The Unread Lectures:
Epistemological Foundations of War Pollution Research

Small Deep Data and Configuration -Based Retrospective Analysis: An Interim Methodological Note for Research on Complex Environmental and Health Relationships

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Abstract

Research on long-term environmental contamination, ecological health effects, and historically reconstructed disease processes is often organized around large datasets and relatively simple exposure–outcome relationships. Such approaches are indispensable for many questions, but they may become misleading when biologically important outcomes depend on rare combinations of environmental conditions, host physiology, pathogen state, chemical exposure, spatial setting, and historical circumstance. In these situations, the number of records alone is a poor measure of the scientific information contained in a retrospective dataset.

This interim methodological paper develops a complementary approach based on small, deeply characterized and explicitly connected datasets. Its central proposition is that the usefulness of retrospective evidence depends not only on sample size but also on identity certainty, biological resolution, temporal precision, measurement comparability, cross-domain connectivity, preservation of changing knowledge states, and the ability of individual observations to discriminate between competing explanations.

The approach emerged during reconstruction of historical evidence concerning Hector's and Māui dolphins in New Zealand, but the dolphin material is used only as a methodological demonstration. The same problems occur in environmental epidemiology, infectious ecology, historical toxicology, archival research, wartime chemical contamination, hospital-based retrospective studies, and other fields in which relevant evidence is heterogeneous, incomplete, distributed across institutions, or generated at different times.

The paper develops several working principles: decomposition of outcomes into biological transitions; representation of physiology as a multidimensional state space rather than a simple healthy–weak scale; analysis of configurations rather than isolated variables; use of process-sharing controls and biologically informative discordance; mandatory counterexample search; separation of several meanings of sample size; preservation of retrospective diagnostic states; connection of evidence before indiscriminate dataset expansion; and formulation of minimal archival requests that recover the specific bridge needed for analysis.

The purpose is deliberately limited. This is not a finished theoretical framework and does not claim that small datasets are inherently superior to large datasets. It records an emerging methodology so that subsequent research can begin from a clearer conceptual position, preserve the reasoning that led to particular analytical choices, and design better experiments from historical evidence.

Keywords: small deep data; retrospective analysis; configuration-based analysis; environmental epidemiology; infectious ecology; historical toxicology; archival reconstruction; evidence connectivity; specimen identity; process-sharing controls; counterexamples; temporal provenance; cohort design; research methodology.

Key Ideas

- Record count is not equivalent to scientific information.
- A small dataset can be highly informative when biological objects are deeply characterized, comparable, and connected across evidence domains.
- Outcomes should be decomposed into biological transitions before causes are proposed.
- Physiology should be represented as a multidimensional state space rather than a weak–strong scale.
- Rare outcomes may arise from configurations of states rather than from one exceptional variable.
- Controls should, where possible, share the upstream biological process and diverge near the transition being studied.
- Counterexamples and discordant cases should be actively sought because they reveal missing variables and constrain mechanisms.
- Identity, diagnostic time, denominator choice, and evidence connectivity are scientific variables, not merely administrative details.
- Retrospective reconstruction is valuable when it reduces the configuration space that must later be tested experimentally.
- The smallest missing archival bridge may provide more scientific value than a much larger volume of loosely related records.

Introduction

This work forms part of a broader effort to investigate the phenomenon of wartime contamination at a deeper scientific level. A conference devoted to these issues will take place in Prague on 15–17 October. In preparation for the conference, a number of theoretical and methodological developments have been formulated. The central focus is wartime contamination itself, treated as an independent and highly complex object of scientific investigation.

One case examined in detail concerns the dolphins inhabiting the coastal waters of New Zealand (1–6). This case is considered as a possible example of the indirect effects of dioxin contamination on living organisms. The rapid decline of these dolphin populations has been studied for many years. A substantial scientific community has developed around this research and has achieved “considerable scientific success”. Yet the dolphin population continues to decline, while the causes of that decline remain incompletely understood.

Work of this kind also produces more limited results that may nevertheless have substantial independent significance. The present text is one such example. It forms part of a series of lectures on the epistemological foundations of research into wartime contamination that were never delivered. The phrase “lectures that were never delivered” is not intended metaphorically: there has, quite literally, been no audience to whom they could be delivered. There is a clear need for a systematic examination of a number of methodological questions, yet there are remarkably few opportunities to discuss them. Research on wartime contamination is still commonly understood in an

extremely simplified way. These lectures emerged partly as a consequence of that situation (7–11).

