

Essay

Old-growth Forests: Anatomy of a Wicked Problem

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Abstract: *Old-growth forest* is an often-used term that seems to be intuitively understood by ecologists and forest managers, and the wide-ranging discussion of its social and ecological values suggests it has currency among the general public as well. However, a decades-long discourse regarding a generally acceptable definition of old-growth, in both conceptual and practical terms, has gone largely unresolved. This is partially because old-growth is simultaneously an ecological state, a value-laden social concept, and a polarizing political phenomenon, each facet of its identity influencing the others in complex ways. However, the public, scientific, and management discourse on old-growth has also suffered from simplifying tendencies which are at odds with old-growth's inherently complex nature. Such complexity confounds simple or rationalistic management approaches, and the forest management arena has witnessed the collision of impassioned and contradictory opinions on the 'right way' to manage old-growth forests, ranging from strict preservationism to utilitarian indifference. What is clear is that management approaches that circumvent, trivialize, eliminate, or ignore old-growth's inherent complexity may do so at the expense of the very characteristics from which old-growth derives its perceived value. We explore the paradoxes presented by the various approaches to old-growth description and definition and present some plausible paths forward for old-growth theory and management, with a particular focus on managed forests.

Keywords: old-growth forests; wicked problems; sustainable forest management

1. Introduction

In North America, for much of its history, industrial forestry has advanced on the premise that “maximizing economic efficiency in the short term was the path to maximizing social and economic benefits into the future” [1]. The diversification of value drivers in industrial forestry to incorporate a broader suite of values than optimizing timber production has been a relatively recent occurrence [2], largely in response to shifting public expectations regarding the management of public lands and resources. Ecologists and forestry practitioners have responded with cohesive paradigms of *ecosystem management* [3], *new* [4] or *ecological forestry* [5], and sustainable forest management [6], which have shown some signs of traction within forestry practice in the last two decades.

The emergence of these new forestry paradigms has been paralleled by a rising interest in old-growth forests in the managed landscape, in part because of its increasing scarcity as old-growth forests have been liquidated and converted to young stands, often even-aged plantations. Old-growth has been a flashpoint for conflict across the continent. In political discourse, on the one hand, old-growth is a senescent and sub-optimal use of valuable tree-growing land; on the other, old-growth serves as a pure and natural foil that offers contrast to an artificial human-influenced forest, and is widely perceived to be of great biotic and aesthetic richness, representing an ecosystem state that offers people a “visual and emotional feast” [7]. Though the debate over this natural-artificial construct is well-trodden (see Cronon [8] and Soulé & Lease [9]), polarizing, and seemingly intractable, the old-growth concept continues to have public currency and thus finds a unique place in sustainable forest management.

This public currency of old-growth—and its politicization—have both compelled and confounded the development of a coherent ecological theory of old-growth development, function, and management. It is possible that the deeply divisive public debate over old-growth management is itself responsible for having created a conceptual dichotomy between forests that are perceived to be either old-growth or not old-growth, though dichotomous classifications are a common feature of many attempts at scientific rationalization [7].

The is/is-not old-growth dichotomy, and efforts to reconcile it, are ongoing [7,10,11-15]. Some have called for stepped-up efforts to refine a definition of old-growth in a “systematic and universal manner” [11] in the interest of a “rational policy” [15] for conservation and management. Others have attempted to side-step the old-growth dichotomy by abandoning the term altogether in favour of more seemingly benign terms such as “old forest” (e.g., Moeur *et al.* [16]), or by accepting that old-growth is an intuitively understood phenomenon (e.g., Carey [17]).

2. Old-Growth as a Wicked Problem

We posit that the definition and management of old-growth is a fitting example of a *wicked problem* (*sensu* Rittel and Webber [18]) at the interface between values, science, and management. Wicked problems are not ‘bad’ *per se*, inasmuch as they are irreconcilably tricky or perpetually vexing. They transcend disciplinary approaches, lack a definitive formulation, and can be approached from a “plethora of mutually contradictory approaches, each of which is plausible in a particular frame of reference” [19]. In this vein, Carey [17] concluded that although the term has broad purchase in both

the public mind and in the forest science and policy arena, old-growth has “metaphysics” that can never be fully addressed by science or management.

