Viewpoint: Concept design in range management science

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Abstract

This paper is an analysis of general principles involved in designing concepts for range science. It discusses the diversity of conceptuality in range science, from dimensional units to variables to simple models to more complex decision-aiding models. It examines how considerations of abstraction, confounding, and generalization allow development of multi-objective concepts needed in a range management science of many variables, interactions, and models. Examples related to each principle are provided. The paper discusses the importance of avoiding internal confounding within concepts and the necessity that such confounding be avoided in order to allow clear analyses. *Ad hoc* indices are characterized as inadequate substitutes for explicit models of more complex concepts such as preference and diet selection. Design efforts emphasizing multiple objectives will produce concepts of general use in range management science.

Key Words: abstraction, confounding, terminology

"The artist was right all the time. Nature is conceptual."

—R. Buckminster Fuller, *Synergetics* (1975).

As a management science of many variables, complex interactions, and multiple objectives, range science is a rich landscape for examining conceptuality and concept design. But apart from some special cases, concept design in range science has historically been neglected as an area of work. In many cases, *ad hoc* concepts, often with origins in obscure specialized reports of field research, have become standards for the science without rigorous evaluation of their general utility. Inadequate conceptual development has contributed to a weak identity for range science (Scarnecchia 1995).

The goal of this paper is to examine the importance and the principles of concept design in management science in general and in range management science in particular. Specific objectives are to (1) discuss the broad interpretation of conceptuality as it applies to range science and generally to natural resource sciences, (2) discuss basic principles related to concept design, including ones such as abstraction and confounding, and (3) provide examples of the importance of these principles in designing concepts in range science.

Concepts and Conceptuality

A concept is a mental image generalized from special case instances. This definition is chosen as a composite consensus of a number of sources. It includes 3 characteristics of concepts important to this paper. First, as a mental image, a concept is inherently abstract; conceptualization involves abstraction. Second, because a concept is developed from special case instances, conceptualization involves experience. Third, because special cases must be generalized to develop concepts, conceptualization involves generalization.

These 3 characteristics of concepts are interrelated. For example, greater generalization usually results from greater abstraction. More experience can allow increased abstraction, which results in greater generalization.

The above definition of *concept*, considered in the case of range science, implies that range science concepts come in a spectrum of forms, from simple experimental dimensional units, to independent variables, to modeled variables, to comparatively complex, integrative models to apply theories. Figure 1 shows a related hierarchy of some range science concepts in which complexity increases outward from the center. To have clear meaning, each concept should be clearly defined in quantitative terms as a mathematical variable, or as a construct of minimally confounded variables. A well designed concept based on clear objectives should be expressible in clear mathematics, but poorly designed concepts are often expressible in elegant mathematics as well. In the latter case, subsequent interpretation of the elegant mathematics is usually unclear.

Intuitively, the proposed hierarchical, rigorous approach to concept development may seem reductionist and counterproductive in addressing the synergies of range science. But rigorous, unconfounded concepts are necessary in analyzing partial behaviors of systems, and understanding the partial behaviors of systems is essential to recognize synergies where they occur. Briefly stated, to recognize that the whole is greater than the sum of the parts, one must know the sum of the parts.

To develop general, effective, interactive concepts for range management science, principles of design within and among concepts must be considered, including abstraction, and avoidance of confounding. How, when and where to apply these principles depends on the objectives of concept design.

Developing Objectives

As a management science, range science's identity comes from its core of interactive concepts used in analysis, planning, and

Fig. 1. Concentric arrangement of 6 range science concepts with the simplest concept in the center and concepts of increasing complexity toward the periphery. Concepts range in complexity from a simple dimensional unit to a comparatively complex decision-aiding concept involving objectives and management options. Abstraction of the animal-unit as a unit of demand allows its unconfounded use in analyses involving all of the outer concepts.

management (Scarnecchia 1995). Because concepts are tools, i.e., artifacts designed for a purpose, any objective of concept design has a claim to legitimacy. But concepts designed as part of the core of a management science should have *general applicability*. They should be as explicit as achievable, and leave as little implicit as possible. Their designs should reveal their design objectives and functions. They should conceptually incorporate only other explicit concepts. They should be *heuristic*, i.e., they should aid in future discovery and research design. They should be compatible with a multiple-objective management science and with systems science in general.

