Review

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Review

Resilience and Veterinary Science

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Simple Summary

This paper explores how the concept of resilience shapes and is shaped by veterinary science in diverse ways. Resilience can refer to animals coping with disease, veterinary professionals managing stress, or whole systems like food production and public health adapting to challenges. By examining three main types of resilience, engineering, psychological and ecological, the paper highlights how each shapes veterinary thinking and practice. It also argues that resilience is often treated as automatically positive, even though it can hide inequalities or place unfair burdens on individuals and therefore calls for a more critical approach to resilience in veterinary science.

Abstract

This paper examines how veterinary science intertwines with the different ontologies of resilience. As resilience has increasingly become an influential yet conceptually diverse framework, its different ontologies shape and are shaped by veterinary science thinking. This paper will begin with a brief overview of the origins of the resilience concept and its three major ontologies: engineering, psychological and ecological resiliencies. Following these different ontologies, the paper then explores animal level resilience, where engineering framings emphasise disease response and production stability, while welfare-oriented perspectives focus resilience on the affective experience and the lived realities of animals. It then considers veterinary professional resilience, highlighting how emotional labour, workload pressures and structural constraints shape wellbeing across the profession. Finally, it analyses how veterinary science contributes to socio ecological resilience through One Health approaches in public health, food systems and climate adaptation. Across these domains, resilience is often framed as a desirable attribute, yet it remains a value laden concept that can obscure inequities or normalise preventable harms. This paper calls for critical, justice-oriented engagement with resilience to ensure it supports ethically grounded veterinary practice and promotes healthier-happier animals, more equitable systems, and sustainable professional environments.

Keywords: resilience; veterinary science; engineering resilience; psychological resilience; ecological resilience; disease resilience; veterinary mental-health; one health

1. Introduction

Veterinary science has had a long and complex history. Ever since humans have had animals in their care, as companions, workers, trophies and, most prominently, as a source of food, there has been someone tasked with overseeing their productivity and safeguarding their health. As human-animal-environment relations have shifted; from small scale to industrialized food production, from

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animal workers to being members of the family and through the effects of a changing climate and diet, veterinary science has, and continues, to adapt to evolving landscapes of care and practice [1].

The concept of resilience itself has also transformed through time and has been broadened across disciplines [2], generating multiple conceptualizations that although related still have different meaning and implications for veterinary science. Within the veterinary field, resilience, for example, can refer to an animal maintaining production under disease, environmental challenges or other stressors [3,4], a practitioner coping with the pressures and demands of the profession [5], or a food system sustaining performance amid internal or external shocks [6].

This review does not attempt to impose a single definition of resilience onto veterinary science. Instead, it examines how different ontologies of resilience intersect with veterinary thought and practice. To do this, this work will trace through time the three main conceptualizations of resilience, namely engineering resilience, psychological resilience and ecological resilience, before exploring their relevance to the field of veterinary science through three thematic lenses.

First, it examines how resilience is applied within veterinary science, particularly through disease resilience research grounded in engineering perspectives, as well as through animal welfare science, which aligns more closely with psychological framings. Second, it considers how resilience is used to evaluate the wellbeing of veterinary professionals and the infrastructures that support their work. Third, it explores how veterinary science contributes to broader socio ecological resilience through public health, food systems and One Health approaches.

The article concludes by discussing the implications of these intertwined conceptualisations of resilience for contemporary veterinary science and policy, and how resilience thinking shapes the lives of animals, the wellbeing of practitioners, and the functioning of the socioecological systems in which veterinary work is embedded.

2. The Resilience Concept and Veterinary Science: A Brief History

Resilience is not a single fixed idea. Its meaning has shifted across time and disciplines, producing multiple ontologies that now inform veterinary thinking. Tracing this development helps clarify how each conceptual thread emerged.

The term resilience originates from the Latin resilire, meaning “to jump back”. It first appeared in the modern English scientific lexicon in the seventeenth century, when Francis Bacon used the term to describe echoes rebounding from surfaces [2,7]. This use of resilience was very much a literal understanding of jumping back; as the term has evolved this literal understanding has been left behind but its conceptual association with rebounding, recovery and redundancy can still be identified in its modern scientific usage [8,9].

The term re-entered scientific discourse during the Industrial Revolution through the field of mechanics, where it described the elasticity and strength of materials under stress [2]. This conceptualization, later known as engineering resilience, focuses on how much disturbance an object can absorb before it fails, and how readily it can return towards its original state once the incursive stressor is removed. Importantly in this conceptualization there exists an underlying assumption that there is a preferred or original state towards which recovery should occur [10]. Veterinary science first engages with resilience through this lens and it continues to underpin contemporary work on disease resilience, robustness, and poor health and welfare [3].

