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Science in a double-bind: Gregory Bateson and the origins of post-normal science

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Abstract

The work of Gregory Bateson, particularly his principles for a new kind of science which, in 1958 "had as yet no satisfactory name", is revisited as a foundation for post-normal science and adaptive approaches to management of complex environmental problems. The addition of usefulness and relevance of results to decision-making as quality criteria in post-normal science implies inquiry into context at different levels of complexity (what Bateson refers to as deutero-learning). This in turn implies emphasis on processes that facilitate inclusion of diverse perspectives—which facilitates an understanding of relationships among different aspects of a problem; also, social learning, an adaptive approach to valuation that also inquires into the process by which values are constructed, and a reflexive approach to decision-making. Though marginalized from policy discourse, Bateson's principles provided the basis for the eventual development of a new shared understanding.

1. Introduction

"All science is an attempt to cover with explanatory devices—and thereby to obscure—the vast darkness of the subject" (Gregory Bateson, 1958).

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> “To use the traditional scientific method to deal with issues where facts are uncertain, stakes are high, values in dispute and decisions urgent is to be like the drunkard who lost his keys. Although he had misplaced them elsewhere, he looked for them under the street light because it was the only place where he was able to see. The problem is that the key is not there, we don’t even know if there is a key, and the light of the lamppost is getting weaker” (Silvio O. Funtowicz).

The rapidly proliferating literature on sustainable development can be classified along a continuum of perspectives, even within particular disciplines, ranging from deterministic to adaptive frames of reference. At one end, the more deterministic approaches are associated with the characteristics of Newtonian science, the Darwinian theory of evolution, neoclassical economics and methods such as cost–benefit analysis that provide utilitarian justifications for decision-making and technical solutions within the existing paradigm or status quo, and which have dominated policy dialogues. At the other end, adaptive approaches are more associated with institutional, political economy, social learning and conflict resolution frames of reference that challenge existing institutional structures and that have raised fundamental questions regarding scientific practice in relation to high stakes and fundamentally political decisions, which are not new but which have had a marginal presence in policy discourse.

The prevailing image of modern science has been that, given enough information and powerful enough computers, it could predict with certainty, in a quantitative form, which would in turn make it possible to control natural systems. Its role has been to provide the knowledge base to make such control possible [1]. However, the growing recognition of irreducible uncertainty, as is particularly evident in complex global problems that cannot be controlled and that have in large part resulted from just such attempts to control natural systems, has led to a new social context in which, according to Ravetz, “any science that assumes certainty and relegates the most urgent problems to “externalities” will be seen as increasingly irrelevant and bizarre” [2]. It has also increased recognition of the need for adaptive approaches to ecosystem management [3,4] and for the practice of a “post-normal science” that can inform decision-making under uncertainty [5].

Though seldom mentioned, much of what is emerging at the adaptive end of this continuum, particularly in the literature associated with post-normal science, is reminiscent of the work of Gregory Bateson who, in 1958, first alluded to a new kind of science for which there was “as yet no satisfactory name”—a science that had been made possible by the recognition that theoretical concepts are “really descriptions of processes of knowing” [6]. However, he had begun to confront this problem in 1936 as he questioned and sought to explain his own rationality for how he chose to characterize Iatmul culture in the ethnography “Naven”. In 1979, frustrated that there was “still no conventional way of explaining or even describing the phenomena of biological organization and human interaction” and unable to convey concepts of evolution in light of cybernetics and information theory for lack of a base of common understanding, he instead offered a set of principles for this new science, which to him were obvious and self-evident, and “that every schoolboy should know”. These seemingly elementary ideas became epistemological principles regarding how we can know or learn anything, which merged with his ideas about evolution and "the wider knowing that holds together the starfishes and sea anemones and redwood forests and human communities" [6].

Earlier in the 1950s, he also began to articulate the contrasting perspectives described above. Harries-Jones [7] credits Bateson with the "transformation of cybernetics from a science predominantly concerned with application of feedback as control towards a science concerned with problems of how society constructs its own models of change and stability, and then proceeds to hide those constructions in its rationalizations about social and ecological order". According to Bateson, one of the major fallacies of the scientific community is the premise that it is possible to have total control over an interactive system of which oneself is a part, a fallacy that he also viewed as one of the major sources of social and individual trouble. He saw false presumptions of an ability to "control" and "manage" ecosystems through quantitative measurement as a primary source of error in ecological science. He also held that values and constraints, as well as knowledge and beliefs, are internally constructed (rather than absolute), as a result of communication among individuals.

