Why is there a persistently increasing gap in the availability of livestock veterinarians in the rural U.S.?

Benjamin L. Turner, Ph.D., Texas A&M University-Kingsville and King Ranch® Institute for Ranch Management

Abstract:Veterinary shortages in rural United States represent a major challenge for all stakeholders in the cattle industry. Poor accessibility to veterinary services can lead to animal health problems and decreased productivity, ultimately impacting producers' bottom line through either increased costs to access services, decreases revenues through reduced production and animal loss, or both. Here we employ the systems thinking approach to better understand the problem of rural veterinary shortages. After starting with a primer on the systems thinking approach, we then use the Iceberg Diagram framework to explore the events of interest in the contemporary discourse, the trends and patterns that have unfolded over time in factors related to the problem, and then unpack the underlying structural forces and processes that have made the problem so difficult to manage, including competing mental models of various stakeholder groups. We synthesize these structural elements in a Causal Loop Diagram that visually illustrates the key feedback processes at work. We conclude with general comments about potential leverage or intervention strategies aimed at reversing the trends in declining rural veterinarians.

Keywords: rural veterinarians, veterinary shortage, systems thinking

Introduction

Veterinary shortages in rural United States represent a major challenge for all stakeholders in the cattle industry. Poor accessibility to veterinary services leads to animal health problems, which ultimately impacts producers' bottom line through increased service costs, reduced productivity, or both. This paper employees a systemsthinking (ST) approach to investigate and discuss how the veterinary shortage came to be over time. The ST methodology has been applied to a variety of ranching, livestock production, and animal health problems[10]. The outline of this paper is as follows: first, an introduction to ST is given, outlining the methodology, conceptual language, role of stakeholders and their personal perspectives, and focus on decision making, which constitute the qualitative scientific process of ST. Then, the rural livestock veterinary shortage problem is investigated with the ST approach, illustrating key trends and patterns over time, underlying structural forces and mental models of people involved in or affected by the problem. Lastly, we discuss potential leverage points of change that may improve the situation.

The systems thinking approach

The need for a Systems Thinking approach

Systems thinking (ST) is a methodology for understanding complex social, management, or environmental problems and crafting more sustainable intervention strategies to achieve desired outcomes[3,6]. Such problems are often are characterized by cause-and-effect relationships best described in terms of feedback (rather than unidirectional linear causality) which often produces nonlinear, counterintuitive and delayed behaviors and consequences[1,7]. The sources of counterintuitive outcomes have been shown to arise when intervention or management strategies are applied from management perspectives that are too narrow in scope or temporally short-term in nature, and these outcomes can be augmented due to non-linear relationships at deeper levels of structure than our current awareness takes account of[1]. The ST perspective and methodology provides a tool box for better understanding these relationships and behaviors in the world around us[4]. More formally, ST involves seeing relationships as feedback processes instead of linear cause-and-effect chains and seeing change over time produced from structural level processes rather than series of events[1].

The Iceberg Diagram framework

One of the most widely recognized concepts in ST that also serves as an introductory tool to apply ST to particular problems is the Iceberg Diagram model. The analogy of the Iceberg Diagram comes from a familiar adage that 90% of an iceberg's mass resides below the water body's surface. In order to fully appreciate and understand complex problems, we need to go deeper than the surface level to the bottom of the structure of the iceberg where the bulk of the problem resides. The Iceberg Diagram model (depicted in Figure 1) forces us to confront three levels of awareness about a problem: what happened [to spark our interest in the problem]? (the event level); what's been happening over time? (the trends and patterns level); and why is the problem the way that it is? (the structural level).

Events capture our attention, and if we remain there, forces us to react to discrete, point-in-time pressures. Trends and patterns over time and are more continuous in nature. Trends can often be captured quantitatively through monitoring, reporting, and data collection about various parts of the system the problem arises from and which can be used for analysis and forecasting. The structural level represents the forces, processes, policies, and mental models that direct and give rise to changes over time and events of interest as well as influence human decision-making within these structures. Data that tells us something about structure may come from biological, chemical, or ecological parameters, expert knowledge and experience, and decision-making criteria, goals, values, norms, and culture. Using the Iceberg Diagram teaches us that it is the structure that drives behavior in complex systems.