During the twentieth century, particularly after the second world war, the concept significantly expanded, developing independently within psychology [11] and ecology [12]. In psychology it became associated with an individual’s capacity to positively adapt in a context of adversity. Originally used to look at some children’s ability to bounce back from adverse rearing conditions [13,14]. Overtime it expanded to caring and high risk professions, including veterinary medicine, where it is now central to discussions of burnout, moral stress, mental health and workforce sustainability [15]. Within veterinary science, this meaning also finds relevance in work regarding animal welfare and affect [8].

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In ecology, Holling [12] reframed resilience as the capacity of a system to absorb disturbances while retaining core relationships, even when conditions shift. Unlike engineering resilience, ecological resilience acknowledges multiple stable states and emphasises thresholds, persistence, and transformation. This framework later migrated into the social sciences, influencing sociology, economics, and geography [2]. It also shaped systems thinking and now underpins socio ecological resilience research and policy discourses on sustainability, risk, and adaptation [16]. This conceptualisation highlights the interconnectedness of animal and human societies with the environment, and it now informs resilience narratives within food systems, public health, One Health, and climate policy.

What the above and the wider resilience literatures reveals is a concept with fungible qualities. It can be thought of as a process, a capacity, a property and, increasingly, as a policy goal, including policies relating to veterinary science. Although there have been attempts at unifying these perspectives (see for examples [17,18]) this review argues that examining how veterinary science both shapes and is shaped by each ontology offers a clearer understanding of how resilience is applied and where limitations arise.

3. Applying Resilience

In veterinary science and animal production literature, one of the most established ways of understanding resilience comes from engineering-based thinking. This framing entered veterinary literature through work on parasitic infection in sheep in the 1980s. Albers et al. [19] defined resilience as the ability to maintain a relatively undepressed production level when infected, explicitly differentiating it from resistance, the immunological capacity of resisting infection. Since then this framing has continued to shape contemporary work on disease resilience and climate resilience in animals, especially through breeding and genetic manipulation, where resilience is understood as sustaining productive function under a wide range of multifactorial challenges [8,20].

This way of approaching resilience has a clear practical appeal. It makes resilience an operational process where deviations in production traits such as growth rate, weight gain or milk yield could be used as measurable indicators of an animal's capacity to withstand disturbance [3]. These production measures provide quantifiable proxies that align with industry priorities and support breeding and management strategies aimed at reducing antimicrobial use and improving robustness and efficiency in variable environments [4]. Recent advances in precision livestock farming have further embedded engineering resilience in the monitoring of animal performance. Continuous sensor based data streams enable the detection of short-term deviations from expected production trajectories [3,21]. In poultry, for instance, daily fluctuations in body weight have been proposed as indicators of resilience, based on the assumption that more resilient individuals show smaller or more rapidly corrected deviations from predicted growth curves [22].

Despite its usefulness, this framing also carries conceptual risks. When resilience is equated to tight control around a production baseline and adaptative changes in behaviour or physiology can be misclassified as failures rather than legitimate coping responses [3,21,23]. This emphasis on maintaining output also obscures the fact that stable or high productive performance is not inherently indicative of good physical or psychological health [24,25].

Recent developments in animal welfare science therefore push for a second lens through which to view resilience. Drawing for psychology-based thinking, rather than focusing on stability of output, this perspective focuses resilience within an animal's capacity to maintain physiological homeostasis and engage in behavioural and affective processes associated with good welfare [3,25]. Here, coping encompasses emotional and motivational processes as well as physical performance. Rather than presuming a single normative equilibrium, this welfare-oriented view acknowledges the diversity of an animal's lived experiences and the possibility that thriving, rather than merely persisting, can serve as a meaningful indicator of resilience. Colditz [3] argues that resilience may be better understood as a competence to thrive, which reframes the concept as a marker of positive

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health and welfare rather than merely the speed or degree of recovery to an expected production level after a stressor.

Each of these framings emphasises different indicators, different welfare implications and different assumptions about what "good" resilience looks like. Recognising these differences is crucial, as the engineering framing continues to dominate breeding and production systems, while welfare focused psychological framings are increasingly present in discussions about animal agency, affect and positive welfare. Together, they illustrate how veterinary science applies resilience.