We propose that old-growth’s ‘wickedness’ is not merely a product of some indefinable metaphysics, the divergence of its utilitarian and aesthetic values, or the politicized debate over its management, though these certainly are notable (for some excellent analyses see Lee [20], Proctor [21], Moyer *et al.* [22]). In our view, old-growth also suffers from the three confounding tendencies associated with forest researchers’ and practitioners’ model building and use identified by Bunnell and Huggard [23]: the need to simplify complexity; the willingness to use loose definitions; and the preference for discrete and hierarchical categorizations, rather than connections or continuous gradations.

In this essay we attempt to dissect some of the wickedness that marks old-growth theory and management, by examining some of the approaches to old-growth definition and the problems arising from their application in a forest management context. Our primary frame of reference is ecological rather than socio-political to the extent the two can be disentangled, and we draw our insights mainly from the managed temperate forests of North America, though we hope that whatever insights may arise for the reader will have relevance to forest management more generally.

Readers seeking a definitive problem formulation and conclusive solutions will be disappointed. Indeed, this is not the nature of wicked problems, they are never solved, though often revisited [18]. Instead, we attempt to set out a number of plausible propositions respecting the definition and management of old-growth forests. We do so primarily as a conceptual rather than an empirical exercise, with an interest in invigorating a continued discussion of old-growth theory and its practical application in forest policy and management.

3. Old-Growth Definitions (and Their Problems)

3.1. Generic Definitions

Not including its indefinable spiritual quality—its perceived *sacredness*—old-growth has a plethora of descriptive synonyms. According to Lund [24], over a hundred definitions of old-growth use the terms *ancient*, *antique*, *climax*, *late-successional*, *mature*, *old*, *original*, *overmature*, *primary*, *primeval*, *pristine*, or *virgin*. Recognizing, as most old-growth theoreticians have, that the concept is layered and complex, in an attempt at parsimony Hunter [25] observed that the only satisfactory conceptual definition might be that old-growth forests are “relatively old and relatively undisturbed by humans”. The ‘by humans’ qualifier on the latter condition connotes at least some kinds of human activity as disqualifying a forest’s old-growthness, and that its consequences are differentiable from disturbances that are ‘natural’. The additional qualifier of ‘relatively’ introduces a suite of ambiguities about what components of human action qualify as unnatural.

Duchesne [11] proposed a lengthier but purposely generalized definition of old-growth for Canada involving seven conditions, reflecting others suggested previously [12,26] (numbers added): *Old-growth forests consist of*

- (1) *climax or sub-climax ecosystems where dominant trees are close or older than their age of physiological maturity.*
- (2) *unique to each biogeoclimatic region, the old-growth stage of a forest*
- (3) *may be reached at different ages depending on site, ecosystem type, or dominant tree species.*
- (4) *relatively devoid of major recent anthropogenic influence, each old-growth type is*
- (5) *characterized by unique ecological processes, canopy structure, woody debris, flora, and fauna.*
- (6) *old-growth patches vary greatly in size but*
- (7) *the ecological influence of old-growth forests on animal and plant populations extends to the landscape scale.*

Even in its comprehensiveness, such a definition cannot transcend ambiguities. With the exception of the first, these conditions describe any forest that is relatively unaltered by humans. The first condition—that old-growth forests are dominated by trees near or above the age of maturity—is the only definitive condition that differentiates old-growth from not-old-growth, characterized by a climax or near-climax successional state and almost- or older-than-mature trees.

Other general definitions that imply old-growth is the ‘last’ or ‘final’ stage of forest development (e.g., [27,28]) are paradoxical, as the upper reaches of forest development are temporally indefinite and ‘last’ is a term that is only given relevance by a conclusion or *end*. Using this definition alone, one could only be sure a forest was old-growth once it was gone. Furthermore, a stand or portions thereof may revert to earlier developmental stages throughout its development [29], and forests of any stage can be subjected to major disturbance, so any stage has the potential to be the final one in any given iteration of the development cycle. In a review of old-growth forest management in Australia, Burgman [30] found that disturbance does not, by itself, suggest that forest has lost all of the characteristics of an old-growth forest.