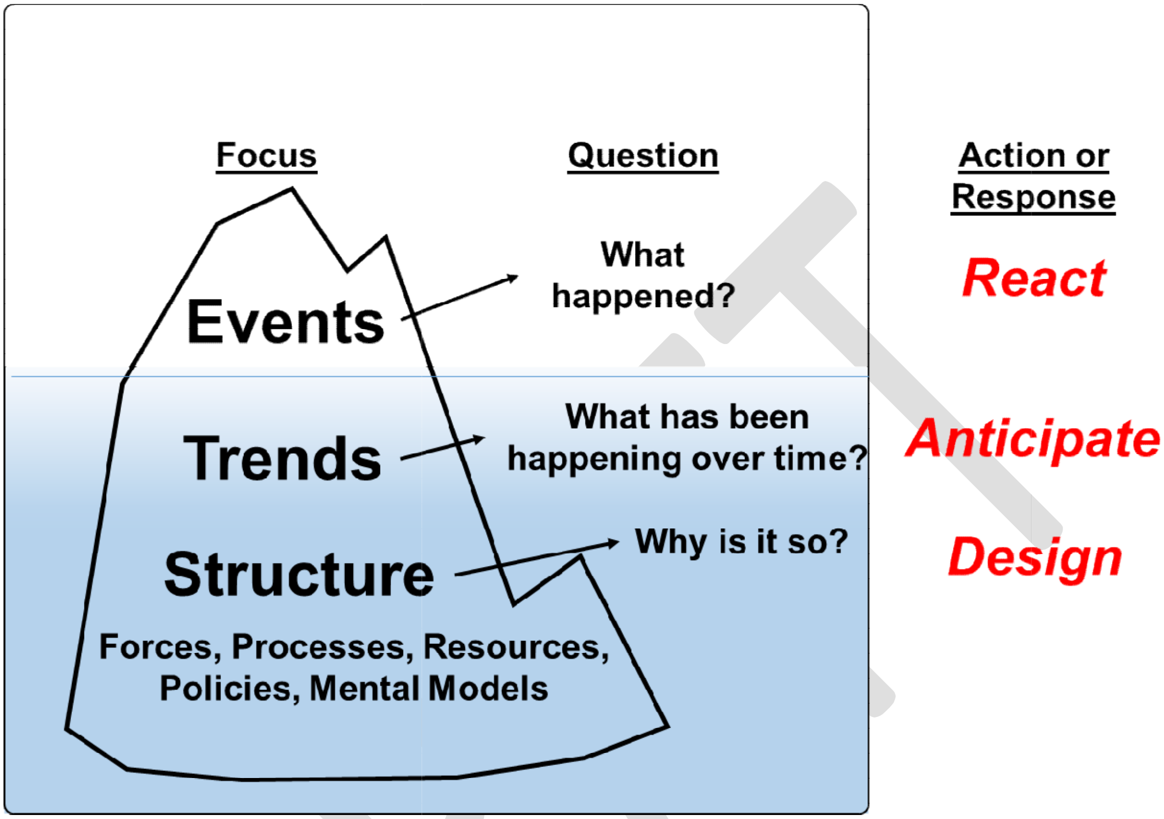

Figure 1. The Iceberg Diagram model, developing the user's awareness from events, to trends and patterns over time, to the underlying structural-level of the problem.

The language of Systems Thinking

Once we begin moving from the traditional or linear perspective toward the ST approach, how do we start to describe and communicate the structural forces and processes we find at the bottom of the Iceberg? The ST methodology provides a language that transcends the deep, specialized language of the scientific disciplines we are historically trained in. Although our traditional language is very powerful within a discipline, it tends to be open-loop (Figure 2) and unintentionally creates communication barriers due to varying terminology, meanings, definitions, and conventions that make it difficult to get deeper than surface-level dialogue. In open-loop thinking, we default to a linear approach to problem solving: identifying the problem, formulating possible solutions, analyzing or optimizing what we believe to be the best solution that fits our goals and constraints, and then we implement. Without a wider appreciation of cause and effect, in the open-loop view, problems arise in isolation and the possible interdependencies with other contemporary or previously-solved problems goes unexamined.

The ST language focuses on closed-loop descriptions and explanations of problems. In this view, solutions that are implemented have delayed or unintended consequences that either reinforce the original problem we aimed to solve, or give rise to completely new issues that were never problems in the past, which lead to new decisions in a process of continuous adaptation, change, and response (i.e., an endogenous perspective that focuses on the role of feedback[1]).