The problem is relevant far beyond the examples considered here. One possible future case is a research project on chemical wartime contamination in Vietnam. The conference will include presentations dealing with Vietnamese archival materials (12). Detailed investigation of these records should not be understood merely as an administrative task of identifying, cataloguing, or gaining access to documents. A very substantial cognitive and methodological distance separates a record concerning a barrel of Agent Orange from an explanation of severe patterns of congenital abnormalities among people living in territories subjected to intense chemical contamination.

Moving scientifically from the first type of evidence to the second requires much more than the accumulation of additional records. It requires reconstruction of exposure, time, place, biological processes, relevant populations, individual histories, competing explanations, and the connections among otherwise separate bodies of evidence. It therefore also requires a substantial rethinking of the methodology used to investigate relationships of such complexity.

Many difficult environmental-health questions are initially expressed in a deceptively simple form: exposure X is followed by outcome Y, and the research task is framed as determining whether X contributed to Y. This formulation is often useful as an entry point because it creates a tractable question and a measurable comparison. However, it can become biologically inadequate when the observed outcome is produced only under a limited combination of environmental, physiological, chemical, infectious, and temporal conditions.

The present text arose as part of the methodological preparation for the conference programme announced at http://www.pdconference.org That preparation required working across environmental contamination, disease, archives, historical exposure, and biological evidence that frequently existed in small, fragmented, and differently structured datasets. The resulting methodological problem became broader than any individual case: how should researchers reason when the relevant information is not absent, but is distributed across many sources and becomes scientifically useful only after identities, variables, time states, and biological processes are reconstructed?

Examples of apparently simple exposure–outcome formulations include:

- dioxin exposure and developmental abnormalities;
- chemical pollution and infectious disease;
- pesticide exposure and reproductive outcomes;
- environmental contamination and population decline;
- wartime chemical use and long-term health consequences.

In real biological systems, a severe outcome may depend on a temporary conjunction of several states. A chemical burden may be biologically important only during a particular physiological transition. A pathogen may be widespread while fatal disease

remains rare because progression requires additional host or environmental conditions. An exposure may be substantial, yet difficult to detect in broad population analyses if the relevant spatial or temporal window is narrow.

$$\text{Environmental State} \times \text{Chemical State} \times \text{Physiological State} \times \text{Biological Agent} \times \text{Time} \rightarrow \text{Outcome Probability}$$

None of the individual components in such a configuration necessarily produces the outcome by itself. The scientific problem is therefore not simply to identify a variable associated with the outcome, but to reconstruct the set of states that may be necessary, permissive, modifying, or triggering for a particular biological transition.

This creates a methodological tension. Increasing the number of records may improve statistical power, but it does not automatically improve biological resolution. If heterogeneous states are combined into broad administrative variables, a very large dataset may support statistically precise answers to poorly defined biological questions. Conversely, a small number of deeply documented and well-connected cases can sometimes eliminate simple explanations, reveal hidden process structure, and define a much more informative experiment.

The methodology described here is intentionally intermediate. It is a working framework rather than a completed theory. Its purpose is to make explicit the rules that repeatedly became necessary while working with small and heterogeneous information arrays. Those rules are presented as methodological principles because they concern how evidence should be selected, connected, compared, and interpreted before formal causal claims are attempted.

From Large Data to Small Deep Data

Sample size remains important in retrospective research, but record count is not a sufficient measure of scientific information. A dataset may be large because an administrative system records many events consistently, while still lacking the specific variables needed to reconstruct a biological mechanism. The relevant question is therefore not only how many records exist, but how much biologically meaningful, comparable, and connectable information is attached to each object.

A dataset containing 100,000 records may be unsuitable for a particular mechanistic question if:

- exposure is poorly characterized;
- diagnostic categories change over time without preservation of historical definitions;
- individuals cannot be linked between datasets;
- different analytical methods are combined as if they were equivalent;
- important physiological states are absent;
- temporal or spatial resolution is inadequate;
- outcome categories combine biologically different stages of one process.

By contrast, a dataset containing 30 or 100 individuals may sometimes be far more informative if each individual can be reconstructed across multiple domains and if the

comparisons are biologically coherent. The distinction proposed here is descriptive rather than evaluative:

Large Shallow Data ↔️ Small Deep Data

Large datasets can also be deep, and small datasets can be poor. The purpose of the distinction is to prevent record count from functioning as a substitute for biological information content.

Consider a hospital containing several hundred carefully documented pregnancies with maternal history, congenital outcomes, residential locations, and temporally defined exposure windows. For a developmental-exposure question, that hospital dataset may provide more mechanistic information than a national database containing millions of births but no usable exposure chronology. The national dataset may remain more appropriate for other questions. The research question, rather than dataset prestige or size, should determine which evidence is analytically useful.