Post-normal science (PNS) represents an important attempt to come to terms with the implications of these concepts in scientific practice. PNS can be characterized as a strategy for dealing with environmental issues in which there are high stakes and uncertainty, plural and conflicting value systems, and in which decisions are urgent [5]. This is in contrast with "normal" science, characterized as an extension of laboratory, puzzle-solving approaches that externalize uncertainty and are not appropriate for addressing complex global environmental problems. Emphasis is on the management of uncertainty, for which it offers a methodology for reflecting on the quality of quantitative information [8], on the implications of complexity for actual decision-making, and on extension of the peer community to include other stakeholders [5], whose local knowledge and experience is complementary to that of experts, and who also implicitly validate scientific knowledge by its use [9]. The decision process itself then becomes a forum for mutual learning among stakeholders, which is essential to adaptive approaches to valuation and decision-making.

This paper is intended to identify and revisit some key concepts put forth by Gregory Bateson that provide a foundation for post-normal science and considers also the ways in which PNS has built on his legacy. These are discussed in the historical context that gave rise to current scientific thought, the emerging context of irreducible uncertainty, and related schools of thought in different fields that provide mutual reinforcement.

2. Bateson's principles and post-normal science

In Bateson's time, his ideas generated some interest but were regarded as "academic" and impractical, as they were at odds with the fundamental premises of "Newtonian" science in which ecological entities are characterized as mere extensions of matter, rather than in terms of their relationships. Though Bateson himself made attempts to communicate the relevance of his work for policy decisions and for ecology itself, he baffled officials and fellow scientists alike with characterizations of ecosystems in unfamiliar terms and concepts such as, that they are "organized systems of communication with an "entropic" (information) budget of flexibility", to which one public official replied: "If you can put up with my obtuseness, I need educating on parts of this. I must make it my own before I can sensibly plan programs to support it" [7].

Since that time, the more widespread recognition of global scale environmental crisis, anticipated by Bateson and others in the 1960s, and the inadequacy of current approaches to social problem solving, has created a new context that may provide an opportunity for the social learning necessary to adapt to a changing environment and respond to disturbances. As pointed out by Funtowicz and Ravetz [8], "Only when a new shared experience reveals the increasing inadequacies of an established worldview, does it become possible for a society to begin the lengthy and painful task of philosophical reconstruction, always focused on the most pressing problems of practice." The following sections selectively revisit some of Bateson's fundamental ideas and ponder their contribution to the practice of post-normal science.

3. Hierarchical structures of inquiry

Bateson relied heavily on the conceptual framework of hierarchically arranged logical types, from members to classes to classes of classes, as a structure of inquiry and as a way to make epistemology explicit. Though derived from the concepts of Bertrand Russell and Alfred North Whitehead earlier in the century, Bateson is generally seen as the first to articulate it in a systems framework [10]. For example, he describes three levels of logical types in characterizing resemblances in gross anatomy—a first order comparison examines relationships between parts within the same individual. A second order comparison might examine relationships between different but closely related species such as crabs to lobsters. A third order comparison would be a comparison of comparisons, e.g. compare a comparison of crab and lobster to a comparison between man and horse. What are important are the differences and the resemblances between such differences, which in turn reveal "the pattern, which connects", and provide the basis for abduction—a fundamental process in human thought. Abduction is defined as a method of constructing knowledge from consistencies in the evidence from multiple perspectives [6]. The perception of differences is also key to a later concern with recursive patterns.

This hierarchical framework provided a foundation for most of Bateson's subsequent ideas, particularly his concepts of deutero-learning, double bind, and recursive patterns. Initially, he used this framework to identify paradoxes that occur when there is a failure to distinguish logical types, such as the characteristics of individuals from those of classes. He traced a number of errors in thinking to errors of logical type. For example, applying statements about classes of convergent characteristics—for which there is some statistical predictability—to individuals, implies predictability also of individuals, whose characteristics tends to be divergent, and who do not necessarily behave according to aggregate characteristics, and vice versa. This confusion between logical types is an error he finds inherent in Darwin's theory of evolution and the notion of "survival of the fittest" as a struggle among individuals, in that natural selection acts on populations rather than on individuals. It is also an error he finds in the ideas of Marx, according to which events unfold in a predictable sequence as a result of class structures, regardless of which individual is credited with starting a trend. He notes that evolutionary theory might be very different today had Wallace rather than Darwin been the primary influence, as Wallace characterized the evolutionary process in cybernetic terms, as a self-correcting system [6].

