irreversible.

3. Step 3: Current Research Examining Norwegian Theater Environmental Disruptions

Much existing research has examined various aspects of the environmental legacy of the Norway theater (Table 9.2). Most empirical scientific studies have focused on the marine environment. More socially oriented archeological studies have examined many of the sites of German military infrastructure in Norway, including fortifications and prisoner of war (POW) camps. Other studies have employed both remote sensing and dendrochronology to gauge the impact of wartime and postwar military activities on local plant life. Finally, several

anthropological studies have examined how Norwegians' attitudes towards the environment changed because of the events that occurred between 1940-1945.

Lithosphere			
Mechanical	Chemical	Radiological	Biological
Construction and excavation	Chemical weapons residue	Fallout	Habitat disruption
Deposition	Explosive residue	Depleted uranium	Landscape abandonment
Cratering	Metal residue	Mining radioactive materials	
Soil compaction	Petroleum product spills		
Hydrosphere			
Mechanical	Chemical	Radiological	Biological
Inundation	Hydrocarbon spills	Fallout	Habitat disruption
Diversion	Chemical weapon residue	Nuclear shipwrecks	Fishery abandonment
Noise and blast energy	Explosive residue	Lost nuclear weapons	
Deposition	Metal residue		
Atmosphere			
Mechanical	Chemical	Radiological	Biological
Noise and blast energy	Chemical weapons use	Fallout	Habitat disruption
	Burning of toxic materials		
	Atmospheric carbon balance		
Biosphere			
Mechanical	Chemical	Radiological	Biological
Military deployments	Chemical/metal poisoning	Radiation sickness	Habitat disruption
Movement of animals	Food chain contamination	Cancer	Invasive species introduction
Refugee flows	Pesticide use		Killing
New economic patterns	Defoliant use		
	Burning		

Table 9.2 Likely environmental disruptions caused by the Norwegian theater. Those that have been the subject of published research are highlighted in green, while those that have not been the subject of published research are highlighted in gray.

On land, several studies have examined the effects of Second World War violence on Norwegian trees and groundcover. Several studies, including Tommervik et al (2003), Li et al (2013), and Rautiainen et al (2016) have uncovered evidence how wartime and postwar conditions shaped land use and land cover in Norway. These studies indicate the conflict was beneficial for forest cover in the short term as wartime economic disruptions prevented normal logging activities and caused some farmland to be abandoned. They note, however, that in the

postwar context the economic recovery across Europe and in Scandinavia led to a rapid acceleration in both logging and agriculture, with downstream effects on the geography of land use and land cover in the region.

The fate of the extensive system of German fortifications in Norway illustrates the importance of forms of social power in determining how long such disruptions persists in landscapes. The German invasion and occupation of Norway was a transformative event in the country's ideological and political understanding of its place in the world. Post-war, the Norwegian government implemented numerous policies to safeguard the country against future conquest. These measures included enacting laws that bound every Norwegian citizen, military or otherwise, to support mobilization and resistance in the event of a war, even without orders from the central government. To support such measures, the Norwegian government preserved many of the artifacts of Nazi occupation, including many of the coastal forts, as witnesses to the consequences of foreign conquest. Indeed, the Norwegian government continues to promote many of these sites as tourist destinations.

In other cases, archeological research has uncovered the altered landscapes caused by military activity in the war. Farstadvoll (2022) documented how abandoned barbed wire from German prisoner of war camps and defensive positions continues to create hazardous conditions for humans and wildlife in these landscapes. He also shows how even minor trench systems in the High North along the former Norwegian-Russian border are still evident in the landscape and have in some cases become dumping grounds for trash and refuse. Mytym and Carr (2012) and Figenschau (2019) have used archeology to examine the legacy of prisoner of war camps in Norway, showing that these internment areas for mostly Red Army prisoners have left lasting scars on their local landscapes as well.

Many studies in recent decades have examined various types of maritime pollution from shipwrecks. These show conclusively that the hundreds of shipwrecks in the North, Norwegian, and Barents Sea represent a major source of heavy metal and other types of poisoning. Some of these, like Bergstrøm (2014), Faksness et al (2014), and Rua-Ibarz et al (2016) have been able to tie specific kinds of contamination in the marine food web to specific military shipwrecks, providing a valuable example of how to distinguish the disruptions of war from those of normal peacetime actions. Other studies, such as Rogowska and Namiesnik (2012), provide more general evidence of overall pollution levels around Norway's marine environments, paying particular attention to the effects of Second World War shipwrecks. Many of these studies have prompted debates about the feasibility of remediating especially problematic wreck sites, such as that of the submarine U-864, which sank with a cargo of liquid mercury as it tried to flee to Japan in February 1945. The Norwegian government has sponsored the offloading of fuel from several wrecks in shallow coastal waters deemed to be especially dangerous, but hundreds of wrecks in the deeper waters of the Barents Sea remain unlocated and unexplored.

Other studies have used records of annual fish takes to extrapolate the effects of fishery abandonment on the post-war populations of aquatic life in the area. Holm (2012) shows that the reprieve granted to fish populations during the war led to a major increase in these populations. However, he also argues that this aquatic population boom also helped to fuel rapid economic development in post-war Norway, contributing to eventual population depletions. Holm also speculates briefly upon the possible effects of noise and blast energy on fish stocks in the wartime context but notes that divining the actual effects of these disruptions is nearly impossible in retrospect.

Several studies have examined environmental impacts of the Second World War on the Norwegian biosphere. In perhaps the most surprising of these studies, Tretli and Gaard (1996) found that Norwegian women who experienced puberty during the years 1940-1945 were at significantly lower risk of developing breast cancer later in life, a fact they speculate could be related to changed diets during the war. In another study, Hartl et al (2019) showed that toxic fumes from the battleship Tirpitz's smoke generators had been absorbed by plants onshore to the extent that they left a record in the dendrochronology of the local trees, illustrating how even short-lived disruptions in the atmosphere can produce long-lasting conditions of slow violence in the biosphere. Other research, already mentioned, has examined the chemical and food chain contamination of biota in the Norwegian littoral, including Bergstrøm (2014), Faksness et al (2014), and Rua-Ibarz et al (2016).