Why Another Research Logic Is Needed

Research on military environmental contamination rarely begins in the absence of scientific knowledge. On the contrary, investigators usually enter a project with substantial professional experience. Soil scientists, hydrologists, chemists, ecologists, physicians, geographers, and environmental engineers all contribute established methods, specialised concepts, and well-developed analytical procedures. Modern investigations are also supported by advanced laboratories, geographical information systems, remote sensing technologies, historical archives, and increasingly sophisticated statistical tools.

From the perspective of individual disciplines, such research may be conducted to a very high professional standard. Sampling strategies can be carefully designed, laboratory analyses can achieve remarkable analytical precision, and spatial distributions can be reconstructed in considerable detail. Individual publications often satisfy the methodological expectations of the disciplines in which they are produced.

Nevertheless, an unexpected difficulty repeatedly emerges. The long-term process of military environmental contamination itself often remains only partially scientifically recognisable.

This observation should not be interpreted as criticism of disciplinary science. The problem is not that individual specialists perform their work incorrectly. Quite the opposite. Each discipline may produce scientifically valid results within its own professional framework. The difficulty appears elsewhere.

Military environmental contamination does not develop according to disciplinary boundaries. Soil contamination, groundwater transport, ecological transformation, biological accumulation, medical consequences, and landscape change evolve simultaneously as different manifestations of the same developing empirical object. These manifestations are investigated separately, while the process connecting them frequently remains insufficiently organised within scientific investigation.

As a consequence, researchers may describe contaminants without fully understanding the process through which they migrate. Ecological effects may be documented without establishing how they are connected across time and space. Highly accurate maps may represent observable manifestations while leaving unanswered the more fundamental question of whether they belong to one continuing process, several interacting processes, or only temporary configurations.

The accumulation of high-quality disciplinary results therefore does not automatically reconstruct the empirical object as a coherent scientific entity.

This distinction becomes especially important in research on military environmental contamination. Scientific projects are commonly evaluated through the quality of their measurements, the sophistication of their analytical methods, the amount of collected data, and the successful completion of planned research activities. These achievements are unquestionably important. They do not, however, answer another question that becomes central for highly dynamic environmental processes.

What has actually become scientifically recognisable about the developing military environmental contamination process?

The need for another research logic therefore does not arise from dissatisfaction with existing scientific disciplines. It arises from the need to organise their contributions around the empirical object itself rather than around the organisational boundaries of individual disciplines. The question is not how to replace specialised expertise. The question is how specialised expertise can contribute to the scientific recognition of one long-term, developing environmental process.

Research Begins Before Theory

Scientific research is traditionally presented as a movement from theory toward empirical investigation. A researcher studies the existing literature, adopts or develops a conceptual framework, formulates hypotheses, selects appropriate methods, and finally collects empirical evidence. In many scientific fields this sequence has proved remarkably productive. Where the object is relatively stable and mature explanatory theories already exist, there is no reason to abandon such an organisation of research.

Military environmental contamination frequently presents a different situation.

Investigators often begin their work while the empirical object itself remains incompletely recognised. The process may already be changing before its principal characteristics have been identified. New manifestations continue to appear while earlier observations are still being interpreted. Different environmental systems become involved at different moments. Spatial and temporal boundaries remain uncertain. Under such conditions, empirical investigation cannot simply wait until a mature explanatory theory becomes available.

This observation should not be interpreted as a rejection of theory. Existing theories remain indispensable. They help formulate questions, identify possible mechanisms, guide measurements, and interpret particular manifestations. The difficulty lies

elsewhere. No single explanatory framework may yet be capable of organising the developing empirical object as a whole.

The practical question therefore changes.

Instead of asking which existing theory should immediately govern the investigation, researchers must first ask how empirical investigation itself can be organised while explanatory understanding continues to develop. The absence of a mature theory is not necessarily an interruption of scientific work. For certain classes of dynamic empirical objects, it becomes the normal starting condition of research.

Military environmental contamination represents precisely such a situation.

The empirical process cannot be postponed until science has completed its theoretical preparation. Investigation begins because the process is already unfolding. Scientific organisation must therefore develop under conditions in which theoretical explanation remains incomplete. The task is not to suspend empirical investigation until certainty becomes possible, but to organise that investigation in a manner capable of supporting the later emergence of scientifically responsible explanation.

The Operational Space Before Mature Theory

Scientific investigation rarely begins from an absence of knowledge. Researchers usually enter a new project with established disciplinary expertise, practical experience, accumulated empirical observations, published literature, methodological traditions, and a variety of explanatory hypotheses. Scientific work therefore starts within an already existing cognitive environment rather than in an intellectual vacuum.