The design objectives stated above can be achieved by sufficient *abstraction* of concepts and by avoiding *conceptual confounding*.

Abstraction

Abstraction is relevant to concept design in management science in at least 2 senses. In the first sense, as discussed previously, conceptualization inherently involves abstraction, so that any concept is inherently abstract. In the second sense, the question is whether the entity about which a concept generalizes is *itself real* or *abstract*; i.e., is a concept an *abstraction of reality* or an *abstraction of an abstraction*.

An example from range science will demonstrate the difference. If an animal-unit (Fig. 1) is defined as a unit of *intake*, the animal-unit is an abstraction of a real, measurable variable. But if the animal-unit is defined as a unit of *animal demand*, i.e., non-interactive requirements (Scarnecchia and Gaskins 1987), the animal-unit is an abstraction of an abstract variable, because animal demand is itself not directly measurable. Intuitively, defining the animal-unit as a unit of intake would seem to make more sense, because intake is real while demand is abstract. In fact, the choice of how to define it depends on the *objectives* the developer has for the concept. If interested in using animal-units *only* to sum intakes of mixed herds of livestock, why not define it as a unit of intake? But in range management science in general, the paramount objective should be the suitability of the concept to meet multiple objectives in the science. Greater flexibility and greater power generally require greater abstraction. A concept of an abstraction (i.e., an animal-unit of demand) makes a more useful multiple-objective, animal-unit concept which can be used to express stocking variables (Scarnecchia and Gaskins 1987), analyze grazing dynamics, and express carrying capacities (Scarnecchia 1990).

The demand-based design of the animal-unit exemplifies a basic principle of concept design. *The design of general multi-objective concepts often requires that you first work backward to more basic concepts of abstractions, then use these concepts to move forward to concepts of reality.* Limiting, by abstraction, the animal-unit to a unit of demand greatly expands the eventual utility of the concept within conceptual hierarchies (Fig. 1.) and within other more complex concepts. This power of abstraction is related to its effect of reducing confounding among and within concepts.

Confounding

Although seldom written about or discussed, inadvertent confounding is a major problem in the natural resource sciences. Explicit confounding among variables within experimental designs is the most familiar kind, and in statistical parlance, such confounding is the circumstance in which individual treatment effects are not separated from combined effects (Kendall and Buckland 1960). Such explicit confounding is especially common in natural resource sciences, e.g., range management science, because, as management sciences of natural systems, they involve large numbers of variables whose actions are not easily separated. Where compound variables are derived from simpler ones, explicit confounding often cannot be eliminated, although techniques are available to minimize it (Scarnecchia 1988).

Such explicit statistical confounding is a problem, but inadvertent, *internal conceptual confounding*, in which *confounding is internalized within complex concepts when they are derived from confounded simpler concepts*, is a more insidious problem.

The previous example of making the animal-unit a unit of intake leads to an example of conceptual confounding. Figure 2 is a familiar graph of animal intake versus stocking level. This graph has clear meaning only if the animal-unit used in expressing stocking level is not *itself* a unit of intake. Otherwise, the confounding between stocking level and intake makes the figure difficult to interpret. If the animal-unit is abstracted as a unit of demand, the confounding in the relationship (Fig. 2) disappears because the animal-unit is no longer confounded with intake, and *no longer dependent on all the other variables which affect intake*.