Numerous anthological studies have also examined the changed cultural landscape of Northern Norway that resulted from the direct violence of the Second World War. Weinstock (2013) provides a comprehensive examination of this issue, but numerous other scholars both within Norway and internationally have contributed literature on this topic, including a project within the history department at the University of Texas at Austin (Johnson, ND), and examinations of memory and identity among current-day Sami such as Berg-Nordlie (2021). These show that the Sami successfully advocated for themselves as a distinct but loyal national minority within the broader Norwegian polity in the aftermath of the war but continue to face marginalization and exploitation from parties seeking to exploit the economic resources of Norway's High North.

Even so, many gaps remain in our understanding of the environmental consequences of the Second World War in Norway. While many of the sites of German defensive and logistical

infrastructure is well-documented in Norway, little research appears to have examined the possible changes these structures have created in their landscapes, such as altered drainage patterns or changed habitats for local wildlife. Moreover, more thorough archeology work paired at battlefield sites in Northern Norway and elsewhere can shed further light on the long-lasting consequences of even relatively minor battles, as Farstadvoll (2022) showed in his exploration of abandoned barbed wire across Norway. The sheer scale and volume of fighting that occurred in Norway from 1940-1945 makes thorough documentation of the Second World War's environmental legacy in Norway a daunting task, but one that a multidisciplinary approach incorporating a broad range of studies can begin to tackle.

4. Step 4: Applying the Heuristic

Once again, the taxonomic identification of environmental impacts identified (Tables 9.1 and 9.2) allowed a topological grading of the various impacts identified (Table 9.3). The resulting acuteness grades across context and geographic scale are recorded in Table 9.4, with visualizations from the heuristic tool shown in Figure 9.2. The Norwegian theater differed from the Aleutian campaign of World War II in several ways. First, the scale of forces committed to the Norwegian theater was far larger than in the Aleutians. This was due to the compelling strategic and military importance of Norway, given the country's central position between several of the broader war's belligerents and its position relative to key natural resources and sea lanes. This led to the second major difference, which was the duration of combat in this theater. The Allies and Germans fought each other across the length of Norway for more than five years after the German invasion, allowing time for the development of significant infrastructure

devoted solely to the needs of the conflict. Third, because of Norway's Neutral status prior to the war, little to no military activity directly related to the Second World War occurred in the theater prior to the outbreak of hostilities.

Earth sphere	Mechanism	Direct violence	Context of direct violence	Slow violence (spatial)	Slow violence (timescale)	Slow violence (severity)	Slow violence (acuteness)
Lithosphere	Mechanical	Construction and excavation	War, post-war	Local, regional	Millennia	Disturbance	3 (Significant)
		Deposition	War, post-war	Local	Centuries	Disturbance	2 (Moderate)
	Chemical	Cratering	War	Local	Centuries	Difference	1 (Minimal)
		Soil compaction	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)
Hydrosphere	Chemical	Explosive residue	War	Local	Decades	Disturbance	1 (Minimal)
		Metal residue	War, post-war	Local, regional	Centuries	Disturbance	2 (Moderate)
	Biological	Petroleum product spills	War	Local, regional	Decades	Degradation	2 (Moderate)
		Habitat destruction	War, postwar	Local, regional	Decades	Disturbance	1 (Minimal)
Atmosphere	Mechanical	Noise and blast energy	War, post-war	Local, regional	Years	Disturbance	0 (No impact)
		Deposition	War, post-war	Local, regional	Millennia	Difference	2 (Moderate)
	Chemical	Hydrocarbon spills	War, post-war	Local, regional	Decades	Degradation	2 (Moderate)
		Explosive residue	War, post-war	Local	Decades	Disturbance	1 (Minimal)
Biosphere	Biological	Metal residue	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)
		Habitat disruption	War, post-war	Local, regional	Decades	Disturbance	1 (Minimal)
	Mechanical	Fishery abandonment	War	Local, regional	Years	Disturbance	1 (Minimal)
		Noise and blast energy	Preparation, war	Local	Years	Disturbance	0 (No impact)
Biosphere	Chemical	Burning of toxic materials	War, post-war	Local, regional	Weeks	Degradation	1 (Minimal)
		Military deployments	War, postwar	Local, regional	Years	Disturbance	0 (No impact)
	Mechanical	Movement of animals	War, postwar	Local, regional	Years	Disturbance	0 (No impact)
		Refugee flows	War, postwar	Local, regional	Decades	Disturbance	1 (Minimal)
Biosphere	Chemical	New economic patterns	Postwar	Local, regional, global	Centuries	Disturbance	2 (Moderate)
		Chemical/metal poisoning	War, postwar	Local	Decades	Degradation	2 (Moderate)
	Biological	Food chain contamination	War, postwar	Local, regional	Decades	Degradation	2 (Moderate)
		Burning	War	Local, regional	Years	Degradation	1 (Minimal)
Biosphere	Biological	Habitat alteration	War, postwar	Local, regional	Years	Disturbance	0 (No impact)
		Killing	War, postwar	Local, regional	Decades	Disturbance	2 (Moderate)

Table 9.3 Topology of likely environmental disruptions caused by the Norwegian theater.