Hierarchical structures of inquiry are also fundamental in ecosystem approaches to the study of complex systems. Holarchical levels of organization are distinguished, which allows expansion of the problem domain to include the observer as well as a system of interpretation from which meaning can emerge and which provides context [10,11]. From this perspective, we can view the relationship between ecological and social systems as an interplay between context and process—ecological systems provide the context or constraints for societal systems at different scales, which can in turn alter the structures of ecological systems as well as the context for self-organizing processes of ecosystems which can in turn alter the context for societal systems. For example, at the local scale, altering drainage patterns into a wetland may alter the vegetation and convert the wetland to dryland, which will in turn affect possible land uses, which may then have larger scale consequences for the ecosystem. The focus of inquiry then is whether the context is maintained for the processes we depend on for context as well as the integrity of the processes [12]. Fundamental to PNS (but not elaborated on here) are distinctions between levels of uncertainty and complexity and their qualitative differences.

4. Deutero-learning in science: NUSAP

Inherent in the above-mentioned hierarchical structures of inquiry are qualitatively different levels of learning, which Bateson defined as "deutero-learning". This is a concept Bateson used to refer to learning about context which, in contrast with rote learning, leads to understanding of a higher logical type because it provides a frame of reference as well as meaning to any given situation. The context may also refer to fundamental premises and habitual behaviors that are seldom questioned, that constrain action, and that are usually taken as given. In the related "action learning" framework, such questioning may then lead to a reframing of the problem in a broader context, which allows participants to view a wider range of factors as affecting their capacity for action, in contrast with seeking to maintain existing responses to recurring problems—as well as to new ones to which they may not even be applicable. However, to the extent that action is constrained by existing institutional structures, it becomes necessary to reframe at a third level, to see the context of the context, which determines the choices available, and the role of one's worldview [13].

PNS offers a methodology, NUSAP [8], that can be viewed as a heuristic device for structuring scientific inquiry into context and uncertainty at different levels and convey it to decision-makers; also, as a systematic way to detect instances in which uncertainties in the information are so high that the results are to be considered completely indeterminate, which is referred to as "GIGO science" as in "Garbage In, Garbage Out" [8]. It can also be viewed as a form of "deutero-learning" which has parallels with Bateson's hierarchy of logical types.

More specifically, it is a notational system for management of data quality, which refers to the categories of Numeral, Unit, Spread, Assessment, Pedigree, which, from left to right, represent information ranging from quantitative to qualitative. Unit notation gives a quick sense of the orders of magnitude and allows for their comparison among numerals. Spread, Assessment and Pedigree are progressively less technical and more qualitative. Metaphorically speaking, they are comparable to whether, in target shooting, the shots are closely clustered (precision), whether they are also near the bull's eye (accuracy), and whether there is a bull's eye at all [14]. Spread is used to indicate numerical precision or degree of random error in the realm of technical uncertainty—it may be indicated in the form of range, variance, plus/minus, within a factor or, or a logarithmic range. Assessment is related to accuracy and systematic error, and is used to represent a judgment of the reliability of the information. This may be in the form of statistics or, when historical experience and data are insufficient, may be represented by more qualitative judgments in a nominal form. Making Assessment explicit can highlight those cases where the systematic error is greater than the random error, and so protect us against hyper-precision either in Numeral or in Spread. In a policy context, Assessment may also consider reliability of the information relative to its intended use. Pedigree, in the form of a rank, expresses a judgment of quality and uncertainty at a deeper level, based on a state-of-the-art evaluation of the process by which the information was produced, the conditions under which it holds. Multiple rankings may be used that are associated with the type of theoretical structure (e.g., established theory vs computational models), type of data input (e.g., experimental, field, calculated, educated guess), degree of peer acceptance at the time, and degree of consensus among colleagues [8]. A key challenge for stakeholder negotiations then becomes one of agreeing on criteria for quality that determine whether the information is acceptable as a basis for decision-making.