4. Living Resilience

While veterinary science frequently applies the concept of resilience to animals, the term is also widely used to address the people who work within and around the profession. Here, resilience draws primarily on psychological conceptualisations, focusing on the emotional, cognitive and relational processes that enable practitioners to cope with adversity. This body of scholarship has become increasingly important as evidence accumulates of elevated rates of burnout, anxiety, depression, compassion fatigue and suicide among veterinary professionals, placing practitioner wellbeing as a central concern in the contemporary professional discourse [15,26].

Across both clinical and agricultural settings, veterinarians routinely perform roles that extend well beyond the provision of medical care. They often act as educators, economic advisors, communicators, and emotional supporters. These additional responsibilities are integral to how veterinary work is delivered, yet they also contribute to the psychosocial pressures faced by the profession [27]. In rural areas, formal mental health services are often limited or stigmatised, resulting in other professionals taking on informal support roles. Veterinarians frequently become "accidental counsellors", as farmers confide distress in those they see regularly and trust, often because formal services are inaccessible or socially discouraged [28].

In clinical environments, veterinarians perform emotional labour by helping owners navigate guilt, grief and moral conflict in the context of medical decision making and euthanasia [29]. Veterinarians also occupy a sentinel role in identifying animal abuse and associated human interpersonal violence. Strong evidence demonstrates consistent co-occurrence between domestic violence and animal abuse, positioning veterinarians as central actors in early detection and intervention [30,31]. These forms of informal emotional and safeguarding work constitute meaningful, though often unrecognised, ways in which veterinary professionals contribute to resilience at the level of households and communities.

However, the emotional demands of this work, combined with other pressures such as client expectations, financial insecurity, student debt, workload intensity, and concerns about ecological change, place significant strain on practitioners' resilience [15,32]. These pressures also prominantly affect students and early career veterinarians, who may have limited experience in managing ethical and emotional challenges within the profession [33,34]. In response, regulatory bodies have increasingly framed wellbeing and resilience as components of professional competence. Initiatives such as the Royal College of Veterinary Surgeons' Mind Matters Initiative [35], the Australian Veterinary Board Council's Day One Competences [36], and the American Veterinary Medical Association's Annual Health and Wellness Summit [37], aim to provide training and support to enhance mental health and resilience across the veterinary profession.

Cake et al. [15], highlight that much of the existing scholarship in this matter concentrates on the negative pressures that erode resilience, while comparatively little work examines the positive psychological, social and organizational factors that enable resilience to develop and be sustained. This is echoed by One Welfare scholarship, which argues that while veterinarians should contribute to cross sector safeguarding systems, many lack appropriate training, placing emotional and ethical burdens on individuals rather than on the institutions responsible for supporting them [31].

Treating resilience primarily as a personal trait or responsibility can obscure these structural factors. Studies consistently show that supportive team dynamics, mentorship, opportunities for rest

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and recovery, and manageable workloads are critical protective elements, emphasising the relational and contextual nature of resilience within veterinary practice [33,38]. Understanding resilience in this broader sense underscores the need for systemic and organisational interventions, not only individual coping strategies, to support the health and sustainability of the veterinary workforce.

5. Building Resilience

Highlighting the importance of wider structures and drawing from (socio-)ecological ontologies of resilience, veterinary science increasingly articulates its role in global health through integrative approaches such as One Health.

The origins of the One Health framework lie in veterinarian science, stemming from Calvin Schwabe's [39] and other veterinarian's call for the unity of human and veterinary medicine (One Medicine). This call was later expanded, grounded in socio–ecological frameworks [40], into One Health systemic thinking. This framework has increasingly been treated a core resilience building approach by international animal health organisations [41,42]. That said, much of the One Health literature does not aim for nor explicitly employ the term resilience. Reflecting on this gap, Nitzan et al. [43] argue for more explicit incorporation of resilience into One Health governance.

Building resilience ontology to align more explicitly to One Health not only assimilates but better captures and values the 'public good' biosecurity properties of veterinary science as social practices that through their work maintain the health of animal and human health systems. For instance, veterinary services have increasingly taken on a distinctive role at the intersection of human, animal, and environmental health. The Lancet's One Health Commission and the World Organisation for Animal Health (WOAH) both highlight the central contribution of veterinarians to surveillance and response systems, biosecurity, zoonotic disease prevention, and antimicrobial stewardship [41,44,45].