		Mechanical			Chemical			Radiological			Biological			Composite ratio		
		Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global
Lithosphere (.34)	Postwar	6	4	0	2	2	0	0	0	0	1	1	0	8.18	8.75	0.00
	War	7	4	0	5	4	0	0	0	0	1	1	0	5.91	6.00	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Hydrosphere (.33)	Postwar	2	2	0	3	3	0	0	0	0	1	1	0	5.45	5.45	0.00
	War	2	2	0	4	4	0	0	0	0	2	2	0	3.64	4.71	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Atmosphere (.06)	Postwar	0	0	0	1	1	0	0	0	0	0	0	0	10.00	10.00	0.00
	War	0	0	0	1	1	0	0	0	0	0	0	0	3.33	3.33	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Biosphere (.27)	Postwar	3	3	2	4	2	0	0	0	0	2	2	0	8.18	8.75	10.00
	War	1	1	0	5	3	0	0	0	0	2	2	0	5.33	6.67	-
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	-
Overall	Postwar	11	9	2	10	8	0	0	0	0	4	4	0	7.35	7.50	1.25
	War	10	7	0	15	12	0	0	0	0	5	5	0	4.84	5.45	0.00
	Preparation	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00

Table 9.4 Cumulative grades of the acuteness of likely disruptions caused by the Norwegian theater according to the topology outlined in Table 9.3.

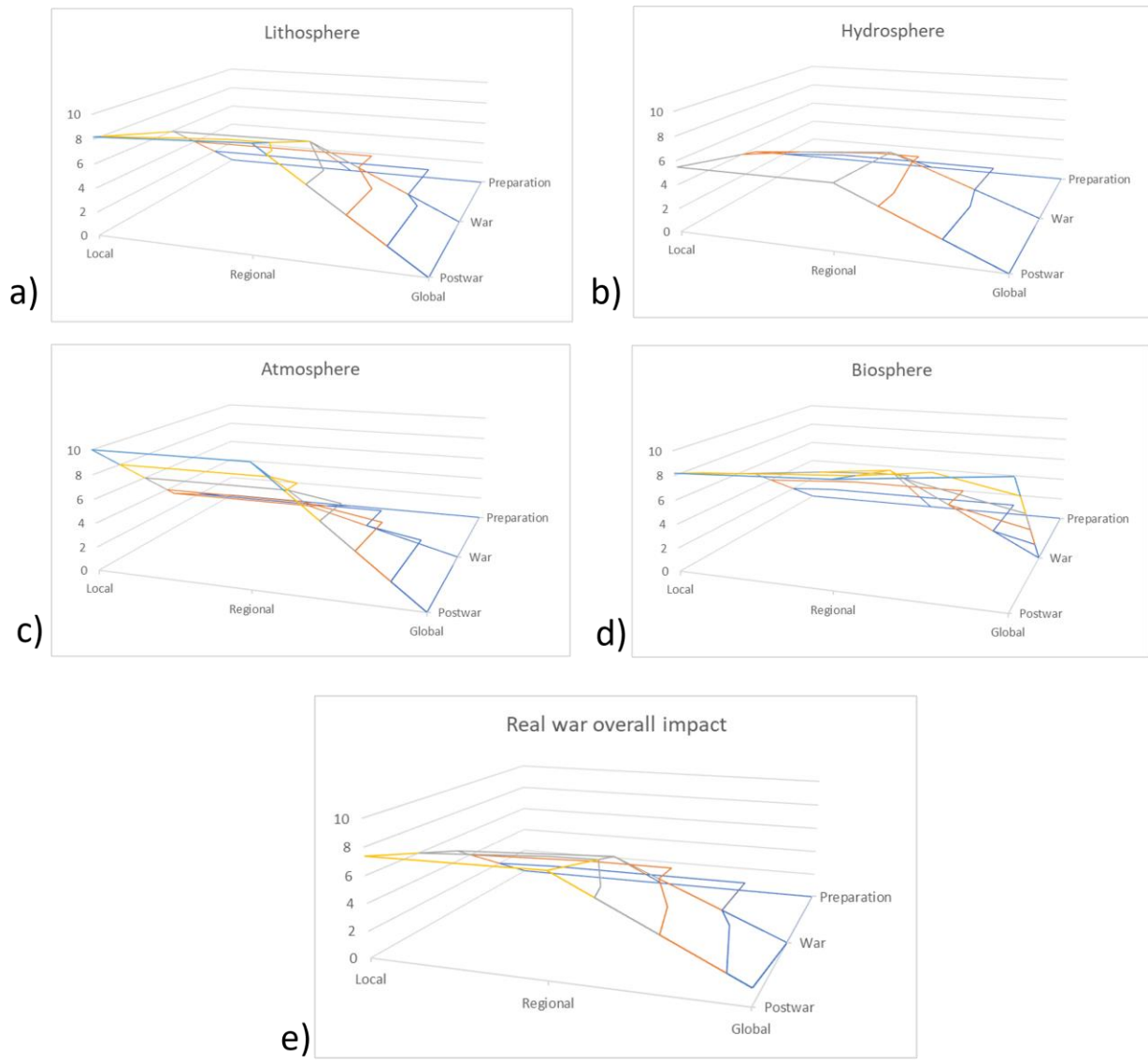


Figure 9.2 Visualization of the overall potential magnitude of acuteness of the disruptions in the lithosphere (a), hydrosphere (b), atmosphere (c), and biosphere (d) and overall weighted impact (e) on the Norwegian environment.

5. Discussion and conclusions

The fact that Norway remained neutral until invaded by Nazi Germany in 1940 and chose not to make meaningful military preparations for a potential war meant that the environmental impacts in the lithosphere are more heavily weighted in the wartime and post-war contexts than

was the case in the Aleutians, where American forces made extensive preparations before Japanese forces attacked. The long-lasting changes in the Norwegian economy that were accelerated by the war, including Norway's abandonment of its neutral status and the unintentional marginalization of the indigenous Sami in the High North, further emphasize the magnitude of environmental disruptions in post-war Norway, despite the rapid cleanup of war detritus that occurred through the labor of German prisoners in the immediate post-war period.

The large volume of shipwrecks around Norway creates long-lasting conditions of slow violence in the hydrosphere, as do the presence of unexploded sea mines that continue to be detonated in the confined waters of Norway's fjords into the second decade of the 21st century. While the Norwegian government has made efforts to remediate some of the most problematic shipwrecks that lie in shallow, coastal waters, the fact remains that hundreds of other shipwrecks, many of them large merchant ships and warships carrying large amounts of fuel and toxic cargoes, remain on the ocean floor where the work of time and water may continue to make these artifacts point sources of chemical pollution for decades, or even centuries, to come.