In an era in which "how-to" books are proliferating, including for the conduct of environmental assessment and sustainable development, and in which the elusive objective of conventional economics is to find a "Pareto optimum" in which there is no loss, a key challenge is to convey a new perspective on decision-making to decision-makers. From this perspective, decision-making becomes a reflexive process of inquiry and learning, rather than of acquiring new and better tools and recipes that can be instrumentally applied to produce right answers or identify the optimum. Even to conceptualize the process as a use of scientific "tools" implies an instrumental rationality that in itself may limit the scope of policy [9], because it externalizes uncertainty and allows policy-makers to continue to avoid actually making difficult decisions regarding inevitable trade-offs inherent in ecological and economic problems. This is not unlike Bateson's mistrust of applied science and concern with instrumental applications of his ideas [7]. Among the key challenges identified in PNS is the need for reflexive discourse in the decision process that allows for diverse kinds of knowledge and perspectives to contribute, and that can facilitate mutual learning among public officials and other stakeholders as to what the trade-offs and uncertainties are, including how they are distributed.

5. The value of diversity

Inherent in the process of mutual learning characterized above is the need for contributions from multiple and diverse perspectives, without which it would not be possible to broaden the frame of reference and view problems in a larger context. In Bateson's rule that "two descriptions are better than one" Bateson emphasized the value of multiple perspectives as a source of insight of a higher logical type, offering the metaphor of binocular vision, in which the perceived differences give a perception of depth. Double descriptions are key to understanding relationships because these result from patterns of interaction that consist of stimulus, response and reinforcement—and provide a context for understanding behavior [6].

A central concern in PNS is with the plurality of value systems and how multiple perspectives can inform the decision process. Stakeholder participation is then necessary not only for purposes of disseminating scientific knowledge to other stakeholders or political legitimacy, but also to improve decisions because it is impossible to characterize complex problems from a single perspective. In other words, science "needs" the participation of stakeholders as their views reflect the problem context, which in turn affects the validity of scientific knowledge intended to address it—outside of the laboratory and in the absence of the ability to do controlled experiments.

Diversity, not only of perspective, but also biological and cultural, provides the basis for adaptive approaches to ecosystem management. These approaches rely on what Bateson termed a "flexibility budget" necessary to respond to change and perturbation. He characterized climax in ecosystems as the "ecological saturation of all the possibilities of differentiation", illustrative of his notion that organization is a greater limiting factor than energy.

This concept is reflected in what has become the icon of adaptive management—the "Holling figure 8" model which represents ecosystems in a four-phase cycle of exploitation, conservation, release or creative destruction and reorganization or renewal—and back to exploitation [15]. However, it does not necessarily reorganize back to the previous configuration, as small changes in this phase may lead to alternative configurations and equilibrium conditions.

In conditions of emergent complexity, this pattern can also be characterized as a cycle between states of hegemony and fragmentation among plural attempted hegemonies [16]. In these frameworks, the saturation point corresponds with a state of high efficiency in which there is high interdependence among interacting components resembling a machine. This is also a brittle and hegemonic state in which small disturbances can be catastrophic because of inability to respond to even minor variation, leading to a phase of creative destruction, as it creates randomness that in turn provides the basis for reorganization, and perhaps novelty. In social systems, this hegemonic state has also been referred to as the “ancien regime” syndrome—a situation characterized by Ibn Khaldun as one in which a dynasty, having been in power for a number of generations, becomes corrupt and indifferent to the responsibilities of governing, unable to respond, and can be easily toppled. A vivid example was the ability of the Bolsheviks to take over Czarist Russia by capturing only the postal and telecommunications center. This characteristic is also recognizable more recently in the responses to the Chernobyl and the Managua earthquake disasters and in modern bureaucracies in general [16].

In human social systems, we can tangibly see the role of organization and the value of diversity in social networks and the informal institutional arrangements that govern access to common-pool resources (e.g., pastures, forests, fisheries, river beds and banks), and provide the basis for adaptation during times of natural disaster and resource scarcity. It is through such relationships that mutual expectations of cooperation are established, which increases the available choices through mechanisms of reciprocity and redistribution [17]. This serves as a non-market form of insurance because it allows people to adjust to the risks of high variability and uncertainty, and also to maintain consumption within limits necessary for resource renewability, which insures future access [18]. The phenomenon is not limited to the more traditional societies—in the United States, following Hurricane Andrew in 1992, neighborhoods that were able to draw on outside contacts and friendships of individuals, particularly of those of the older people, were better able to overcome bureaucratic inertia and recovered more rapidly from the impacts [19]. It can also be seen in the international arena, in which, absent a centralized authority, agreements also rely on relationships of reciprocity and commitments among nation states. These are facilitated by heterogeneity of interests which make possible gains from trade [20].