Veterinary public health interventions also provide clear illustrations of how veterinary science contributes to broader socio ecological resilience. Longstanding rabies control programmes, including mass dog vaccination and integrated surveillance across human and animal health systems, have reduced human disease burden while strengthening health system stability [46]. Climate driven shifts in wildlife disease patterns further emphasise the need for ecological surveillance and veterinary engagement in preventative measures. Analysis shows also the accelerating impacts of rising temperatures and shifting vector ranges on wildlife health, underscoring the importance of incorporating ecological dynamics into veterinary resilience planning [47]

Veterinary science further contributes directly through the resilience of food systems. Research and education in herd health, biosecurity and antimicrobial stewardship are key to the stability of animal-based food production. In Denmark, for example, the Yellow Card scheme has produced sustained reductions in antimicrobial use in pig herds [48]. In addition, work on climate mitigation shows that improving animal health can reduce greenhouse gas emissions per unit of product, highlighting resilience pathways that benefit both environmental and production outcomes [49]. Further research on sustainable production methods distinctly influences modern intensification, species choice and management practices [50].

Empirical research from crisis settings further illustrates the role of veterinary services in nurturing capacities and properties that strengthen socio ecological resilience. Interviews with Ukrainian farmers and veterinarians during the recent conflict reveal how adaptive practices, contingency planning, and decentralised expertise were essential for maintaining food production amid supply chain disruptions and infrastructural instability [51]. At the household level, surveys show that pet owners regard veterinarians as trusted sources of disaster preparedness information, indicating that brief, structured conversations during routine clinical visits can significantly strengthen household resilience, particularly for animal owning families [52].

These examples reveal a reciprocal relationship between veterinary science and resilience at multiple scales. Veterinary services contribute to individual and community preparedness, yet their

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own institutional readiness remains uneven. WOAH notes that despite clear global interdependencies, veterinary participation in international crisis management remains limited and laboratory infrastructures in many regions are underfunded or understaffed [41]. At the same time, the environmental sustainability of veterinary practice itself requires closer attention. A systematic review highlights that the environmental footprint of veterinary practice remains largely unaddressed [53]. Addressing these deficits is integral to aligning professional practice with broader One Health socio-ecological system-wide resilience commitments.

6. Discussion

This paper has explored the many ways resilience intertwines with veterinary science across conceptual, practical, and ethical domains (Figure 1). The concept engages with widely differing aspects of veterinary science, and its normative appeal is easily appreciated. Animals must cope with disease and hardship, ideally with minimal compromise to welfare. Veterinary professionals must navigate the inherently stressful conditions of the field, and the broader health and food systems within which veterinary work is embedded must be able to absorb or adapt to disturbances without major disruption. Its conceptual breadth also allows it to function as a bridge across scientific, policy, and practice settings [54]. Yet this same flexibility introduces important challenges. Each ontology answers different questions about what should persist, who should adapt, and which outcomes should be valued [17,54,55]. Without careful attention to these differences, resilience can appear coherent while masking tensions across domains. This is particularly significant as resilience is frequently treated not only as an analytical concept but also as a normative goal.

Across the wider literature, resilience is routinely precented as a desired state and an inherently positive property [3,6,18]. However, a system can be resilient and remain undesirable. A classic ecological case is the persistence of a turbid lake, which despite being an unfavourable state for ecosystem functioning remains difficult to shift back to a clearer condition [17]. Similar dynamics can be observed in livestock production where animals bred for high resilience to maintain performance under stress may still experience compromised welfare [8].

Critical scholarship across disciplines has emphasised that resilience can operate as a political and ethical shortcut. Questions such as who determines what should be resilient, how resilience is achieved, what constitutes a desirable outcome, and who bears the costs of adaptation are central to understanding the consequences of resilience framings [9,11,18,55–57]. These critiques highlight that resilience is never value neutral.

In response to these concerns, scholars across literatures have called for the explicit incorporation of justice and equity into conceptualisations of resilience. In climate resilience research, the equitable resilience framework emerged to address the persistent inequalities produced by policy approaches that burden already vulnerable and marginalised communities with disproportionate adaptation responsibilities. Parallel critiques appear in disaster management studies. Doorn [59] argues that resilience indicators often fail to address distributive justice; he further argues for capability-based definitions of resilience that recognise nontangible harms and differences in recovery capacity [60]. In health services, Suslovic and Lett [56] point to the ways resilience discourse can reinforce white cis normative assumptions about whose suffering counts, while critiques in psychology and sociology similarly show how resilience framings may penalise those whose responses to adversity deviate from dominant expectations [11].

This critical stance is equally important for veterinary science. The way resilience is framed can shape what harms are normalised, who is expected to endure them, and which forms of suffering remain unseen. While veterinary scholarship has significantly engage with measuring resilience in animals, professionals, and systems [3,5,21,24]. It, however, has comparatively limited critical attention to the normative assumptions embedded in these approaches. Social changes within the profession, such as its ongoing feminisation [61] may lead to question of what is normalised within

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conceptualisations of resilience and whether these expectations reflect, reinforce or challenge existing inequities.