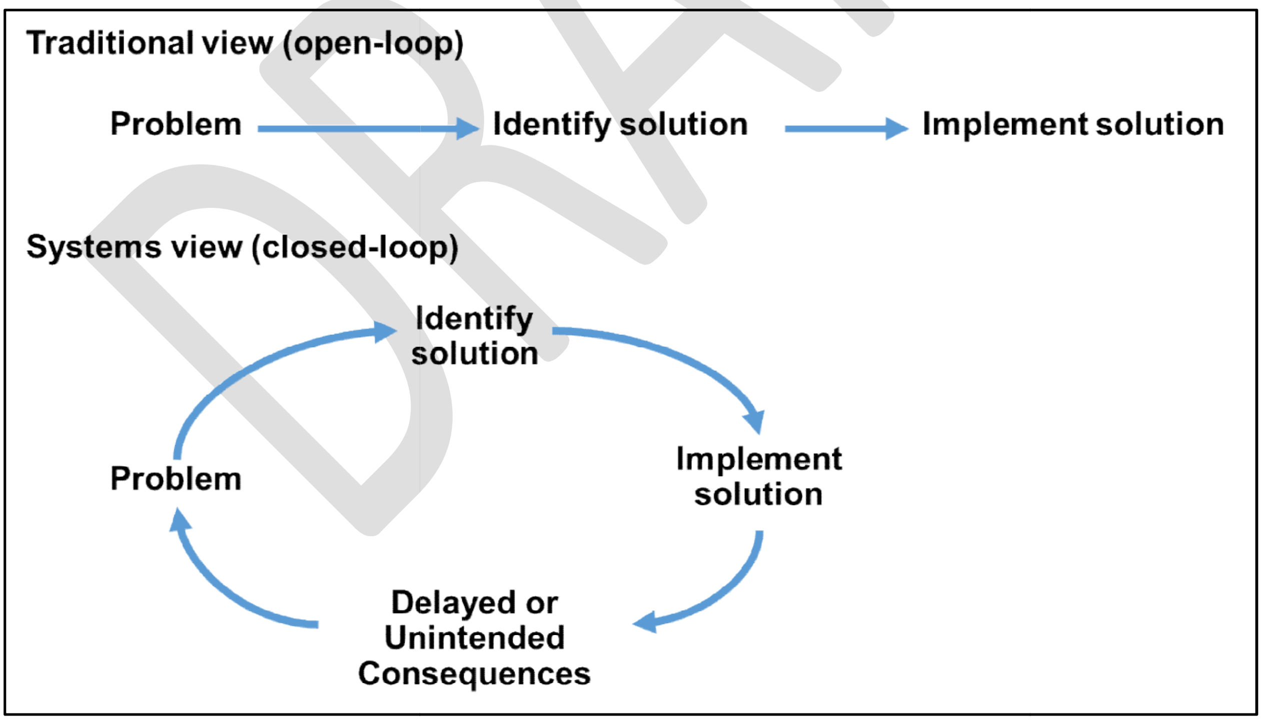

Figure 2. Traditional (open-loop) view of causal mechanisms vs the systems (closed-loop) view of causality which forms the basis of defining the underlying feedback processes in systems

problems.

With the closed-loop perspective defined, we can start to add the building blocks of the language to aid in our identification, description, and illustration of system structure. The three key building blocks include causal links that propagate pressure the same direction (denoted as a S link) or the opposite direction (denoted as an O link) as the original force, and the notation for delays, indicated when the effect that's time to see after the causal influence occurs (Figure 3). With these building blocks in place, more advanced structural stories and explanations can be constructed that represent more dynamic feedback processes[6].