6. Recursive patterns

Another key concern of Bateson’s was the inability of linear logic to deal with circular causation and recursiveness inherent in living systems, as it inevitably leads to paradox. He also found it inadequate because its inherently quantitative analysis cannot be used to describe patterns, and therefore cannot be used to characterize interactions among organisms or internal organization. He became particularly interested in recursive relationships by which patterns of order are constructed and maintained. More specifically, he saw recursive patterns as reflective of temporal relationships between the organism and its environment, or the internal and external, in which action is motivated by perceived differences between an existing and preferred state. The comparison of differences provides the information or feedback necessary to achieve homeostasis [6,7]. Norms and values regarding the preferred state do not exist in isolation but, rather, are an emergent feature of this process of communication.

In other words, the economy and the ecosystem are not tangible entities that can be universally defined—any order we experience is merely the outcome of networks of recursive relationships that reflect goal-directed behavior. In ecosystems, an index based on the concept of ascendancy, which takes into account the level of information and total energy throughput in a system, has been proposed as a way to measure the degree of self-organization and as an indicator of ecosystem status, or what Ulanowicz also refers to as "non-cognitive" aspects of ecosystem values [21]. In human social systems, this ordering is a reflexive process involving selection [22] through which values are adaptively constructed. In that values develop over a long period of time as a response to situations of uncertainty in which it is not possible to trace the consequences of actions, they may also serve as indicators of key system–environment relationships that determine survival of the system [23], and may be viewed as representing pooled local knowledge.

As mentioned above, a focus of research in post-normal science is on characterizing processes in ecological and social systems at different levels of complexity. In social systems, the focus is on processes for reflexive decision-making under conditions of irreducible uncertainty, and how such decisions can be more effectively informed. Analysis of discrepancies among diverse perspectives and stakeholder deliberations may direct the inquiry, serve to reconcile those perspectives, establish criteria by which to maintain Quality, and provide feedback that is the basis for making decisions. Integrated assessment is viewed as a process that facilitates the mutual learning and negotiation among stakeholders.

Decisions on complex problems with high uncertainty typically take place in situations of high stakes and social conflict regarding what is to be sustained. In such a situation, valuation becomes an institutional problem, of access to the decision-making process [24], in which those who would be most affected are the most likely to be marginalized or excluded. Valuation is thus reframed as a process of negotiation and conflict resolution rather than of finding a single most optimum and efficient solution. According to O'Connor [25], it is in just such situations of conflict and risk, when ways of life are threatened, that value statements emerge and are expressed. However, they are also influenced by the process of elicitation and the institutional context—an important difference between Contingent Valuation methods in which participants are isolated and reactive to questions framed by the researchers and, for example, a Citizens' Jury, is that the participants have an opportunity to learn, deliberate, and contribute to the framing of the problem [25]. This creates the possibility for mutual understanding, at least of how the issues are perceived.

Ultimately, it raises the question of how values are constructed and what underlying principles and beliefs are being used to legitimize neglect or consideration of missing information and perspectives as well as explain values, and how these conflict. These may include criteria of economic efficiency, technical performance, public interest, and concerns with conservation and transmission of heritage [25]. Such principles provide a basis for conflict resolution by establishing a distribution of rights and responsibilities. For example, in US law, the Public Trust doctrine, which establishes that certain resources belong to all citizens, and are held in trust by the government on their behalf, was constructed in the context of 19th-century conflicts and orchestrated courtroom drama between oystermen and riparian property owners who sought to exclude them by claiming private rights to adjacent oyster beds, to plant oysters [26].

The process itself isn't new. Native people, who participated as stakeholders at the final workshop of the Mackenzie Basin Impact Study (MBIS) (an Integrated Assessment regarding regional impacts of climate change), described their traditional knowledge as a process of community dialogue that enables them to reconcile different perspectives. By reconciling the historical knowledge of the elders with the changes witnessed by the young people, they had been able to notice many of the changes seen by scientists that were attributed to climate change, with whom they reconciled their perspectives at the workshop. They also pointed out that traditional knowledge systems are dynamic and exist because survival depends on it and have enabled them to take immediate action as a group. Inherent is a method of transmission across generations as well as communication in the present [27]. What is new is the context of rapid global change and the need to reconcile local, regional and global knowledge. Regional forums between scientists and local and regional stakeholders may be important as a way to bridge different levels of discourse.