3.2. Threshold Definitions

Since generic old-growth definitions cannot escape ambiguity, Frelich and Reich [13] suggested that old-growth forests are simply forests that have reached some context-specific threshold that has been determined by a scientific or political process. The threshold approach defines a suite of characteristics—an idealized model—against which the characteristics of real forest stands are judged. Such thresholds may be derived from empirical observation, where some stands that *seem to be* ideal examples of old-growth are identified and studied, and their attributes used as the standard. This approach is tautological, in that the ideal example is defined before the definition process begins and the criteria used to define the ideal are derived from observing the ideal itself. Furthermore, what are perceived to be defining features may not be present, even in stands dominated by very old trees [31] or with other valued features.

Hunter and White [32] noted that under most circumstances, “no point along the continuum of succession, and no point along the continuum of disturbance severity, suggest themselves as clear, unambiguous thresholds” upon which to base an empirical definition of old-growth. There are numerous development pathways that can lead a piece of forest toward an old-growth condition [31].

These findings, and those of others (e.g., Franklin *et al.* [29]; Spies and Franklin [33]) suggest that models of old-growth that rely on discrete categorical thresholds cannot avoid arbitrariness.

As recourse, some have proposed multiple categories or an *index of old-growthness*, differentiating old-growth into several stages based on a forest's fulfillment of a variety of criteria [34-36]. This approach does not escape thresholds but merely diversifies their application to multiple rather than single discrete categories, which are then applied in concert in the same way as a single threshold. It is therefore still an elaboration of a tautological normative model.

3.3. Descriptive Approaches

Some empirical old-growth work has focused less on developing a normative model of old-growth and has taken a more observational and descriptive approach [28,37]. Two basic tendencies of old-growth ecosystem behaviour dominate these observations: (1) the self-evident tendency toward larger structures as living and dead biomass continues to accumulate in the stand; and (2) the tendency toward increasing diversification of forest components, or increasing *structural complexity* [37]. *Structural complexity* is the variability in the three-dimensional distribution of biomass in space [38]. In the early stages of forest development following a homogenizing disturbance such as clearcutting, internal characteristics are kept relatively uniform by competitive interaction among stems [29]. This homogeneity is what qualifies tracts of forest for definition as uniform and discrete areas of forest—that is, 'patches' or 'stands' in those terms' conventional usage. As stands age and autogenically develop heterogeneity of structure, internal uniformity of age and structure disintegrates. Prolonged periods of development offer a broad window of opportunity for small and intermediate-sized disturbances—not 'stand-replacing' in the conventional sense—to introduce significant variability to stand structure [37].

Old-growth forests are therefore not only heterogeneous, but *heterogeneously heterogeneous*—that is, they exhibit spatial heterogeneity at multiple scales, in a non-uniform way. Furthermore, as a forest develops in the absence of major disturbance, the scale at which development processes occur shifts from the stand- to the within-stand or gap scale; thus, stands that have undergone this scale shift incorporate all structural development processes simultaneously [29].

3.4. Value-Based Definitions

A range of values, including biodiversity, scarcity, and visual and emotional impression, have been considered definitive aspects of old-growth forests. From a conservation perspective, old-growth forests derive some of their perceived value from their inherent complexity. Some definitions of *biodiversity* include structural diversity as a key component (e.g., Hunter [39]), and because structurally complex habitats provide more habitat niches and more-diverse ways of exploiting resources [40], forest structure has been identified as a measurable proxy for compositional or species-based biodiversity as well [17,41,42]. Certain structures—for example, large-dimension dead wood or long-continuity forest patches within the broader landscape—act as *keystone structures* that can significantly enrich biodiversity capacity [40].

Old-growth forests also derive some of their perceived value from their current scarcity and perceived vulnerability. A long history of human settlement expansion, and forest use across North America under an industrial forestry paradigm, has greatly reduced the quantity of old-growth since European colonization [43,44]. Because they are scarce, old-growth forests are perceived to be extraordinary and therefore valuable.

4. Some Propositions

We propose an approach to conceiving old-growth that, we hope, should help make it a less mysterious concept, less wicked, and more operational. We have no comprehensive solution or final definition, but rather offer prompts for a re-orientation of thinking. Old-growth forest is too important to ignore and too complicated to corral, so we encourage all forest researchers and practitioners to wrestle with its myriad dimensions and reconceptualize it frequently.