Finally, the effect of the war on the Sami population of Northern Norway drives long-lasting, perhaps accelerating, conditions of change in that part of the country. The Sami population suffered disproportionately due to the fighting in Norway's Arctic, leading many members of this national minority to permanently flee the region. This changed patterns of land-use in the region and may have even changed the political balance regarding how Norwegians view and exploit natural resources in the Arctic. Though the Sami population continues to assert their rights within the broader Norwegian polity, their interests have often been overruled by the economic interests of the entire Norwegian state. Some of this marginalization is no doubt due to the significantly decreased proportion of Sami residents in the High North, making this an

example of how direct and slow violence in the environment related to war can combine with altered elements of social power to create changes in landscapes that are not simply permanent, but continue to be dynamic as the consequences of war propagate through time.

6. Comparison of the Falklands, Aleutians, and Norwegian Case Studies

The three case studies selected for analysis present several points of difference and commonality (Figure 9.3). Many of these points of comparison yield interesting general observations about the potential impacts of military conflict in Arctic or high latitude regions. Some of the more salient of these observations relate to the interplay of the strategic, operational, and tactical levels of war as they effect military operations in these environments, the fate of indigenous population in high latitude war zones, and the importance of elements of social power in shaping post-war remediation and recovery. Some of the commonality can be attributed to the similar environmental conditions in which these conflicts occurred, while many of the points of divergence indicate why the unique social conditions in which each conflict occur defy any efforts at generalization.

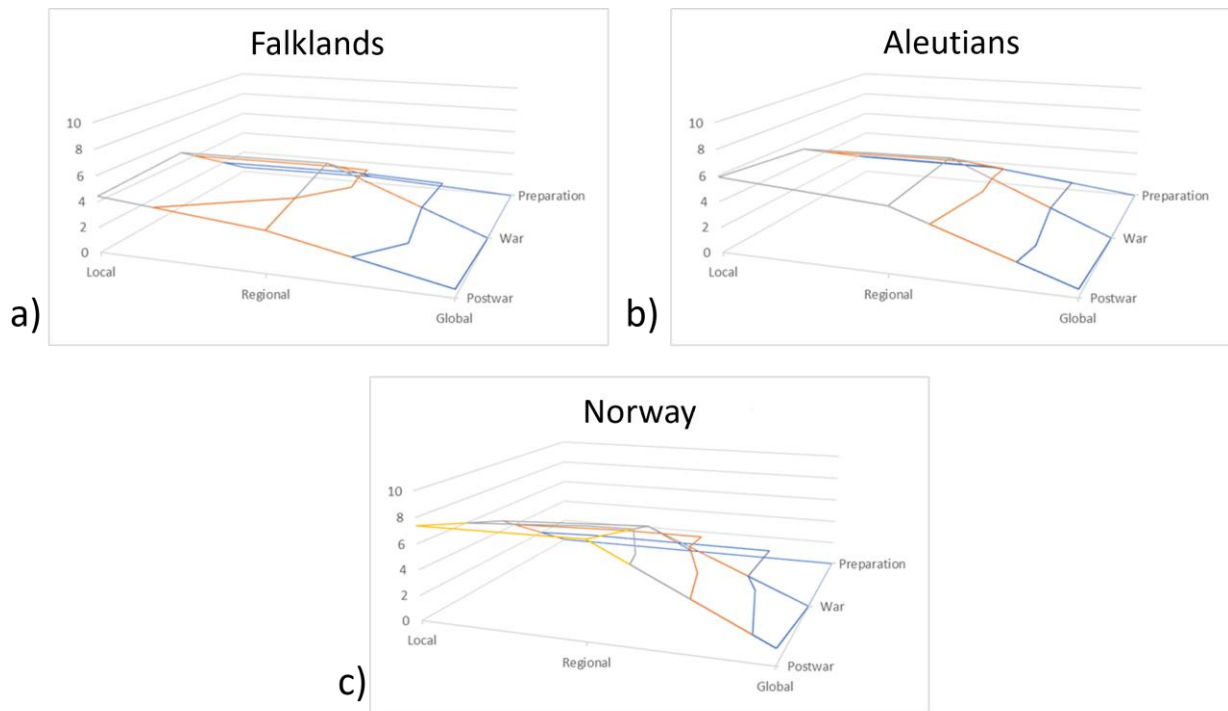


Figure 9.3. Comparison of the overall environmental impact of the three case studies showing the heuristic visualization for the Falklands War (a), the Aleutians campaign (b), and the Norwegian theater (c).

A comparison of the strategic analysis of the three case studies indicates some conclusions about the relationship between these levels of war in high latitude conflicts. In only one of these case studies did the region in which the conflict occurred present compelling military and strategic logic for why belligerents should engage one another there, that being the case of Norway. The other conflicts, by contrast, were borne out of either ideological and political imperatives generally divorced from the relative location of the contested territory (Falklands) or misunderstandings about the actual military threat that enemy possession of the territory in question posed (Aleutians). This fact did not correspond to how belligerents chose to act in the preparation for war context of the various conflicts, however. The region that experienced the heaviest preparation activity was the Aleutians, even though neither Japan nor the US anticipated conducting major campaigns there. In Norway, where strategic imperatives

drew great powers to intervene like months to a flame, the Norwegian government opted to make almost no pre-war preparations for conflict. The lack of preparation for military activity in the Falklands is more understandable, given the fact that the British government was seeking to convince the islanders to accept Argentinian sovereignty before the outbreak of hostilities. Strategic imperative did correspond to the length and intensity of the conflicts, however. In these attributes, Norway stands out for the size of the forces committed to this theater and the length long duration of the combat in which they engaged, with correspondingly transformational results in the environment. These observations indicate that environmental effects related to war will be more pronounced when at least one of the belligerents possesses a compelling strategic reason to maintain their presence despite the challenging environmental conditions of a high latitude campaign.