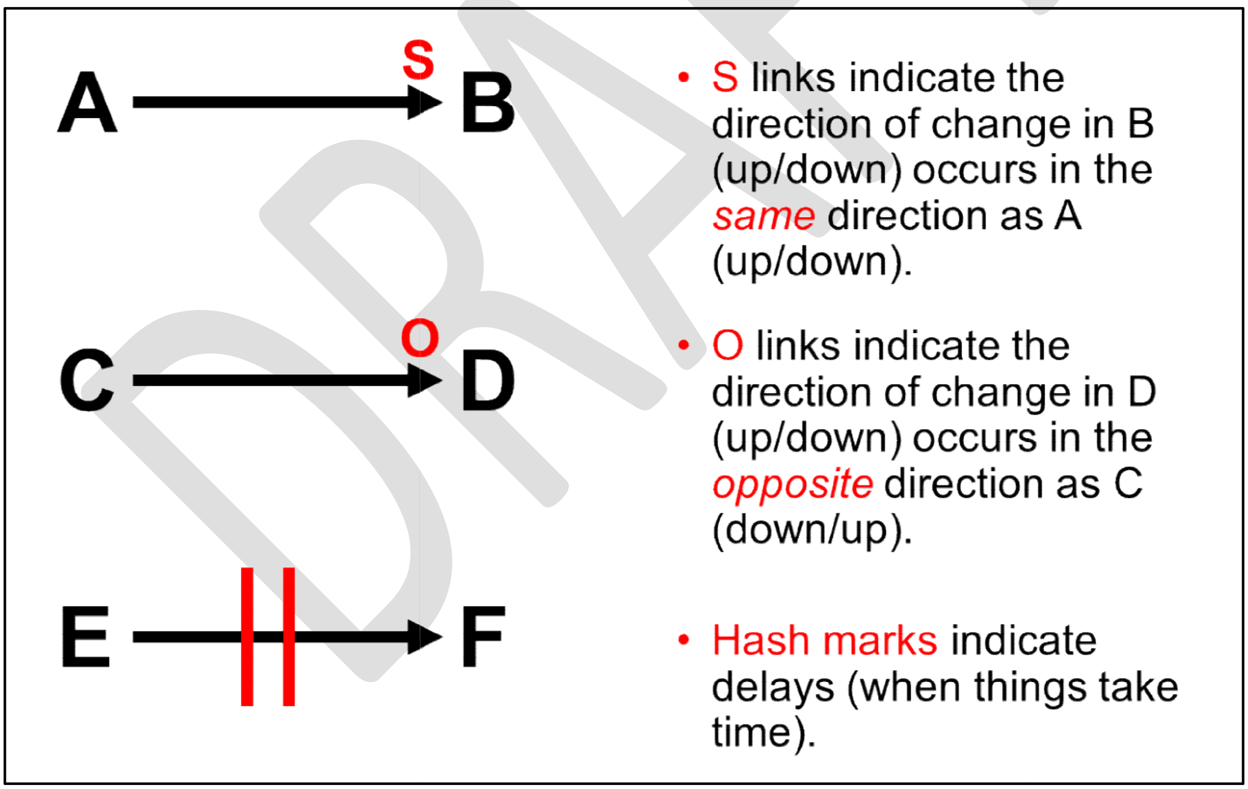

Figure 3. Three building blocks of the systems thinking language, same (denoted S link) and opposite (denoted O link) causal links and the recognition of delays.

There are two primary feedback loop structures: reinforcing (denoted with 'R') and balancing (denoted with 'B') (Figure 4). Visually, feedback loops are constructed using causal links, specified with an "S" or "O" sign depending on the cause-and-effect relationship (shown in Figure 3). Indicators of reinforcing feedback relationships are runaway growth or decay, where the condition or performance level increases/decreases, the growing action also increases/decreases (i.e., moves in the same direction), reinforcing the condition or performance level to still greater/lesser levels (Figure 4). An elementary example of a basic reinforcing process would be population growth (e.g., increasing egg hatchings will lead to greater number of chickens, leading to still more eggs). When the causal linkages interact such that growth or decay is hindered, offset, or regulated in some way, the feedback is called balancing (B). Balancing loops (also known as negative feedback), are self-correcting, or serve to counteract change in a system. The generic balancing B-loop shown in Figure 4 provides the basic schematic, whereby as the problem, symptom or pressure increases, the corrective action also increases. Once the corrective action has been increased (and often after a time delay), the problem symptom or pressure declines, and we remove (decrease) the correction action. As an elementary example, as the chicken population rises, various negative loops will act to balance the population with its carrying capacity: the greater the number of chickens, the greater the road crossing that will be attempted; greater road crossings leads to fewer chickens. Reinforcing and balancing feedback, the basic building blocks of systems, provide the means to describe, illustrate, and communicate deeper levels of Structure below Events and Trends on the Iceberg Diagram[10]. Mastering the systems language facilitates improved translation between different scientific disciplines and assist with overcoming pre-existing communication barriers[2]. Incorporating the systems language into our own daily, conversational language can be a high-leverage skill that enhances our ability to wrestle with complex problems and fills a knowledge gap created by the reductionist view that we often fall back on[2].