The difficulty arises because these different forms of knowledge do not necessarily constitute a mature explanatory theory. They may coexist without forming a coherent organisation capable of guiding investigation of a highly dynamic empirical object. Individual explanations may be scientifically valuable while remaining insufficient for understanding the developing process as a whole.

This situation is particularly characteristic of military environmental contamination. Empirical observations continue to accumulate while explanatory understanding remains incomplete. New manifestations appear before previous ones have been fully integrated into a coherent interpretation. Alternative explanations coexist. Some are complementary, others compete, and many remain only partially developed. Scientific investigation nevertheless continues because waiting for complete theoretical certainty would mean abandoning the empirical process while it is still unfolding.

The practical question therefore changes once again. The problem is no longer whether scientific investigation should begin before a mature explanatory theory exists. In practice it already does. The real question is how this stage of investigation should be organised so that empirical work contributes to the later emergence of a more coherent explanatory structure rather than simply increasing the volume of disconnected observations.

For the purposes of the present study, this operational stage is referred to as the Pre-Theoretical Domain. The term does not describe the absence of theory. It

describes a stage of scientific investigation in which theories, hypotheses, disciplinary explanations, empirical observations, and practical experience coexist without yet forming a sufficiently mature explanatory architecture for the investigated object.

The Pre-Theoretical Domain should therefore be understood as a normal scientific condition for certain classes of dynamic empirical objects rather than as a temporary methodological deficiency. It represents the operational environment within which Scientific Recognition continues to develop before explanatory integration becomes possible.

Scientific Recognition as the Primary Operational Process

The existence of a Pre-Theoretical Domain does not imply that scientific investigation lacks direction. On the contrary, a distinct form of scientific development already takes place during this stage. Although mature explanatory theory has not yet emerged, researchers continuously distinguish relevant empirical manifestations from irrelevant observations, establish new relationships between previously disconnected phenomena, identify recurring patterns, and gradually reorganise the empirical object itself.

This process differs fundamentally from the immediate construction of explanatory theory. Its primary result is not explanation but recognition. The investigated object progressively becomes more scientifically recognisable. Certain empirical manifestations acquire greater significance. Others lose explanatory importance. Previously isolated observations begin to form meaningful relationships. The empirical object gradually changes from a collection of observations into an organised scientific structure capable of supporting future explanation.

Scientific investigation therefore advances long before explanatory completeness has been achieved. What develops first is not necessarily theory, but the scientific recognisability of the empirical object.

The development of Scientific Recognition should not be interpreted simply as the accumulation of additional empirical information. New observations remain indispensable. Their principal contribution, however, lies in their capacity to reorganise the empirical object itself. The quantity of available information and the degree of scientific recognition should therefore not be regarded as equivalent characteristics of scientific progress.

Scientific Recognition is consequently understood as a continuous developmental process rather than as a single scientific achievement. It evolves together with the investigation itself. Each new observation, newly recognised relationship, revision of interpretation, or empirical clarification contributes not only additional information but also to the progressive transformation of the investigated object into something increasingly available for scientific understanding.

For the purposes of the present study, this process is referred to as Scientific Recognition. The term denotes the progressive increase in the scientific recognisability of a developing empirical object before the emergence of a sufficiently mature explanatory

theory. Scientific Recognition therefore constitutes the primary operational process through which empirical investigation prepares the conditions for later scientific explanation.

At this stage another important question naturally emerges. If Scientific Recognition develops progressively rather than instantaneously, under what conditions does this development take place? More specifically, how should scientific investigation proceed when explanatory uncertainty remains an unavoidable characteristic of the research process?

Persistent Scientific Uncertainty

Scientific Recognition does not develop under conditions of complete explanatory certainty. On the contrary, its development is accompanied by a form of uncertainty that remains an intrinsic characteristic of scientific investigation throughout the research process.

This observation is familiar to many researchers working with complex empirical objects. New observations often resolve one uncertainty while simultaneously revealing several others. Additional empirical material rarely reduces the investigated object to a stable explanatory structure. More frequently, it transforms the structure of scientific uncertainty itself. Questions change, relationships become more complex, and new empirical manifestations appear before previous ones have been fully integrated into a coherent interpretation.

This condition should not be interpreted as a methodological weakness. It reflects the developmental character of the investigated object. Long-term environmental processes continue to evolve while scientific investigation is taking place. Scientific understanding therefore develops together with the empirical object rather than after its completion.

The persistence of scientific uncertainty should not be confused with the absence of scientific progress. On the contrary, Scientific Recognition frequently advances precisely because uncertainty continues to stimulate the reorganisation of empirical observations, the revision of previous interpretations, and the identification of new relationships. Scientific investigation progresses not by eliminating uncertainty altogether but by transforming it into progressively more organised forms.