Operationally, the ruggedness and remoteness of these three high latitude conflict zones emphasized the importance of naval control of the region's sea lanes. In all three cases, the belligerents devoted major effort to contesting one another's access to the ocean and the littoral of the territory in question. Warships, convoys, port facilities, and landing areas all became targets as both sides sought to cut one another off from their distant bases of supply. This commonality indicates that future conflicts in these environments will also be expeditionary in nature, with long logistical tails vulnerable to interdiction. In an age when the preferred weapons system for conducting such interdiction is the nuclear-powered submarine, the environmental legacy of future military shipwrecks is troubling due to the potential for not just increased chemical disruption, but also long-lasting radiological contamination.

Tactically, the logistical and terrain difficulties presented by high latitude battlefields meant that all three case studies centered around dismounted infantry combat on land that where

mechanization and heavy artillery firepower was absent, other than in the cases where heavy naval guns to be brought to bear as was the case in the Aleutians. This fact emphasized the importance of fortifications in all three conflicts, most notably in Norway but also in the Aleutians and the Falklands. Landmines formed a key component of these fortifications too, leaving disrupted and hazardous landscapes in the conflicts' aftermath. By contrast, the low density of heavy equipment and heavy firepower limited the amount of mechanical damage that military forces could inflict on the terrain of the battlefield in many cases. One can assume that any future conflict in a high latitude environment will exhibit a similar pattern, where light infantry forces must rely on field fortifications and superior training to overcome their lack of mobility and firepower, with corresponding effects in battlefield landscapes.

The ratio of real war versus absolute war acuteness for all three conflicts provided some interesting insights as well. Across all three conflicts, the ratio of disruption in the biosphere was higher than any of the other three spheres. This probably is a reflection of how vulnerable Arctic or high latitude environments and organisms are to even seemingly minor effects.

The fate of the indigenous populations of the three case studies provides interesting insights into the environmental effects of warfare as well. In the Falklands, the post-war meaning ascribed to the conflict elevated the status of the local islanders and increased their political power within the United Kingdom. By contrast, the Aleutians campaign was economically devastating for the Unangan people who, in many cases, were never able to return to their homes after the war. In Norway, the fate of the Sami people and their relationship with the Norwegian government was more complex. The war elevated their status within Norway politically, but in practical terms the displacement of so many of the Sami population into the more populous south of the country diluted their ability to use this new status to advance their interests in the High

North. Perhaps more interesting is the point of commonality between all three of these groups. All three, both during and after the wars that raged in their homelands, chose to employ discourses that emphasized their status as members of the broader state and that highlighted their members' participation in combat as evidence of their loyalty and patriotism to the same. This provides examples of how indigenous groups have agency to leverage the ideological, legal, and political structures of the state to advance their interests.

Additionally, the three case studies show how elements of social power can shape the post-war environmental legacy of high latitude conflicts. In all three cases, the contested regions became economic resource frontiers in the aftermath of hostilities, with significant oil exploration and exploitation occurring in the Falklands, Alaska, and the Aleutians, all enabled by the pre-war, wartime and post-war military infrastructure that had supported these conflicts. While this exploitation would doubtless have occurred regardless, the presence of ready-made ports, airfields, and highways accelerated the pace at which this exploitation could occur. The meaning ascribed to a conflict's outcome seems important to its environmental legacy. In the Falklands, where the British recapture of the islands was framed as an important national turning point both politically and ideologically, the national government chose to devote significant resources to remediate the battlefield landscapes. In contrast, battlefields in the Aleutians became largely forgotten even before the end of the war and the US government devoted almost no resources to clear hazards from its territory. In Norway, the general antipathy felt towards the brutal Nazi occupation led the government to employ poorly equipped prisoners in remediating hazardous landscape, resulting in hundreds of deaths and injuries among these prisoners. Finally, in all three cases the reality of having fought a conflict in the region created a perceived need to secure the contested territory against future aggression. The UK government in the Falklands, the

US government in the Aleutians, and the Norwegian government in Northern Norway all devoted significant resources to develop new military infrastructure designed to defend against possible future aggression in the area, illustrating how altered perceptions of the military importance of an area can play a part in reshaping landscapes long after the guns have fallen silent.

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Chapter 10 - Conclusion

This dissertation has outlined the structure of a heuristic tool that can aid researchers to identify, classify, measure, contextualize, compare, and predict the environmental disruptions caused by war. In doing so, it has built upon research and thinking across a variety of fields, including military geography, militarized landscape studies, environmental military history, environmental geopolitics, and warfare ecology, among others. The tool outlined, while no doubt imperfect as all attempts to provide a framework for such a complex issue must be, is a useful evolution of Machlis and Hanson's (2008) suggested framework for warfare ecology that answers many of the imperatives for future research that they outline. Furthermore, the three case studies in this dissertation have demonstrated how the heuristic can help study the environmental disruptions caused by real world conflicts that occurred across different geographic, temporal, and operational scales.

1. Pitfalls

Despite its utility, researchers who employ the heuristic approach outlined here dissertation should approach the task with some caution, as no system for exploring a topic as complex as war can be without pitfalls that might skew results. These include failing to understand the taxonomy and topology that form the tool's foundation, misunderstanding concepts of scale and context inherent in the model, and failing to account for relative mitigating and amplifying factors that are tied to the specific place and social context in which a conflict occurs.

Failing to thoroughly work through the taxonomy and topology of environmental disruptions outlined in Chapters 5 and 6 represents one potential source of error and/or bias that can compromise results. The taxonomy of war-related environmental disruptions outlined in Chapter 5 draws from an extensive reading of existing literature that has examined war's impact on the environment. The categories of disruptions in the taxonomy represent an interpretation of the broadest possible "baskets" into which different and specific types of military disruptions of the environment can be divided. These categories represent a qualitative, albeit somewhat subjective, judgment and another researcher might choose differently. However, as the relative weighting of the heuristic tool across earth spheres is directly tied to the number of categories within each sphere and mechanism of the taxonomy, as are the cumulative grades of acuteness within each sphere, so altering the topology would also change the "absolute war" baseline against which "real war" disruptions are measured and ratioed.