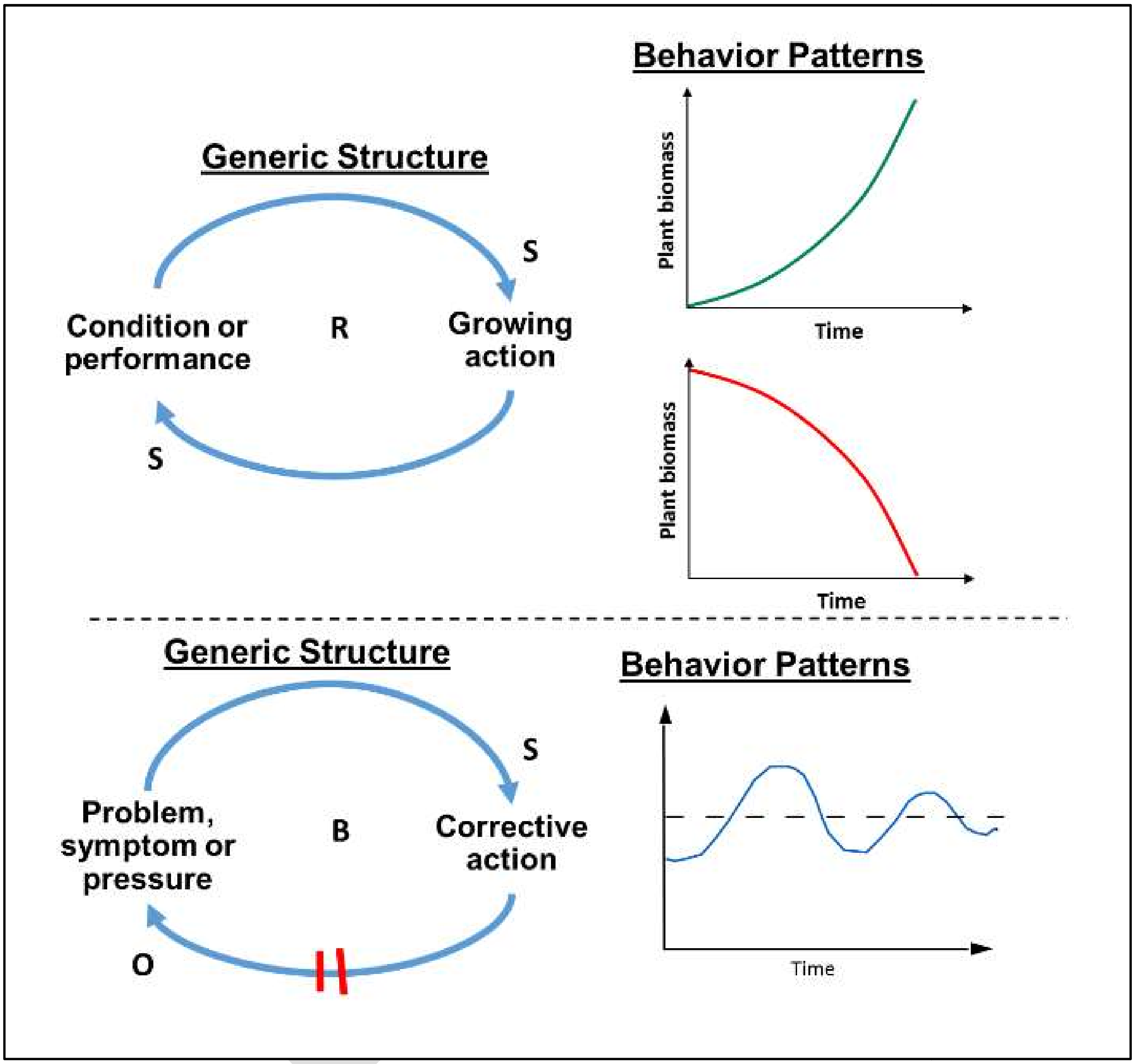

Figure 4. Primary feedback processes: reinforcing (denoted R) and balancing (denoted B), along with their most commonly occurring trends or patterns over time that arise from each.

Mental models and decision-making

Mental models are the beliefs, assumptions, and relationships about a system that a person carries in their mind. Ford[1] provided a rigorous formal definition of mental models with the following: “a relatively enduring and accessible, but limited, internal conceptual representation of a system (historical, existing, or projected) whose structure is analogous to the perceived structure of that system”. In essence, our mental models are perceptions of the world that are durable enough to influence what we say and do, how we structure our lives and organizations, and drive our decisions, but flexible enough to adapt to changes in our environment and context. We can access and describe them, but it takes serious introspection and reflection to “unpack” our underlying assumptions and belief templates that form them. Often, it is easier to recognize others’ mental models than to be able to describe our own. Because we don’t have full access to them and our own internal capacity is limited, mental models are always incomplete. These lead, often subconsciously, to the construction of mental short-cuts or “heuristics” in order to better cope with the complexity and uncertainty around us.

Because of these mental heuristics become associated below the level of our conscious awareness, mental models tend to reinforce or perpetuate themselves. Our mind builds inferences about phenomena based on the observable data and experiences available to us, but heuristics tilt our perspective such that we only select a fraction of the available data that we can access with our five senses. To make sense of the data we have, we add meanings and assumptions which aid our ability to draw conclusions. Given those conclusions, we update our particular belief template. When confronted with new or evolving problems, we select data from observation and experience that conform to our particular beliefs, thereby reinforcing our original mental model perspective. Over time, the beliefs, assumptions, and meanings about our experiences become ingrained, which becomes imbedded in our decision-making processes and ultimately biasing our decisions (in some cases for good, but in many cases for the worse).

Although abbreviated in nature, the above sections have provided a ST foundation from which to explore the important structural problem capturing our interest today: shy is there a persistently increasing gap in the availability of livestock veterinarians in the rural U.S.? Below, we apply the ST process, following the Iceberg Diagram model, to investigate the structural forces and processes that make this a difficult problem to sustainably address.