For the purposes of the present study, this operational condition is referred to as Persistent Scientific Uncertainty. The term denotes the continuing presence of scientifically productive uncertainty during the development of Scientific Recognition. It does not describe ignorance, methodological failure, or insufficient empirical work. It describes the normal operational environment within which investigation of highly dynamic empirical objects proceeds.

Scientific Recognition therefore develops not after uncertainty has disappeared, but together with it.

This observation naturally leads to another question. If Persistent Scientific Uncertainty represents the normal operational environment of investigation, how does scientific work preserve direction while continuing to develop under these conditions?

Scientific Navigation

Persistent Scientific Uncertainty does not prevent scientific investigation from moving forward. Researchers continue to make decisions throughout the investigation. They select empirical observations for further analysis, establish provisional relationships, revise previous interpretations, identify emerging regularities, and occasionally abandon explanations that no longer correspond to the developing empirical material. Scientific work therefore remains directional even when explanatory certainty has not yet been achieved.

These decisions are often described in practical terms as scientific judgement, professional experience, or research intuition. Such descriptions acknowledge that investigators continuously maintain the coherence of the investigation despite the absence of complete explanatory certainty. What they rarely provide is an operational description of how this continuity is maintained.

The present study proposes that these sequential decisions should not be regarded as isolated acts of individual judgement. Together they constitute a continuous operational process through which Scientific Recognition develops under conditions of Persistent Scientific Uncertainty.

For the purposes of the present study, this process is referred to as Scientific Navigation. Scientific Navigation denotes the continuous organisation of empirical investigation while explanatory completeness remains unavailable. It does not replace disciplinary expertise or scientific methods. Rather, it provides operational continuity between empirical observation and the later emergence of explanatory theory.

Scientific Navigation therefore performs a specific function. It preserves the developmental coherence of investigation while the empirical object continues to reveal new manifestations, relationships, and explanatory possibilities.

At this point another question naturally emerges. If Scientific Navigation continuously organises investigation, what exactly constitutes the empirical structure through which this navigation proceeds?

Relational Field

Scientific Navigation does not proceed through isolated observations. As investigation develops, researchers gradually recognise that individual empirical manifestations rarely possess scientific significance independently. Their meaning increasingly depends on the relationships they establish with other manifestations observed across different places, time periods, environmental compartments, and disciplinary perspectives.

This gradual shift is familiar in many investigations of long-term environmental processes. A single analytical result may initially appear important in isolation. Later

it acquires a different significance after being connected with hydrological observations, ecological changes, historical information, medical evidence, or spatial patterns. Scientific investigation therefore progresses not simply through the accumulation of observations but through the progressive organisation of relationships among them.

These relationships should not be understood merely as statistical correlations or causal hypotheses. They represent the developing empirical organisation of the investigated object itself. As new relationships become recognised, the object gradually acquires a more coherent scientific structure while remaining open to further empirical development.

For the purposes of the present study, this evolving empirical organisation is referred to as the Relational Field. The Relational Field denotes the continuously developing network of empirically recognised relationships through which Scientific Navigation and Scientific Recognition become operationally possible. It is neither an explanatory theory nor a completed model of the investigated object. Rather, it represents the empirical structure within which further scientific understanding becomes progressively achievable.

The development of the Relational Field therefore changes the character of investigation itself. Researchers no longer work primarily with isolated empirical manifestations but increasingly with the relationships that connect them into an evolving scientific object.

This development naturally raises another question. If the empirical object progressively acquires an organised relational structure, what overall form does this developing organisation eventually assume?

Process Morphology

As the Relational Field develops, scientific investigation gradually begins to reveal not only individual relationships but also the emerging organisation of the empirical process itself. Relationships that initially appeared isolated increasingly become components of a larger and more coherent empirical structure.

This transformation does not occur suddenly. It develops progressively as Scientific Recognition advances and Scientific Navigation continuously reorganises the empirical material. New observations no longer contribute only additional information. They also modify the developing organisation of the empirical object.

The resulting organisation should not yet be interpreted as a complete scientific explanation. At this stage, investigators are not primarily explaining the process. They are progressively recognising its evolving form. The empirical object begins to exhibit an internal organisation that becomes increasingly distinguishable through continued investigation.

For the purposes of the present study, this emerging organisation is referred to as Process Morphology. The term denotes the progressively recognisable form of a developing empirical process as revealed through Scientific Recognition. Process Morphology is not imposed upon the empirical object by explanatory theory. Rather, it

gradually emerges from the organisation of empirical relationships established during investigation.