7. Mutual reinforcement

Just as mutual reinforcement between science and policy has played an important role in legitimizing controversial policy decisions, reinforcement between ideas from different scientific fields of inquiry plays an important role in validation and in determining what counts as relevant knowledge. However, science is also influenced by its social context. The most notable example is in the use of Darwin's ideas in reinforcing ideas of neoclassical economics and social Darwinism. But Darwin's views on the relationships between population pressure on resources, competition and the division of labor were also influenced by the dismal social conditions of his era, at the beginning of the Industrial Revolution, and his reading of Malthus and other works of political economy.

Bateson found a major source of bad ideas with extensive implications in the theories of Darwin because evolution is fundamental to how the modern world is understood and organized. In addition to the error of logical type discussed above, the characterization of evolution as a linear process, as a force of progress, and as a "cause" of material change, fails to account for ecosystem organization and denies the interdependent relationships between organisms and their environment. Thus it supported human aspirations of overcoming the limitations of nature. He blamed these premises for the present environmental predicament and a number of simplified biological and social dogmas that he regarded as disastrous [6,7].

According to Bateson, evolution requires a dual description in that it consists of a dual process, of selection acting on randomness, without which there would be no basis for novelty. It is the criteria of selection which determine which message material is communicated and which account for organization. The selection process is not physically embodied, nor can it be characterized as a linear chain of communication. He saw the underlying principle of selection or decision-making as that of abduction and mutual reinforcement of conditions needed to maintain homeostasis. Though it operates on the physical world, it is not physical but is inherent in the thought process itself. Abduction, for example, characterizes the process by which ideas about nature are reinforced by social systems and vice versa, as in the likening of people and society to 19th-century machines. Bateson himself suggested a reason his views were marginalized from policy discourse when he stated that "any change in our epistemology will involve shifting our whole system of abductions—we must pass through the threat of that chaos where thought becomes impossible" [6].

Part of the problem of bringing different kinds of knowledge into policy discourse has been that this kind of mutual reinforcement between different accounts gives the appearance that they are independently stable and reflective of an ultimate truth. In an analysis of the discourse of complexity, Shackley et al. [9] characterize this mutual construction as one in which "the social science belief in consistent and unambiguous preferences, identity and interests supported the concept of management and control of elaborate sociotechnical systems"; however, "… if the certainty and accuracy of technical control could not be guaranteed, social certainty meant rather little". Conversely, social uncertainty could undermine the value of deterministic scientific certainty and technical knowledge, as its usefulness depends on its relevance to the social context.

From this perspective, the emerging context of increased uncertainty and complexity is occurring primarily because of a breakdown in this previous mutual construction. In other words, science and society are coming unglued because of tensions created as scientists, social scientists and publics push in different contradictory directions. Shackley et al. [9] regard the "simplicity of the past" as reflective of constraints on how problems were framed—in narrow technical terms—rather than of actual differences in the nature of the problems themselves.

Post-normal science adopts a deliberately constructive and creative approach that views problems of sustainable development as ones of design rather than as analytical ones with strictly technical solutions. In what is characterized as a coevolutionary approach to economic development [28], the objective is to look for elements that provide mutual reinforcement for what is to be sustained—an economic system cannot be sustained without the support of ecosystem services, appropriate knowledge, institutions that govern access to resources (e.g., enforce property rights), appropriate technology, and values through which the desired endpoint is decided. Diversity becomes the key criterion for sustainability because it implies choices, or, to use Bateson's terms, flexibility. Science has a crucial role to play in informing the decision process and in defining what is possible, based on ecological information—in contrast with what is desired, which is based on values and culture, and which needs to be defined by all stakeholders [29].

8. Conclusion

Normal science, in the Kuhnian sense, finds itself in a number of double-binds—a paradoxical situation that Bateson describes as one in which behavior is constrained by a perceived context or definition of a relationship that is no longer relevant. He specifically identifies a bind on the science of ecology in the insistence on characterizing ecological interrelationships as only extensions of matter and as if organisms and their environment were discrete entities. Characterization of behavior and ecological processes through relationships is regarded as a form of deutero-learning that gives understanding of a higher logical type because it represents the context in which the processes occur and thus reveals meaning [6,7].