The systems thinking approach applied to rural livestock veterinary shortages

Limited access to veterinary services in rural areas poses a significant risk for both animal welfare and the overall food production system, as inadequate supply of veterinary care can result in delayed or poor animal health treatment. Deficient care increases the probability of prolonged suffering for animals or death if treatment is not administered in time. These delivery delay or veterinary care bottlenecks translates into negative consequences on animal-based agricultural enterprises, an important income source for rural communities (e.g., losing a cow-calf pair can cost about $1,800[5]). A shortage of veterinarians limits the capacity of farmers and ranchers to prevent or treat disease and hinders their overall management capabilities. Lack of accessibility can also drive up costs, given producers are forced to transport animals needing special treatment long distances to find a clinic that offers the needed services[8].

The scarcity of veterinarians increases the burden for those few clinics remaining in rural areas. Over time, the geographical area they must provide service for has grown, overwhelming some practitioners. This pressure may lead to excessive stress and work hours for veterinarians, increased waiting times, and lower quality of care for customers. This situation has reinforced the already negative perception of graduating veterinary students about working in rural areas[9].

To better understand the issue, we use the Iceberg Diagram model steps to capture data, experience, and observations at each level of awareness pertaining to the rural veterinarian shortage problem:

Events

- We are experiencing a severe lack of large animal veterinarians, particularly in rural areas. Producers are being forced to drive considerable distances to obtain this service and incur significant costs in doing so. Contemporary news articles capture the state of affairs in headlines such as:
    - "Very few vet students are interested in food animals." - UC Davis School of Veterinary Medicine 2023
    - "500 counties in the country have shortages." – Bovine Veterinarian 2022
    - "Cattle quality and health compromised" – John Hopkins Center for a Livable Future 2023
    - "Travel costs are adding up" – Farm Progress 2023

Trends

- Total enrollment in veterinary schools have almost doubled in 30 years
- Increasing numbers of veterinarians self-report as companion animal focused
- Number of veterinarians self-reporting as food animal or mixed animal (food and companion) have declined
- Increasingly more women enter the profession than men

- Better paid work tends to be found in the cities, which also offer more amenities and perceived social benefits relative to rural communities
- Incentives like loan forgiveness do not seem to work given the amount of funds expended to eligible graduates relative to the approved level of funding
- Money in the short-term is a big incentive. Real incomes are stagnating but debt loads have increased tremendously with rising tuition costs.

Structure: contributing forces to feedback processes

- Average herd size of producers influences the demand of veterinary services,which has shifted with industry consolidation
- Quality of service and reputation of current and past veterinarians drives perceptions of veterinary care in a locale, thereby influencing how producers' source veterinary caregivers
- Retention factors at the individual (urban vs rural experience as a child), firm (incentive plans, ownership structure, start-up or financing costs), family (spouse career opportunities), and community-levels (quality of and distance to schools, extracurricular opportunities for children, distance to and quality of healthcare and other services)
- Academic qualifications and expectations of veterinary schools, which generally have raised academic entrance rigor and enforce strict enrollment capacity constraints
- Culture, goals, experiences, and preparedness of students with urban vs rural backgrounds (which connects to agricultural exposure and interest, quality of primary and secondary education prior to veterinary school, ability to acclimate and communicate in a rural setting, and desires to work with either companion animal or livestock animal species)

- Sources of information and criteria which define “shortage” for policymakers, which are based on reported veterinarian numbers and agricultural animal populations at the county level
- “Signals” of the cattle production industry, which has led producer-level education efforts about basic animal health practices and promoted and trained producers their adoption and use

Mental models

There are a variety of unique mental models that contribute to the rural veterinary shortage problem. We may segment these based on the stakeholder group that perceive and contribute to the problem differently: institutions of higher education, recent graduates, existing veterinarians, and livestock animal producers. Each of these are summarized as quotations in Table 1. Although many of the points of each group are unique to themselves and their position in the system, emphasizing their individual goals and issues, what nearly all groups share in common is that they desire high quality outcomes and performance that cross-cuts the problem: producers desire good service at a reasonable cost, veterinarians desire balanced quality of life without taking on excessive financial risk, veterinary schools desire top-tier incoming students and graduates that have maximized their potential for impact in industry and public service, all want to see animal health and well-being continuously improve and all want to see the investment in system capacity to mitigate risk of and ability to respond to disease outbreaks.

Table 1. Synthesis of stakeholder mental models, described using hypothetical quotations from each group which characterizes a part of their unique perspective and goals and constraints associated with rural veterinary supply issues.