The recognition of Process Morphology represents an important transition. Scientific investigation is no longer concerned primarily with individual empirical manifestations or isolated relationships. Attention progressively shifts toward the developing organisation of the process itself.

The emergence of Process Morphology does not conclude investigation. It marks the beginning of a new stage in which the principal challenge is no longer recognising individual empirical relationships, but preserving correspondence between the developing organisation of the empirical object and the explanatory interpretations that gradually emerge from it.

At this stage another important question arises. If Process Morphology continues to emerge throughout investigation, how should researchers avoid prematurely reducing this developing structure to a single explanatory interpretation?

Morphological Cognitive Openness

The emergence of Process Morphology represents an important stage in scientific investigation. As empirical relationships become progressively organised, the investigated object begins to exhibit an increasingly coherent internal structure. At this point, researchers naturally experience a growing confidence that the principal organisation of the process has already become scientifically understandable.

This tendency should not be regarded as a scientific error. On the contrary, it represents a normal consequence of successful investigation. The more coherent the developing empirical organisation becomes, the stronger the expectation that a sufficiently complete explanation has already been achieved. Scientific investigation naturally seeks explanatory completion.

The difficulty arises because the empirical object itself may continue to develop. New manifestations continue to appear. Existing relationships acquire different significance. Previously unnoticed interactions become empirically recognisable. The investigated process therefore continues to reorganise itself while scientific explanation simultaneously attempts to stabilise its interpretation.

Under these conditions, explanatory closure may occur earlier than the completion of Scientific Recognition. The explanation itself may remain logically coherent, internally consistent, and scientifically plausible. Nevertheless, it gradually becomes less capable of corresponding to the continuing development of the empirical object. Scientific uncertainty then begins to arise from a new source. It no longer originates primarily from the complexity of the investigated process. Increasingly, it originates from the growing discrepancy between a developing empirical object and an explanatory structure that has ceased to develop together with it.

The problem, therefore, is not scientific explanation itself. Neither is the problem scientific uncertainty. Both remain indispensable components of scientific investigation. The critical issue concerns the timing of explanatory closure. When explanatory

organisation stabilises before Process Morphology has reached sufficient empirical maturity, investigation risks replacing the continuing development of the empirical object with the continuing defence of an already established explanation.

For this reason, the preservation of cognitive openness becomes an operational requirement rather than a philosophical preference. Cognitive openness does not imply the rejection of explanation. It does not require the indefinite postponement of theoretical interpretation. It preserves the possibility that Process Morphology may continue to develop beyond the explanatory organisation currently available.

For the purposes of the present study, this operational condition is referred to as Morphological Cognitive Openness. The term denotes the deliberate preservation of multiple scientifically plausible explanatory possibilities while the empirical organisation of the investigated process continues to evolve. Morphological Cognitive Openness therefore protects the correspondence between explanatory organisation and the continuing development of the empirical object.

Scientific investigation does not become stronger by postponing explanation indefinitely. It becomes stronger by allowing explanation to emerge together with the continuing maturation of Process Morphology rather than in advance of it.

This understanding naturally leads to the next stage of investigation. If Morphological Cognitive Openness preserves several scientifically plausible explanatory directions, how do these possibilities gradually transform into scientific explanation itself?

Explanatory Possibilities

The preservation of Morphological Cognitive Openness does not delay scientific explanation indefinitely. On the contrary, it creates the conditions under which explanation can develop together with the continuing maturation of the empirical object. At this stage, scientific investigation is no longer limited to isolated hypotheses or preliminary interpretations. Multiple explanatory possibilities gradually emerge from the recognised organisation of Process Morphology itself.

These explanatory possibilities should not be understood as competing opinions in the ordinary sense. They represent scientifically plausible directions of explanation supported by the existing empirical organisation of the investigated object. Some possibilities gradually acquire stronger empirical support. Others become less consistent with the continuing development of Process Morphology. The relationship between them is therefore determined primarily by the investigated object rather than by theoretical preference alone.

Scientific investigation progresses through the continuous interaction between explanatory possibilities and the further development of Scientific Recognition. New empirical manifestations may strengthen one explanatory direction while simultaneously weakening another. Existing interpretations remain subject to revision as the Relational Field expands and Process Morphology becomes increasingly coherent.

The existence of several explanatory possibilities should therefore be regarded as a normal stage of scientific development rather than as evidence of theoretical

weakness. Under conditions of highly dynamic empirical objects, explanatory plurality often represents the most scientifically responsible position available before explanatory maturity has been achieved.