Such conceptual confounding is a pervasive problem among range science concepts. *Many complex range science concepts*

Fig. 2. Hypothetical relationship between animal intake and stocking level. This relationship is internally confounded and difficult to interpret if the animal-unit used in calculating stocking level is defined as a unit of intake.

are internally confounded because more basic concepts used to derive them are confounded with each other. Sufficient abstraction of the basic variables is essential in preventing confounding. In the previous example, abstraction of the animal-unit allows it to be used all the way up the hierarchy of conceptual complexity in Fig. 1. The basic principle of concept design here is that *the more confounded a concept, the more immediately useful it appears, but the fewer applications it actually has*.

The temptation, originating in management, is to try to condense too much information into single concepts—to practice a kind of primitive holism by integrating within concepts rather than integrating unconfounded concepts in formal analyses. Once a concept is conceived as an aggregate of many variables, it usually cannot be precisely related to other concepts in analyses. Range management science needs unconfounded basic concepts to use in analytical models, and even to explain simple relationships such as that in Fig. 2.

Other Considerations in Concept Design

The character of a designed concept should reflect the objectives for its use. For example, the rangeland condition concept is best designed as a modular concept (Scarnecchia 1995) to give it a discrete identity, and simultaneously to allow it to apply ecological theories whose appropriateness vary in space and time. Its discreteness as a model of rangeland values apart from ecological theories provides its generality and simultaneously contributes to the much needed identity of range science. Rangeland condition is an example of a conceptual model that should be used in more complex models as a complete submodel rather than being woven piecemeal throughout another model as a simple variable might be.

Some concepts are no more than simple variables, and such variables, whether measurable or abstract, can be useful as indicators to assess more complex concepts, as, for example, readily measured soil or plant variables can serve as indicators of rangeland condition. Some variables, such as those a modeler might encounter, can represent important concepts even though they are not directly measurable or their utility is as yet unknown. Just because a variable does not have immediate physical meaning does not mean it cannot eventually have great conceptual value, either alone or when applied with other variables.

Concepts and Definitions in Range Science

"Definition requires conceptuality."

—R. Buckminster Fuller, *Synergetics* (1975).

Recent years have seen several large committees attempt to develop definitions related to range science. Such committees have been much concerned with standardization of terminology. The problem of inadequate terminology in range science is really a symptom of inadequate basic concepts. Rather than attempting to define terms, attention would be better directed at concept design and development; *a definition of a well-designed concept falls out naturally*. But a poorly designed concept, (i.e., one that is inadequately abstracted, internally confounded, or based on *ad hoc* objectives) defies clear definition and/or general application.

A glossary of terminology is usually a list of verbal definitions. A glossary of concepts would be more meaningful, and would be a detailed framework of variables, approaches and models, based on explicit objectives of design, constituting the core of range

management science (Scarnecchia 1995). An objective-driven annotated glossary, it would have explanations of design and application to go with the definitions. In a management science like range science, a glossary of terms is of less value than in a technical science. A glossary of concepts would be of immense value to range management science.

An Exercise in Concept Design

The concepts of palatability, preference, and diet selection are familiar to range scientists and are a challenging exercise in concept design.

According to the first edition of *Range Management* by Stoddart and Smith (1943), *palatability* was originally used to describe the avidity with which an animal ate a plant. At that time, those authors abandoned the term palatability and suggested instead that the term *preference* should refer to the taste an animal "displays" for a plant. Over time, palatability has come to refer to *plant* characteristics and preference to *animal* reactions, as described by Heady and Child (1994). If interpreted rigorously, this distinction requires that palatability be defined independently of any animal, and that preference be defined without reference to any plant. This distinction seems reasonable because if the interaction of palatability and preference is to be a clean plant-animal interaction (e.g., actual *diet selection*), one of the concepts must be a *plant* concept, and the other must be an *animal* concept. A second alternative is to design palatability and preference as mutually dependent, which amounts to defining a single interactive preference-palatability concept which is species-specific on both the plant and animal sides. This single, interactive concept is closer to reality, i.e., to real, measurable species-specific diet selection. In the first alternative, the distinct concepts of plant palatability and animal preference are both significantly *abstracted* from real, measurable diet selection and are more abstract than the interactive preference-palatability concept. In this alternative, plant palatability and animal preference are in fact independent of animal or plant species, respectively. Which alternative is preferable?