Group	**Mental Models**
Educators/Academics	• **“**We want to recruit the cream of the crop.” • “Higher admission standards will yield a better situation in the veterinary industry.” • “We want to attract the best and brightest.” • “We want to be perceived as exclusive, high level, prestigious.”
Veterinary School Graduates	• “I don’t want to relocate my family.” • “I would like good employment opportunities for my spouse.” • “I want the best possible school district for my child.” • “Only the top students should have the privilege to practice the profession.” • “I don’t want to live in the middle of nowhere.” • “I want to live where I don’t have to drive more than 30 minutes to a grocery store.” • “I want a good work environment.” • “I want good facilities.” • “I don’t want to argue with every rancher about welfare practices.” • “I don’t want to be responsible when a rancher may have to resort to euthanasia/slaughter when a treatment is too expensive.”
Veterinary Students / Potential students	• “I don’t want to buy/run my practice.” • “I don’t want to be in debt my whole life.” • “Livestock veterinarians don’t make as much money as small animal veterinarians” =False. • “It’s harder to get into veterinary school than medical school – why apply?
Ranchers	• “I want good quality help and low prices.” • “Kids don’t want to work as much as we do. They only want 40 hours or less.”
Livestock Veterinarians	• Love small-town rural life • Believe in being a trusted, humble advisor to producers
Urban Veterinarians	• Love animals • Prefer the luxuries of urban life
New Students	• High ego, very prideful, believe they bring value because of their degree.

Mapping the system

After working through some key events, trends and patterns over time, and structural forces and mental models potentially at work that give rise to the veterinary shortage problem, we now move to constructing a causal feedback view of the problem which could help explain why the problem persists despite our best efforts to reverse it.

We start with food animal (FA) clinics formed and sustained (Figure 5). The healthier these are, the greater exposure to youth and undergraduate (UG) students to FA practice, which over time leads to more rural applicants to veterinary school, students enrolled and graduated, and choosing to become FA veterinarians (a reinforcing, R, loop named “FA veterinarian growth”). This growth or replenishment of FA practitioners is limited by a number of feedbacks and external factors: as graduates choose to prioritize companion animal (CA) practice, youth and UG student exposure to FA declines and leads to greater exposure to veterinary careers from a CA perspective, which geographically is centered on more urban centers, such that the number of urban applications increases, reinforcing CA practice (shown as “CA veterinarian growth” in Figure 5). The more that graduates prioritize CA over FA career pathways, FA clinic sustainability erodes, limiting youth and UG exposure and therefore the fraction of students choosing FA in the long-term diminishes (shown as the B loop, “preferences limit growth”, in Figure 5). In addition, community attractiveness to rural areas, which FA clinics contribute positively to, is further constrained by spouse career opportunities (which have declined over time as communities have hollowed out and people have relocated to urban and suburban areas), distance to public schools and other services (which complicate choices for veterinarians who are parents), and socio-cultural opportunities (due to a lack of professional, service, or social clubs that are no longer viable due to population and demographic shifts). These factors limit community attractiveness, shown in the R loop "rural community pull" (Figure 5).

Several other feedback and external factors further constrain FA clinics and the replenishment of veterinarians there. The shortage of FA vets leads to a shift in how the remaining FA practitioners conduct their practice. By increasing investment in infrastructure, technology, and support staff, FA practitioners raise their individual productivity needed to keep pace with their case load, lowering the demand for new services, and which, importantly, masks the shortage of FA vets (this is shown in the balancing, B, loop named "existing FA coping strategies"; Figure 5). This investment rate itself is constrained for new FA practitioners due to the escalation of tuition costs, which burden newer graduates with high debt-to-income ratios (shown as the R loop, "new FA financial pressure").

Finally, to account for the connection to animal agriculture industries, we recognize that over time, both the productivity of animal agriculture and the quality standards of the industry have risen significantly. If FA veterinarians are not available to help industry fulfill its demands (due to a shortage of FA veterinarians, poor quality FA service in the past, or any other reason), producers have to cope by addressing animal health needs themselves in the short-term. In the long-term, this has several consequences. First, their short-term coping leads to acquiring skills on the job that, although may not be as high quality as FA veterinary care, is good enough to get by. Therefore, they may be reluctant to go back to FA clinics in the future if they can do some of those jobs themselves and eliminate some costs of service (shown as the R loop, "producer adaptation"). In addition, their industry gets the signal that they themselves need to build capacity to support their producers' actions to maintain industry quality goals, and as that industry capacity comes online, the unfilled livestock demand for FA services is reduced (shown at the B loop, "long-term industry adaptation" in Figure 5).