For the purposes of the present study, Explanatory Possibilities denote the set of empirically grounded explanatory directions that remain simultaneously compatible with the current stage of Scientific Recognition and Process Morphology. They do not represent competing belief systems. They represent different scientifically legitimate trajectories through which explanation may continue to develop.

Scientific explanation becomes progressively stronger not by eliminating explanatory plurality prematurely but by allowing the investigated object itself to determine which explanatory possibilities continue to correspond to its ongoing empirical development.

This progression naturally leads to the final question. Under what conditions does one explanatory possibility become sufficiently mature to be regarded as scientific explanation rather than merely a scientifically plausible direction of interpretation?

Scientific Explanation

Scientific explanation does not appear at the beginning of investigation. Neither does it emerge as the immediate consequence of isolated empirical observations. Within the present framework, scientific explanation represents the progressive outcome of Scientific Recognition, Persistent Scientific Uncertainty, Scientific Navigation, the development of the Relational Field, the emergence of Process Morphology, and the preservation of Morphological Cognitive Openness.

By the time scientific explanation becomes possible, the investigated object has already undergone a substantial transformation. It is no longer experienced as a collection of disconnected manifestations. It has become an empirically organised process whose internal relationships, morphological organisation, and explanatory possibilities have matured sufficiently to support a coherent explanatory structure.

Scientific explanation therefore should not be understood as the termination of scientific investigation. Rather, it represents one stage in the continuing development of scientific understanding. Future empirical observations may strengthen the explanation, modify it, or reveal previously unrecognised aspects of the investigated process. Explanation remains scientifically responsible precisely because it preserves correspondence with the continuing empirical development of the object.

Within this framework, explanatory maturity is achieved not through the elimination of uncertainty but through the progressive correspondence between explanatory organisation and the evolving empirical object. Scientific explanation therefore represents the highest degree of Scientific Recognition currently supported by the available empirical organisation rather than the permanent completion of scientific understanding.

For the purposes of the present study, Scientific Explanation denotes the explanatory organisation that emerges after Scientific Recognition has reached sufficient

empirical maturity to support coherent interpretation of the investigated process. It does not conclude investigation. It provides the most scientifically responsible explanatory organisation presently justified by the developing empirical object.

This understanding also clarifies the overall structure proposed throughout the present study. Scientific investigation is presented not as a movement from theory toward observation, but as the progressive organisation of empirical recognition through which scientific explanation gradually becomes possible.

Discussion

The present study began with a practical methodological difficulty. Research on military environmental contamination frequently develops before a sufficiently mature explanatory theory becomes available. Empirical observations accumulate across different disciplines, environmental compartments, spatial scales, and historical periods, while the investigated process itself remains only partially scientifically recognisable.

The proposed framework does not treat this situation as an interruption of scientific work. Investigation already proceeds under these conditions, and the central question therefore concerns its organisation. The Pre-Theoretical Domain describes the operational space in which empirical observations, disciplinary knowledge, hypotheses, practical experience, and preliminary interpretations coexist before they form a sufficiently mature explanatory structure.

Within this domain, the primary developmental process is Scientific Recognition. The investigated object becomes progressively more recognisable as observations acquire significance, relationships are established, earlier interpretations are revised, and the empirical material is reorganised. This distinction is important because an increase in the quantity or precision of data does not necessarily produce an equivalent increase in the scientific recognisability of the object.

Scientific Recognition develops under conditions of Persistent Scientific Uncertainty. Such uncertainty is not expected to disappear from research on highly dynamic empirical objects. New observations may resolve particular questions while revealing additional relationships, manifestations, and explanatory difficulties. Scientific progress therefore often transforms uncertainty into more organised forms rather than replacing it with complete certainty.

Scientific Navigation preserves the continuity and direction of investigation under these conditions. It consists of the sequential decisions through which researchers select observations, test relationships, revise interpretations, and maintain correspondence between the developing investigation and the developing empirical object. Navigation does not replace disciplinary methods. It organises their contributions within a continuing process of recognition.

The Relational Field and Process Morphology describe two successive levels in the empirical organisation of the investigated object. The Relational Field emerges as observations become connected across time, space, environmental systems, and

disciplinary perspectives. Process Morphology becomes recognisable when these relationships begin to reveal the developing organisation of the process itself. At this stage, military environmental contamination can no longer be adequately represented as a collection of separate contaminants, locations, measurements, or consequences. It becomes scientifically accessible as an organised and continuing empirical process.

The emergence of Process Morphology also creates the possibility of premature explanatory closure. An increasingly coherent empirical organisation may produce the impression that a final explanation has already been achieved. Morphological Cognitive Openness preserves correspondence between investigation and the developing empirical object by allowing several empirically grounded explanatory possibilities to remain available while Process Morphology continues to mature.