4.1. Forsake Virginit

We propose that the concept of virginit and its associated ‘purity tests’ is a root cause of significant wickedness in old-growth theory, and in some cases as a potential obstruction to developing effective old-growth management strategies. The virginit criterion is an application of a broader principle that categorically separates human activity from ‘natural’ forces. We see the debate surrounding this principle as truly mythological in character and will not wade further than ankle-deep into it, and we admit that these propositions fall squarely on one side of it.

Following from Holling *et al.* [45], we propose that the deadlock created by the purity criterion might be broken by incorporating the principle that humans need not be separated from ecosystems for the purposes of ecological study or ecosystem management. In other words, that an influence is human-caused does not make it categorically different from other influences, nor afford it any greater significance than other influences. What matters is the material nature and scale of the effect of an influence upon system behaviour—not its cause.

Purity criteria have utility in old-growth management only when the central focus of management is the outright preservation of extant forest, since any other management intervention would, by definition, be despoiling. This ‘museum approach’ to old-growth management so narrows the forest practitioner’s range of options as to run the risk of undermining management or conservation objectives. This is in part because the purity criterion implies that ‘true’ old-growth can never be actively created through management action, and also because preserved forest will inevitably cycle out of the old-growth state.

In regions of North America where old-growth was once common and is now scarce—in some areas critically—if old-growth values are to be an integral part of sustainable forest management, old-growth management strategies focused solely on preserving the ‘purest of what is left’ would assure old-growth’s eventual eradication from the landscape. We do not imply that forests that have escaped significant direct anthropogenic influence are not valuable for a number of reasons, and preservation may indeed be the most appropriate management strategy for those forests.

We also regard the socio-political aspects of old-growth theory as fertile ground for scholarship. Indeed, the concept of old-growth virginity is highly relevant in the socio-political realm, and is particularly interesting as a value motivator. However, we believe virginity's value as a concept is iconic and rhetorical, not ecological or operational, and to the extent the concept can be deliberately disentangled from ecological old-growth theory and on-the-ground management, it should be.

4.2. Reimagine Old-Growth as Ordinary, Not Extraordinary

The phenomenon of *shifting baselines* (*sensu* Pauly [46]), where that which is perceived to be normal, and alternatively, what is extraordinary, are redefined repeatedly on a human-generational time scale, is a significant influence on current interest in and perceptions of old-growth forests. Hunter and White [32] suggested that current scarcity of old-growth could play a useful role in shaping its definition. They proposed that arbitrariness might be deliberately turned into an advantage by using the definition itself as a tool to prompt interest in conservation, whereby a sufficiently narrow definition would keep old-growth rare enough to be perceived as valuable and unique, and therefore worthy of conservation.

This idea has drawbacks. While scarcity of old-growth may be historically definitive—that is, of an era, namely the present—old-growth is not ecologically extraordinary in many forest regions. It would be reasonable to expect its presence as a predictable part of the forest landscape. The persistence of old-growth was facilitated by landscape-scale disturbance dynamics and old-growth was an ordinary, and even predominant, forest state in many temperate regions (e.g., White and Mladenoff [47]; Lorimer and White [48]).

The paradox of scarcity as a value motivator is that which is valued must remain scarce in order to be valuable. A narrow definition may also serve to justify the lack of conservation interest in the majority of forests that don't meet the narrow definition but are still of current or future conservation value. We propose that, where there is an ecological case to do so, old-growth be considered ecologically common, or at least ecologically predictable, for forest management purposes. That it is not actually common is not definitive of old-growth, but merely a consequence of management decisions. Were old-growth considered ecologically ordinary, forest management decision-making would always include the old-growth condition as a viable option for any single location in the forest landscape.

4.3. There is No Normal Old-Growth

Whereas early stages of forest development are dominated by the homogenizing legacy of a significant disturbance event, old-growth forests are an accumulation of legacies captured over long histories in non-deterministic ways. The multiplicity of overlapping processes associated with old-growth development, and the functional, compositional, and structural complexity these processes create, make complexity a defining feature of these forests [49].

It is therefore not surprising that attempts to develop a normative model of old-growth structure and function have encountered wickedness and gone largely unfulfilled. We see some of this wickedness arising from attempts to apply a normative model that attempts to separate out 'noise' and

define an average or normal old-growth state, where it is in fact the noise itself that is definitive of old-growth.