Veterinary science also interacts regularly with marginalised communities whose adaptive capacities are constrained, including low-income pet owners and rural smallholder farmers. Empirical evidence shows that such communities often rely heavily on veterinary services to maintain livelihoods yet face profound structural barriers in accessing care. These constraints shape their capacity to adapt and can place additional burdens on veterinary professionals when resilience is expected without addressing underlying inequities [62].

Veterinary professionals also act as advocates for animal health and welfare, placing them in a key position to interrogate normative framings of resilience in animals. As earlier sections discussed, dominant engineering-based approaches of animal resilience, prioritise productivity, yet maintaining production under stress does not necessarily reflect good health or welfare [8]. Recognising these tensions is essential if veterinary science is to engage critically and ethically with resilience as both a scientific and normative concept.

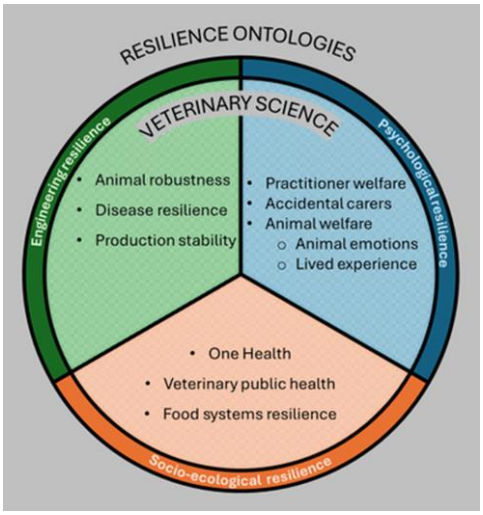

Figure 1. Conceptual map illustrating how veterinary science intersects with three major ontologies of resilience. Engineering resilience emphasises animal robustness, disease resilience and production stability; psychological resilience focuses on practitioner welfare, emotional labour, and animals' lived experiences; and socio ecological resilience encompasses One Health, veterinary public health and food systems resilience.

7. Conclusions

Resilience is woven through veterinary science in ways that are both intuitive and complex. Across engineering, ecological and psychological conceptualisations, it provides tools for understanding how animals, people and systems respond to disturbance. Yet, as this review aimed to highlight, each framing carries distinct assumptions, ontological commitments and ethical implications that shape how resilience is interpreted and enacted within veterinary contexts. This plurality is not a weakness, but it demands careful and critical engagement if resilience is to serve as more than a rhetorical placeholder.

For animals, resilience has been used to guide breeding priorities, welfare assessments and interpretations of animal responses to stress. When resilience is operationalised primarily as production stability, it risks narrowing welfare to performance metrics and treating adaptive behavioural or physiological changes as deficits. Broadening resilience to include thriving, affective experience and lived quality aligns more closely with welfare science, but it also highlights that resilient systems are not necessarily humane unless welfare is treated as a core function [3].

For veterinary professionals, similar cautions apply. Initiatives designed to strengthen practitioner resilience can offer valuable support, however, they also risk reframing structural

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problems as individual deficits if organisational and systemic determinants of distress remain unaddressed. The documented burden of psychological strain across the profession is exacerbated by workplace cultures that normalise overload as professional competence [15,26]. Effective approaches to resilience must therefore extend beyond individual coping strategies and include organisational reforms, professional culture change, and attention to the demographic and social diversity within the profession.

At the systems level, veterinary science plays a central role in supporting the resilience of food systems, public health infrastructures, and socio ecological networks. Veterinary engagement underpins disease surveillance, biosecurity, and One Health preparedness, and research shows how veterinary expertise strengthens community resilience both in stable contexts and in times of crisis [41,45,51]. Yet resilience strategies that fail to account for justice and equity can reproduce or intensify existing vulnerabilities, as demonstrated in climate adaptation and community health research [57,58]. These concerns are equally relevant in veterinary domains, particularly in under-resourced, rural and low-income communities.

Ultimately, resilience is not a neutral scientific descriptor nor an inherently positive policy objective. It is a framing that can illuminate vulnerability and motivate transformative change, or one that can obscure structural injustices by making endurance appear virtuous. Veterinary science must therefore approach resilience critically and reflexively. Asking who or what is expected to be resilient, to which disturbances, at what cost and under whose authority is essential if resilience is to support rather than undermine the ethical commitments of the field. Resilience should not be pursued blindly, but rather used judiciously to guide research, policy and practice towards healthier-happier animals, more equitable systems and more supported veterinary professionals, this requires veterinary science to more critically engage with how it shapes and is shaped by resilience thinking.

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