This openness should not be understood as a preference for permanent theoretical plurality. Explanatory Possibilities remain subject to the continuing development of the empirical object itself. Some acquire stronger empirical support, others require revision, and some cease to correspond to the recognised Process Morphology. The transition toward Scientific Explanation is therefore organised by empirical maturation rather than by the premature selection of a preferred interpretation.

Within the proposed framework, Scientific Explanation is neither the initial organiser nor the final termination of investigation. It is the most mature explanatory organisation presently supported by Scientific Recognition. It remains open to revision because military environmental contamination continues to develop and because new empirical manifestations may alter the recognised organisation of the process.

The operational sequence proposed in the present study may therefore be summarised as follows:

Empirical Observations

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Scientific Recognition

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Persistent Scientific Uncertainty

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Scientific Navigation

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Relational Field

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Process Morphology

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Morphological Cognitive Openness

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Explanatory Possibilities

↓

Scientific Explanation

This sequence does not prescribe particular disciplinary methods. Soil analysis, hydrological modelling, toxicological investigation, epidemiological research, remote sensing, geographical reconstruction, historical analysis, and other specialised approaches retain their full scientific importance. The proposed framework concerns the organisation of their results around a developing empirical object whose boundaries and internal relationships cannot be determined in advance by any single discipline.

Military environmental contamination provides a particularly clear setting for such an organisation. Its manifestations may appear at different times, move between environmental systems, cross disciplinary boundaries, and remain active long after the military activities that initiated them have ceased. Scientific investigation must therefore remain capable of recognising a process that is simultaneously dispersed, partially invisible, historically extended, and continuously developing.

The architecture proposed in this paper represents one possible organisation of investigation under such conditions. It does not seek to replace existing scientific disciplines or established explanatory theories. It provides an operational framework within which their contributions may progressively converge toward the scientific recognition of one developing empirical process.

Its practical value ultimately depends upon scientific use. The relevant questions are whether it helps preserve the investigated object across disciplinary contributions, whether it improves the organisation of empirical relationships, whether it makes persistent scientific uncertainty operationally productive, and whether it supports explanations that continue to correspond to the ongoing development of the empirical object.

Research on military environmental contamination does not require the suspension of explanation until all uncertainty has disappeared. Such a condition is neither attainable nor scientifically necessary. It requires an organisation of investigation in which scientific explanation develops together with the continuing development of the empirical object it seeks to understand.

Principal Propositions

The present paper is based on the following principal propositions.

1. **Scientific investigation of long-term military environmental contamination frequently begins before sufficiently mature explanatory theory has emerged.**

Existing disciplinary knowledge remains indispensable. Nevertheless, it may be insufficient for organising investigation of a highly dynamic empirical object whose empirical development continues while research is already underway.

2. **The primary developmental process during this stage is Scientific Recognition rather than scientific explanation.**

Scientific investigation first increases the recognisability of the empirical object. Explanatory organisation develops subsequently as recognition progressively matures.

3. **Persistent Scientific Uncertainty represents a normal operational condition rather than a methodological deficiency.**

Scientific uncertainty accompanies the development of Scientific Recognition because the investigated empirical object continues to evolve throughout investigation.

4. **Scientific Navigation preserves the continuity of investigation under conditions of Persistent Scientific Uncertainty.**

Scientific Navigation continuously organises empirical work while explanatory completeness remains unavailable.

5. **The investigated object progressively develops through the organisation of empirical relationships.**

The Relational Field and Process Morphology describe successive stages in the emergence of an increasingly coherent empirical organisation of the investigated process.

6. **Scientific explanation should not emerge before the empirical organisation of the investigated object has reached sufficient maturity.**

Morphological Cognitive Openness preserves correspondence between explanatory organisation and the continuing development of the empirical object.

7. **The coexistence of several explanatory possibilities represents a normal stage in the maturation of scientific explanation.**

Scientific investigation progressively reduces explanatory plurality through continued empirical recognition rather than through premature theoretical selection.

8. **Scientific Explanation represents the present outcome of Scientific Recognition rather than the completion of scientific investigation.**

Explanation remains open to further empirical development because the investigated object itself continues to evolve.

9. **The proposed framework does not replace disciplinary science.**

It provides an operational organisation through which disciplinary contributions progressively converge toward the scientific recognition of one developing empirical process.

10. **The architecture proposed in this paper is intended as an operational framework for investigating highly dynamic empirical objects whose development precedes sufficiently mature explanatory theory.**

Military environmental contamination represents one important class of such objects.

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