Failing to understand the concepts of scale and context the heuristic is built upon is another danger. The heuristic relies upon an understanding of scale that brings together concepts from military geography and military geopolitics. Users of the heuristic should keep in mind that the local-regional-global scales used in this tool do not simply represent increasingly larger perimeters within which military disruptions occur. Rather, the jump from the local to the regional scale represents the relationship that a disruption on one landscape possesses with changes in another landscape separated from the original by either time or distance, or both. The jump from the regional to the global scale represents a situation in which the changes wrought by military action are so widespread as to change the environmental context of every landscape. Misunderstanding this concept could lead another researcher to fail to examine relationships and how they can manifest differently across scales.

2. Mitigating and Amplifying Factors

Another potential weakness of the heuristic tool as it now exists lies in its failure to account for the different environmental and social conditions in which wars occur. Neither war nor its associated environmental disruptions occur in a vacuum. Indeed, the field of military geography is largely devoted to understanding how both the environmental and social context in which conflict occurs can influence military operations (Palka & Galgano, 2012). Similarly, war-environment research must also consider how the environmental and social context can influence the severity and persistence of disruptions in landscapes. Chapter 1 addressed the contested meaning of “the environment,” noting that this project generally considers humans to be part of it. However, the following discussion breaks from this assumption briefly to discuss how human agency as expressed by elements of social power (economic, political, ideological, military), can shape the fate of war-related disturbances in a landscape (O’Lear, 2010). In doing so, it differentiates these factors from the non-human physical and biological processes that can also influence landscape recovery.

2.1 Environmental Factors

Chapter 5 described how the context of which earth sphere a military action disrupted was important for understanding the resulting conditions of spatial and temporal slow violence. Similarly, the combined environmental conditions of a landscape (climate, weather, geomorphology, etc.) can exert a mitigating or amplifying influence on both the severity and

persistence of disruptions across earth spheres. Empirical physical science-based studies and models drawn from environmental geography and science, such as climate science, succession theory, and LEMs, can be especially useful for understanding this intersection of war and the environment.

A broad reading of war-environment literature indicates that climate conditions can play an important role in both the spatial reach and temporal persistence of disruptions (Lawrence *et al*, 2015). More specifically, the factors of humidity and temperature appear to be important because of the effect they exert upon rate of chemical reactions and the fluidity of effects. In simplistic terms, warmer temperatures increase the rate of chemical reactions, thus accelerating the breakdown of contaminants such as explosive residue, chemical weapons, heavy metals, or hydrocarbons, while colder temperatures slow these rates (Broomandi *et al*, 2020). As such, disruptions that involve some form of chemical reaction will generally persist longer in cold climates than in warm ones. Lower temperatures also slow the growth of organisms, meaning biological damage in colder climates will be slower to recover (Dalby, 2003).

Similarly, the presence of water as expressed by humidity can influence the persistence and geographic reach of environmental disruptions. Water can act as a solvent for disruptions that incorporate a chemical reaction (Von Stackleberg, 2005). Perhaps more importantly, the presence of water as a fluid medium can increase the spatial reach of a chemical disruption by moving contaminants from one landscape to another (Lawrence *et al*, 2015). Moreover, the presence of water as a geomorphic shaping agent can also amplify the effects of physical damage to a landscape, as when disruptions to landscape's geomorphology result in changes to its hydrology, creating new and patterns of drainage and erosion (Rijal *et al*, 2018). Thus, the combined climate and weather effects of temperature and humidity represent factors that can

influence the spatial and temporal scale of slow violence (Figure 10.1). A useful method for judging the environmental factors at the site of a disruption could be to use the Köppen climate classification system to determine both the climate and humidity patterns of the local area (Peel *et al*, 2007).

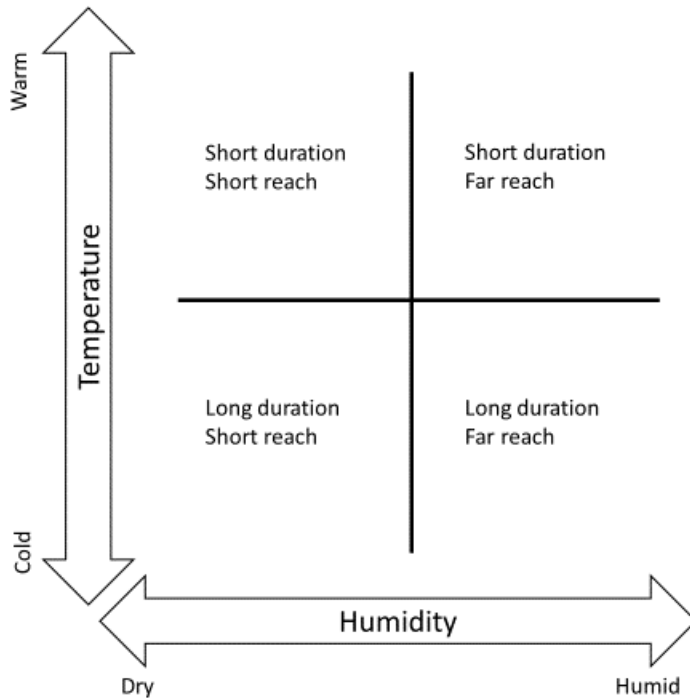


Figure 10.1 A simplistic diagram for visualizing how the climate and weather effects of temperature and humidity can influence the duration and spatial reach of war-related environmental conditions of slow violence.

Finally, the specific geomorphology of a landscape is an important physical factor influencing the effects of war-induced slow violence in the environment. The diversity of geomorphic factors and processes that can influence the duration, reach, and severity of a disruption is vast and includes factors such as slope, aspect, soil parent material, and wind and hydrological patterns, among many other (Temme *et al*, 2013). In this case, the richness of

models and research present in the field of landscape evolution modeling represents a promising avenue for geomorphologists and LEM researchers to intervene in war-environment studies.