Because a stand is defined by uniform behaviour and spatial homogeneity and old-growth by a diverse, disaggregated suite of processes and spatial heterogeneity, old-growth stand appears to be, at least conceptually, an oxymoron—at least, where a stand is defined not so much on the basis of differences with neighbouring forest locations but rather on conditions within. We propose that a functional definition of old-growth may simply be forests in which the predictability of system behaviour disintegrates at the scale of the stand. In our empirical work in old-growth forests, we have come to view normative metrics—for example, median bole size or mean tree age—as largely meaningless except for the coarsest of comparisons, and metrics of diversity—for example, the range of tree ages or the variability of structural measures between neighbouring sample plots—as truly informative. In this sense we echo Jerry Franklin’s (quoted in [50]) proposition that “heterogeneity rules” the old-growth phenomenon. In recent years there have been a number of complexity-based forest metrics proposed (e.g., Zenner and Hibbs’ [51] Structural Complexity Index). We have some optimism that these tools may open new insights and ways of describing old-growth.

4.4. Treat All Disturbance as Part of System Behaviour

Old-growth discourse has been challenged by the task of differentiating which types of ecosystem change add to old-growthness—for example, continuous gap formation—and which types subtract from or even eliminate it—for example, discrete stand-replacing disturbance events. We see these challenges as an artifact of viewing disturbance as a discrete event—that is, as something that *happens to* ecosystems. This emphasizes a static view of old-growth, rather than dynamic one. Recent meta-theoretical developments in systems ecology have proposed that the line separating exogenous and autogenic change is arbitrary. Holling *et al.*’s panarchy model [45] internalizes the conventional concept of disturbance as an integral part of system behaviour, rather than as a discrete external influence that acts upon ecosystems—that is, disturbance is something the system *does*. Within this frame of reference, changes to system attributes are viewed as relatively slow or relatively rapid [48], rather than as continuous or discrete.

In this meta-model, there is no null state, but an accumulation of legacies affecting future system behaviour in a continuous and cyclical progression. We see recent forest development models, in which type of disturbance and subsequent system behaviour are linked and legacies are treated as significant (e.g., Franklin *et al.* [29]), as more consistent with this meta-model than with development models based on agricultural precedents in which forest development is a repetitive but discrete process that initiates in a null state [50]. We believe broader adoption of the former into management practice is warranted.

This conceptual shift may also allow forest scientists and practitioners to transcend the concepts of threat and loss that have politicized the old-growth management discourse. There is, however, an opportunity for this re-framing to be abused; that is, if any kind of change is integral to system behaviour—in effect, ‘normal’—rather than disruptive, then any change caused by management actions is justifiable. We suggest that social choice discussions through management planning, not ecological theory, are the proper venue for such arguments, as duly informed by ecological knowledge.

In our view, if old-growth theory is to be of use to management decision-making, best efforts must be made to disentangle it from its politics.

4.5. Reimagine the Patch

In forest practice, both uniformity and difference in forests are interpreted through the lens of a forest patch's provision of specific value. The measurements chosen to characterize and differentiate spatially discrete forest units in inventories, maps, or management plans are artifacts of the forest's dominant use [52]—which is most often the extraction of timber. Regardless of the multiplicity of scales at which functional heterogeneity may be expressed across the forest landscape, management maps of forest landscapes rarely depict stands less than one hectare or greater than 100 hectares in size, because small units are merged together for efficiency, and reasons are found to split large ones up into manageable pieces [23]. Therefore, in industrial forestry, stand or patch definition does not reflect the dynamics of forest ecosystems inasmuch as it represents the distribution of values across a landscape.

Internal uniformity and discrete temporal and spatial boundaries are self-validating assumptions in even-aged industrial forestry. Under a system of even-aged management where a defined spatial extent of standing forest is rapidly and near-completely harvested, discrete spatial and temporal edges are created. Internal variability of forest characteristics is first minimized through harvest practices, and then can be controlled by silvicultural intervention in subsequent forest development. The recognition of legacies as important determinants in stand behaviour is a relatively recent departure from the assumptions of classical forestry science, based as it was on agricultural precedents.

We propose that the concept of the stand as the spatial definition of a forest management unit be revisited and approached with greater nuance and sophistication than has historically been the case. For far too long, we have in North America been simplifying our forests to conform to our simplified models of forest development and utility. Theory, empirical analysis, and forest modeling technologies now support the application of silvicultural approaches built on the premise of actively propagating complexity within forest ecosystems (for example, see Puettmann *et al.* [53]).