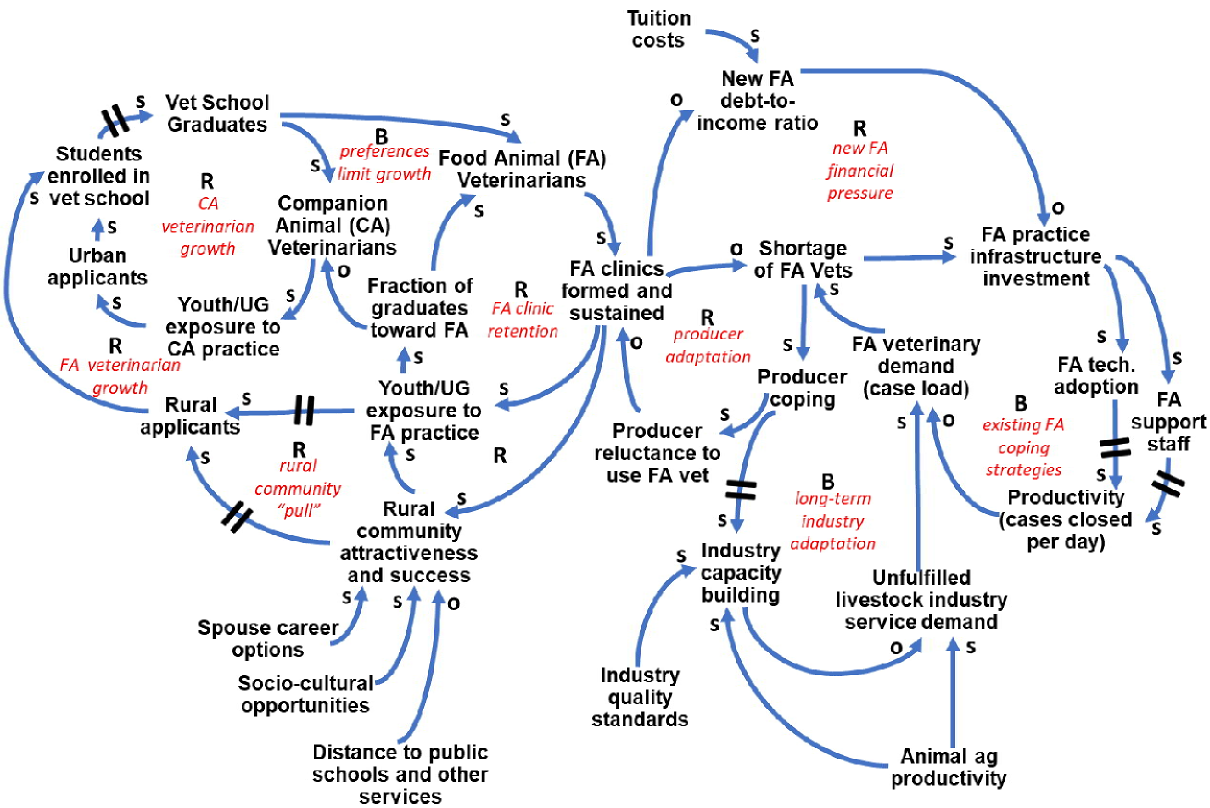

Figure 5. Synthesis of the rural livestock veterinarian shortage issue displayed in causal loop diagram. The notations on causal links are interpreted as either same, S, links, meaning the variable at the arrow head moves in the same direction as the variable that preceded it (e.g., as tuition costs go or down, new food animal debt-to-income ratio also goes up or down), or opposite, O, links meaning the variable at the arrow head moves in the opposite direction as the variable that preceded it (e.g., as the number of food animal clinics are sustained goes down, the shortage of food animal veterinarians goes up). Notations R and B representing either reinforcing or balancing feedback processes.

Conclusions

As we have explored in this paper, the rural veterinarian shortage problem is a complex problem with a number of interacting and overlapping feedback processes that make the effectiveness of simple straightforward solutions much less than desirable. Any possible interventions, such as the veterinary student loan forgiveness program being promoted in many states, or other strategies, such as incentives for importing international veterinary students, designing specific veterinary schools devoted to solely food animals and which target students from rural areas, financial incentives or relief for spouses of new rural veterinarians, or industry partnerships to create internships and apprenticeships in rural food animal practice for students prior to graduation, must consider how these forces will accelerate and strengthen the feedback processes identified in the CLD or resist or mitigate the feedback processes that should be strengthened (Figure 5). How rural veterinary shortages are defined is a critical consideration, since this definition informs and influences how strategies are crafted and supported by industry and policy makers. Adding greater nuance and clarity to shortage area determination to be more respectful of the agricultural and socio-economic context in each county may provide more flexibility in crafting intervention strategies that respect the feedback processes identified above and work with rather than against them.

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