2.2 Economic Factors

Researchers have long recognized human activity as an increasingly dominant factor in shaping landscapes (Wainwright & Millington, 2010). Similarly, human activity can influence how and even if a landscape recovers from war-related disruptions. Perhaps unsurprisingly, historical anecdotes indicate that wealthy urban environments can prove extremely resilient to the effects of even massive violence, as demonstrated by the rapid recovery of cities in both Europe and Japan in the aftermath of the aerial bombing campaigns of the Second World War (United States Strategic Bombing Survey, 1945; Schlosser, 2013; Giangreco, 2017). Similarly, the Vietnamese recovery of the Red River Delta area in the aftermath of US bombing campaigns during the Vietnam war indicate how the application of economic resources by a society can mitigate the duration of slow violence conditions (Biggs, 2018).

By contrast, rural and poor areas are often neglected in the aftermath of a conflict, forcing residents to affect what remediation they can using local resources (Lackenbauer & Farish, 2007). The economic cost of remediating a landscape, such as in the case of landmine clearance or recovery of petroleum spills, can be far higher than the original act of direct violence that created the disruption (Lawrence et al, 2015; Chiovelli *et al*, 2018). Often, governments and communities opt to simply restrict access to such landscapes rather than recover them, or even turn such areas into “sacrifice zones” where further environmental degradation is deemed less

distasteful, which can extend the conditions of slow violence (Pitkanen & Farish, 2018; Dalby, 2022).

2.3 Political Factors

Political factors too can influence the way a landscape recovers from violence, sometimes in ways that counteract the prevailing economic context. Governments can deem some areas as worthy of remediation regardless of the economic cost-benefit balance and devote resources from the broader community to achieve it, as evidenced by efforts to recover militarily polluted landscapes in the Canadian Arctic and successful landmine-clearance efforts in Mozambique during the 1990s (Lackenbauer & Farish, 2007; Chiovelli *et al*, 2018). Alternately, areas that experience political discrimination from the broader polity can be starved of even proportional resources for landscape remediation based on cultural or ethnic grounds, or due to government corruption (O’Lear, 2018).

2.4 Ideological Factors

The post-war meaning that societies ascribe to militarized landscapes can also influence these areas’ recovery, sometimes in surprising ways. Areas of preparation for war, such as fortifications or training grounds, can become meaningful for the veterans who served there and the local community that hosts these activities. The case of Camp Hale, near Vail, Colorado, where the US 10th Mountain Division trained during the Second World War, is a clear example of such a legacy. Veterans of the 10th Mountain Division returned to the Vail area after the war

and were instrumental in starting Colorado's ski recreation industry (Witte, 2015). This fact, and the veneration of the US World War II veterans by the local community and other stakeholders, have in many ways hindered local and federal government efforts to remediate the Camp Hale landscape, despite the significant disruption still evident there (US Forest Service, 2020).

Alternately, the ideological meaning a culture assigns areas of military violence can lead to both accelerated remediation. Landscapes of particularly significant or impactful battles can often become state- or internationally administered military parks, such as the battlefields of Waterloo, Gettysburg, and Normandy (St. Pierre & Marcotte, 2020). In these cases, the battlefields are recovered so that they are generally safe for tourist visitation, then essentially culturally freeze-dried to preserve the landscape in a state as close to that of the day of the battle as possible (Murray, 2015). Similarly, postwar landscapes such as military cemeteries assume cultural meaning and significance that they did not possess before the conflict, leading to remediation efforts to render these areas safe for visitation, such as with the US First and Second World War cemeteries in Europe and the Pacific (Sledge, 2005). In all these cases the landscapes are remediated of some slow violence effects, but the changed ideological meaning ascribed to the landscape induces other changes as well.

2.5 Military Factors

Finally, the military and political outcome of a conflict can cause military forces to militarize new landscapes in preparation for the next conflict. This can lead to the abandonment of areas for security purposes, which occurred with the Korean Peninsula's Demilitarized Zone after the inconclusive Korean War of 1953. In this case, the large swathe of country was

effectively closed off to economic development to form a buffer zone between north and south, eventually resulting in a *de facto* nature reserve of significant ecological diversity (Kim et al, 2020). The threat of future conflict can also lead to further disruption, as exemplified by the outcome of the 1982 Falklands War. The Argentinian invasion and British recapture of these islands prompted the British government to construct military infrastructure in the area as a safeguard against future invasion. These facilities include a new military airfield and military barracks and training areas, which significantly increased the persistent military footprint in this landscape (Pollard, 2023).

2.6 Human Development Index as a Proxy for Social Factors

The preceding sections have summarized some aspects of the elements of social power that can influence a landscape's recovery from military action. This is clearly a complex issue, with factors that can both mitigate and amplify landscape disruptions. One possible way to abstract the influences of social power on landscape recovery is to use the United Nations' Human Development Index (HDI) as a proxy for these factors. The HDI is the primary statistic of a country-level report issued annually that attempts to encapsulate a holistic measure of a state's development beyond just economic measures such as GDP (Sagar & Najam, 1998). The index measures three dimensions of development including access to education, access to healthcare, and economic standard of living.

Thus, a final step in the application of the use of the heuristic tool could involve the application of environmental and social modifiers to the results to help predict more specific, conditions-based patterns of war-related disruption. Environmentally, such modification could

take the form of adding weight to the regional scores of disruptions for conflicts that occur in humid environments, reflecting the increased potential for water flows to carry disruptions from one landscape to another. Alternately, one could increase the magnitude of effects in local landscapes for disruptions that occur in cold climates, reflecting how slower chemical and biological conditions in these environments can extend impacts in terms of time.

Socially, the HDI can be a useful modifier to help predict how economic and political conditions of a specific area may affect the longevity of environmental impacts. As the HDI grades on a scale between zero and one, with higher scores indicating higher levels of development, using the HDI as a denominator with individual measures of the magnitude of scale/context acuteness as a numerator could give an indication of how poor developmental conditions can amplify the effects of violence by reflecting a reduced capacity to mitigate its effects in the post-war context. A similar index that measures the military power of the belligerents, or at least the relative amounts of violence that the conflict produced, might also be a useful tool for mitigating and amplifying factors.