4.6. Reconfigure the Birth-Old-Death Metaphor

Old-growth forests are, by logic and definition, old. *Old* is a relative measure of distance from a point of birth; the path between the two is linear and unidirectional. Forest development theory has until recently made use of a meta-model which sets homogenizing disturbance as the beginning (birth) and old-growth as the end (senescence or pre-death), and forest management still makes wide use of such a meta-model, for example in linear growth-and-yield models.

The stages of forest development of most interest to industrial forestry—that is, the homogenizing early stages during which optimal timber production occurs—continue to dominate research and management innovation. However, the criticisms leveled against microcosm experiments in ecology (e.g., Carpenter [54]) also apply to models that draw conclusions about 'normal' forest development from a relatively small portion of the development cycle. In many temperate forest regions of North America, and in many forest types within others, time-to-maturity is a relatively small fraction of the potential longevity of late-successional species and the return interval of major disturbance, such that

the ‘post-mature’ stages of stand development often constitute the majority of the period between homogenizing disturbances [26]. For example, Franklin *et al.* [29] noted that many stand-development models focused on early development in ideal even-aged stands such as plantations, and covered only 10% of the potential development process of a coastal Douglas-fir (*Pseudotsuga menziesii*) forest. In some temperate forest regions, disturbance events that are large and severe enough to be considered fully homogenizing at the stand scale are so infrequent under natural disturbance regimes—recurring at intervals of many centuries—that their recurrence transcends dozens of human generations, making them beyond the scope of the individual human experience [29,55].

If we accept that forest development is continuous and cyclical, any forest development stage is no more or less arbitrary a starting point for a forest development model. We propose on these grounds that for many forest types in many temperate forest regions in North America—or anywhere that old-growth may be of management interest—an adjustment to the basic structure of the forest development meta-model may provide a basis for expanding old-growth theory and management, and indeed sustainable forest management more generally.

5. Summary and Conclusion

Old-growth is a metaphor (*sensu* Proctor and Larson [56]). Its use as a common term and a conceptual nexus has value, particularly in a rhetorical and political sense (and in a colloquial sense, as it has been used throughout this essay). There is value in continuing to use old-growth as a relevant contemporary concept, but its application in forest management practice must be part of a more comprehensive effort to move beyond forest simplification and normalization through management. Until the sophistication of forest management practice matches the complexity of forest ecosystems—of which old-growth is the quintessence—old-growth management will continue to be an enigmatic prospect with the simplest strategy being the preservation of remnant patches. This is ultimately a zero-sum game for both old-growth theory—which would be relegated to the study of an isolated curiosity—and old-growth management.

Purely normative approaches to old-growth are, by themselves, largely unhelpful. We are encouraged by developments in the panarchy meta-model and by recent empirical tools and novel approaches for understanding complexity (e.g., Zenner and Hibbs [51], Staudhammer [57]), along with insightful applied approaches to silviculture and forest management based on complexity concepts (Puettmann *et al.* [53]). It is time to develop a forward-looking, richly nuanced old-growth theory with meaningful application to sustainable forest management in the 21st century. Such a theory would need to embrace fully the impending wickedness of climate change, for the influences of a changing climate on old-growth forest ecosystems poses potentially overwhelming challenges to our understanding of successional processes [58].

Old-growth’s “visual and emotional feast” [7] continues to captivate the public interest, and brings depth and richness to old-growth scholarship and to forest management discourse. However, when deeply entangled with its ecology, its value-rich “metaphysics” [17] create seeming intractable wickedness. We prefer to see this wickedness not as a frustrating obstacle to a rationalization of old-growth, but as an opportunity for forest scientists, policy-makers, and forestry practitioners to challenge conventional thinking—not just about old-growth itself but about forests and forest

management. We see a need to bridge the gap between ecological science and theory, forest policy, and management practice through discourse that explores multiple plausible propositions in all their scientific, philosophical, and practical dimensions and to their logical ends. The application of this kind of transdisciplinary imagination (Brown *et al.* [59]) may be a most productive avenue for advancing a coherent theory of old-growth forest and securing its sustainability. The wickedness of the old-growth problem should continue to provide the opportunity to revisit, re-orient, and reinvest in the effort.

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