The answer depends on the objectives of design. If the only design objective is to be able to document case by case diet selection, then the interactive palatability-preference concept is convenient. But abstracted, independent concepts of palatability and preference are generalized to work independently in any situation, i.e., in any model, and for any of multiple objectives. So the approach shown in the first 2 rows of Table 1 is the superior general approach for range management science. Over time, the trend among scientists working with these concepts has been to *work backward*, often reluctantly or imperfectly, to discrete, abstract concepts of palatability and preference for use in models to predict diet selection and for other objectives. This exemplifies a general principle that either explicitly through design or pragmatically to increase utility, *in management sciences, concepts tend to evolve to accommodate multiple objectives*. The evolution of the concepts of carrying capacity (Scarnecchia 1990) and rangeland condition (National Research Council 1994; Scarnecchia 1995) are examples of this principle. When concepts originate from management in the absence of systematic design, their evolution to abstracted, multi-objective concepts can be slow and difficult.

The abstracted concepts of palatability and preference in Table 1 are models of a number of plant and animal variables, respectively. Each could be visualized, for example, as a matrix of plant

or animal variables contributing to the larger model/concept. As abstract concepts, the 2 models can be used intact in diet selection models (Table 1) or individual variables can be extracted from either matrix and used individually. In either case, the palatability and preference concepts and the contributing variables are more abstracted, less interactive, less confounded, and of greater analytical value.

Table 1. Summary of characteristics of the concepts of palatability, preference and diet selection. Although concepts are inherently abstractions, column 1 refers to whether the concept is abstracted from the real world or further abstracted from an abstraction. Column 2 describes whether the concept is directly measurable. Column 3 indicates whether each has been conceptualized as a plant concept, as an animal concept, or as an interactive concept. These general characteristics of abstraction, measurability, and interactivity are interrelated.

Concept	Real (R) or Abstract (A)	Directly Measurable ?	Plant (P) - Animal (A) or Interactive (I)
Palatability	A	No	P
Preference	A	No	A
Diet Selection	R	Yes	I

Indices

Limiting concepts by abstraction requires that more analysis be done through explicit modeling and less through calculating *ad hoc* indices. For example, easily calculated selectivity indices are often used to relate diet selection to some concept of availability and thereby rank forages. Such an approach was reviewed by Heady and Child (1994). They cited earlier research (Loehle and Rittenhouse 1982) which described analytical inadequacies of selectivity indices, saying in essence that attempts to condense all of the variables and variability of diet selection into a single index had been unsuccessful. In another paper, this author (Scarnecchia 1986) described major conceptual inadequacies in interpreting and applying indices of dietary overlap. Such indices have numerous conceptual weaknesses, including that they (1) are usually derived from interactive, real concepts and so are seriously confounded, (2) defy clear interpretation because they are confounded, (3) are impossible to use and interpret in subsequent calculations without even further confounding, and (4) are incompatible with abstract concepts of palatability and preference as defined by Heady and Child (1994), and as shown in Table 1.

The general principle here is that *ad hoc indices derived from interactive variables are not substitutes for explicit, rigorous models of unconfounded concepts*. Some indices may have specific situational uses, but they have little general use in range management science.

Looking Ahead

The future development of range science depends on having well designed concepts to meet the multiple objectives and multiple interactions of a management science. The principles outlined in this paper relate abstraction, confounding, and generalization in concept design. They serve as a guide to the development and application of future concepts, from the simplest dimensional units and variables to the most integrative models.

Without well designed concepts, range science will remain a science of weak identity (Scarnecchia 1995). Effective concepts that are consistent with a management science, a systems science, will lead to a range science of stronger individual identity and will also make range science more compatible with supporting

basic sciences and with other natural resource sciences. So work on conceptuality in range management science is a win-win activity. The quality of design of its underlying concepts will help determine whether range management science fragments into its surrounding sciences or contributes to a unified natural resource science of the future.

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