Unsurprisingly, the UN HDI has been the object of near-constant criticism since it was introduced in the 1990s, including assertions that it does not sufficiently account for ecological context (Hickel, 2019). Moreover, the HDI operates at the state level of analysis, thus falling into the “territorial trap” identified by O’Lear (2010) and others, in which the state becomes the scale of analysis whether or not this framework is appropriate for a given study. This concern is especially relevant in war-related research as a unique condition of the wartime context is its violation of state-based concepts of both territory and sovereignty (Elden, 2009 & 2010). Moreover, the environmental consequences of war are even less likely to respect state boundaries and sovereignty than are the political forces driving a conflict.

Nevertheless, the HDI remains a useful tool for providing a rough gage of the relative socio-economic development level of areas in which war occurs, especially because the UN revises the HDI annually, meaning it can account for the socio-economic damage sustained by a state in wartime and tie this damage to environmental disruptions (Kovalyshyn, 2023). In the absence of a better index based on more complete data, the HDI appears to be a good starting point for visualizing the influence of elements of social power on the persistence of conditions of slow violence in war-disrupted landscapes.

3. Reflections on Military Geography

One of the most important contributions of this dissertation is its demonstrations of how a better integration of military geography into war-environment studies can enrich research in the latter field by adding a perspective on *where* and *why* disruptions occur to the more narrowly empirical scientific examinations of *what* and *how* disruptions occurred. Chapters 3 and 4 of this dissertation showed how the study of military cartography can provide a window into how military forces view and understand terrain. However, reintegrating military geography into the broader academic community will require more than new windows through which to examine the topic. Rather, military geography must respond to the valid criticisms that have been leveled against the field in recent years by changing to better engage with its theoretical roots, specifically the theories of war espoused by Carl von Clausewitz (Clausewitz, 1993).

Military geographers must better integrate core theoretical concepts like scale, context, space, place, site, and situation, into their examinations of the spatial dimensions of military conflicts. Clausewitz's opus provides ready-made frameworks for many of these topics.

Moreover, Clausewitz as a philosopher remains relevant across many diverse fields in the academy, providing military geographers with opportunities to reach out and engage with cutting edge research occurring in other fields as well. Moreover, military geographers should alter their case study research approach to incorporate Clausewitz's perspective of treating war as a form of human discourse like commerce or politics. Doing so will not only help to improve the standing of military geography within the geographic discipline but will also improve the field for the applied purposes that it currently serves (Lohman & Fuhrman, 2019).

4. Utility of the Heuristic Tool

The results attained with the heuristic tool have numerous practical applications both academically and in the realm of policy. It can be used as a predictive and comparative tool to aid research and analysis into war-environment topics. It can also act as a stand-in assessment for ongoing conflicts or areas that are too dangerous for researchers to conduct direct empirical studies. Furthermore, the tool has applications that can aid policymakers in decision-making, such as where to prioritize resources for landscape remediation in the aftermath of a conflict. Finally, an aspirational application of the heuristic would be to advance the understanding of war's environmental costs in a way that helps to restrain future war-related violence.

As an analytical tool the heuristic can aid students of war and the environment by helping them to systematically analyze which kinds of violence have occurred in a conflict, which in turn can help researchers prioritize where to investigate effects of slow violence. Moreover, as demonstrated in each of the case studies, the analytical process that feeds the heuristic can identify knowledge gaps that exist concerning the environmental legacy of even well-studied

past conflict. Normalizing the relative magnitude of a conflict's impacts by ratioing its grades of acuity against the hypothetical costs of a theoretical absolute war also allows comparison between conflicts, which can yield important information about the different patterns of disruption that occur across operational and temporal scales, as well as within different environments and social contexts. Overall, then the heuristic can help in many ways to organize and advance the understanding of the war environment relationship, which suggests some ways in which it can inform policy decisions as well.

Ultimately, the potential value of the heuristic tool may lie not in its ability to classify the acuteness and relationships of environmental disruptions within a conflict, but rather to prompt deeper thinking about the fundamental inner workings of war. Military forces, being themselves tools of policy and politics, already take into account the political and ideological costs of employing certain kinds of violence because the employment of certain kinds of violence, though tactical advantageous, can carry a political cost that is ultimately out of all proportion with the tactical advantage gained. Chemical and nuclear weapons use comes to mind as convenient examples of this process. An altered political culture in which governments and military decisionmakers factor not just the immediate effects of direct violence into their calculus, but also the long-lasting and far-reaching effects of the associated slow violence, could serve to place further restraints upon what types of violence are considered ideologically acceptable within the international community. This then has the potential to move discussions of violence away for comparison of the relative utility or advantages of certain types of weapons or munitions and towards a better understanding of the effects that the mere waging of war must and will entail.

5. Conclusion

Increasing overall understanding of the environmental costs of war can help to restrain the violence of future wars. As already noted, Clausewitz's theory of war posits that war's inherent tendency to extremes of violence is often tempered by the very interests that caused the war to occur in the first place. Examples of how a better understanding of war's destructive effects can restrain governments in the use of certain weapons have been numerous over the past century and a half. These examples include the international banning expanding "dum-dum" bullets due to a better medical understanding of the horrific kinds of wounds they could inflict, international treaties banning the use of chemical, nuclear, and biological weapons due to a greater understanding of how uncontrollable their effects can be, and international agreements restricting the use of land mines and cluster munitions that reflect how difficult and expensive governments can find the task of remediating landscapes where these weapons have been employed (Dalby, 2022). The fact that none of these measures have entirely eliminated these types of weapons from the battlefield does is sobering, but the very existence of these agreements also shows that at the very least the use of these weapons now carries a political and ideological cost that cannot help to restrain their use. As such, an assumption that underlies this dissertation is that efforts that increase the understanding of war's costs can also serve as tools to restrain war's violence.

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