Another bind is in the ideal of positivism in science, of doing objective and detached research that builds on established conceptual frameworks. If we restrict the definition of science to this positivist approach, problem and policy-driven scientific research will always operate in a double-bind because new sources of uncertainty typically fall outside the paradigm and are either not seen or are considered intractable and therefore not suitable for scientific consideration. This limits the relevance of normal scientific methods for real-world problem solving, as when researchers seek information and refrain from answering questions in order not to bias the outcome [30]. In a "constructive" approach, considered more appropriate to a problem-driven post-normal science, in a particular case study, "researchers, when asked, provided information they had in a balanced way, which improved landowners' knowledge of the issues, allowing their decisions to be based on a richer set of information, and helped researchers better understand needs and wants of landowners", which also helped to build reciprocal trust. As in the valuation studies discussed above [25], the decision-making framework then became a process that gave individuals and institutions an opportunity to exchange perspectives and reconsider their objectives in light of new information [30].

The definition of science, in isolation of social context, is analogous to the definition of personal identity separately from personal relationships that sustain that identity and without which it would not exist, which, as Jaeger [31] points out, is a nonsensical belief. As he also points out, "the relationship between human agents and their environment is then detached from the social reality which enables and constrains those agents to sustain relationships of responsibility to each other". Relationships between means and ends then become reduced to instrumentalities only externally related, as when human agency is construed as labor. Such beliefs are not only nonsensical, but are also an underlying basis of common madness that has led to social disintegration and alienation [31]. This madness is also what Erikson sees as a "a new species of trouble" heralded by the dropping of the first atomic bomb on Hiroshima and the Nazi concentration camps, that is associated with breakdown of human solidarity, absence of gestures of reciprocity that maintain social ties, and loss of trust—symptoms he finds associated with environmental disasters and extreme poverty [32].

The paradoxical relationship of science and society was also discussed by Bateson:

> I have been playing recently with the idea that the position of the scientific community vis-a-vis nature is comparable to the position of one complex culture in contact with another. In such a culture contact there are various tendencies towards oversimplification. The themes of the other culture which are actually complex

> patterns tend to be reified, and, especially the modes of interaction tend to become quantitative (money, trade, etc.). [33]

Inherent in Bateson's emphasis on relationships is a focus on patterns of communication through which relationships are constructed and maintained. Bateson is also credited with developing an interactional perspective of communication [34], in which information, defined as "the difference that makes a difference in some prior event", is not confined to specific circuits of senders and receivers—rather, it is conveyed by any means through which differences are perceived [6,7]. In cross-cultural situations such as is found in the relationship of science to society, or in any extended conversation, negotiation of meaning itself is necessary for mutual understanding [35]. According to Lakoff and Johnson, who show in greater detail the way that metaphors structure experience and are mutually constructed, this entails a form of communication that allows participants to reconsider their worldview and adjust the way that they categorize experience. This is distinguished from the "conduit" metaphor of communication, in which meaning is "captured", messages are transmitted in a common language, in which all parties are assumed to have the relevant common knowledge, assumptions and values, and in which "what is most crucial for real understanding is almost never included"—such as in computerized files.

A key objective of this paper has been to revisit Bateson's work as historical context for the practice of post-normal science, to reflect on the reasons that such perspectives have been marginalized from policy discourse and, in the process, to illustrate how the "orthodox consensus" that privileges scientific discourse over that of morality [36] as well as experience was constructed and sustained. This has as much to do with principles that guide the coherent selection of facts as well as with social power and outcome of social conflict as much as with the scientific facts themselves—which are selected. That the historically less dominant perspectives are perhaps becoming less marginal appears to reflect a breakdown of the consensus that has sustained modernity and a crisis of legitimacy for modern governments. From the perspective of post-normal science, we might look upon such a crisis, and upon the context of increased complexity and uncertainty resulting from the breakdown in the previous mutual construction of science and policy, as an opportunity for a Post-Cold War Reconstruction. What is important is not which perspective dominates, but how diverse kinds of knowledge can all contribute not only to the decision process, but also towards a new shared understanding that has relevance for our time, and the practice of science as if life depended on it.

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