CAST® Issue Paper
Number 67
April 2020

Impact of Recruitment and Retention of Food Animal Veterinarians on the U.S. Food Supply

Food animal veterinarians are a necessary part of our food system. Many challenges and questions remain regarding getting students interested in food animal medicine, and keeping veterinarians in this specialty. (Graphic by Megan Wickham with illustrations from Vlad Klok/ Shutterstock and majivecka/Shutterstock.)

Abstract

Food animal veterinarians (FAV) in the United States safeguard livestock, poultry, and aquatic food animal health and welfare as well as food safety and quality along the entire "farm to fork" continuum. In doing so they help to ensure the financial sustainability of producers and global food security. Of particular importance is the role veterinarians play in preparation for and mitigation of emerging or transboundary (foreign animal) disease outbreaks which could have serious economic impacts on the entire U.S. economy as well as possible public health concerns regarding zoonosis and food security.

Changes in animal agriculture have influenced changes in food supply veterinary medicine (FSVM). FAV now focus on the population as whole as well as continuing to attend to individual animals. They are employed in both private and public practice and many private practice FAV live and work in rural communities. The issues surrounding recruitment and retention of FAV, particularly in rural areas, have been debated for decades. Several FSVM workforce studies have been conducted over the years with conflicting results. Lack of detailed FAV employment data and differences in methods of estimating demand have contributed to the difficulty in characterizing the current status and future needs of FSVM.

Food supply veterinary medicine (FSVM) has unique supply and demand challenges. Demand for FAV is driven by the private and public sectors. Consolidation and vertical integration of animal agriculture as well as fluctuations in farm profitability have impacted private sector demand. FAV have responded to these challenges by practice diversification (both in species attended to and/or services offered), expansion and in some cases downsizing. FAV are also taking advantage of the broad training they receive to fill non-traditional roles in animal agriculture.

CAST Issue Paper 67 Task Force Members

Authors

Dr. Christine Navarre, Chair, School of Animal Sciences, Louisiana State University Agricultural Center, Baton Rouge, LA

Dr. Angela Daniels, Texas Animal Health Commission, Austin, TX

Dr. Michael O. Johnston, Social and Behavioral Sciences Division, William Penn University, Oskaloosa, IA

Dr. Clay Mathis, King Ranch Institute for Ranch Management, Texas A&M University–Kingsville, Kingsville, TX

Dr. Tye Perrett, Feedlot Health Management Services, Okotoks, AB, Canada

Dr. Dan Posey, Texas A&M Veterinary Education, Research & Outreach, West Texas A&M University, Canyon, TX

Dr. Alejandro Ramirez, College of Veterinary Medicine, Iowa State University, Ames, IA

Dr. Anjel Stough-Hunter, Department of Sociology, Ohio Dominican University, Columbus, OH

Dr. Carie Telgen, Battenkill Veterinary Bovine, PC, Greenwich, NY

Dr. David Welch, American Association of Bovine Practitioners, Ashland, OH

Dr. Nicole Olynk Widmar, Department of Agricultural Economics, Purdue University, West Lafayette, IN

Contributor

Dr. Matthew Salois, American Veterinary Medical Association, Schaumburg, IL

Reviewers

Dr. Bruce Akey, Texas A&M Veterinary Medical Diagnostic Laboratory, College Station, TX

Dr. Corrie Brown, College of Veterinary Medicine, University of Georgia, Athens, GA

Dr. Ron DeHaven, Principal, DeHaven Veterinary Solutions, LLC, El Dorado Hills, CA

Dr. Gregory Parham, Assistant Secretary of Agriculture and Administrator, Animal and Plant Health Inspection Service (Retired), U. S. Department of Agriculture, Washington, D.C.

CAST Liaisons

Dr. Gabe Middleton, Orrville Veterinary Clinic, Orrville, OH

Dr. Jason Nickell, Merck Animal Health, De Soto, KS

Public sector demand is complicated by questions of societal perceptions of need balanced with government funding challenges. A rise in the popularity of non-commercial or "backyard" food animals puts further pressure on public health and brings a need for involvement of non-FAV in FSVM.

Supply of FAV is influenced by both recruitment and retention factors, many of which are overlapping. One of largest barriers to recruitment and retention of all veterinarians is student debt. The educational debt accumulated during veterinary school to starting salary ratio is above what is considered acceptable. Solutions to high student debt have largely focused on mitigating it after the fact via loan forgiveness programs, in particular for FAV entering underserved rural practice areas. The largest of these is the federal Veterinary Medical Loan Repayment Program (VMLRP). The long-term effectiveness of these types of programs in other professions is debatable. The short-term retention for the VMLRP is high but long-term retention not known.

Challenges of rural life such as lack of social and cultural opportunities, lack of access to jobs for spouses, and childcare are of particular concern for recruitment and retention of FAV in rural communities. This is compounded by rural practices' attributes such as long workdays and high on-call demands. The complex nature of these issues requires multifaceted solutions. Prior ties to the community are key factors in retention of physicians and physician's assistants to rural communities. Recruiting potential students from geographical areas of need could be a priority in efforts to facilitate students returning to their geographical regions of preference as FAV professionals.

Based on limited data, it appears that the demographics of FAV are different from veterinarians in general (older, male, less diversity of race and ethnicity). The reasons for this are not known but will be important to elucidate to help direct future recruitment and retentions efforts.

Certain practice attributes such as caseload, facilities, and practice atmosphere and availability of mentorship are particularly important to retention. Better utilization of veterinary technicians/nurses, telehealth, business and human resource skills can enhance both the financial and social qualities of a practice and improve recruitment and retention.

Recruitment and retention of public practice FAV is also important. Lack of awareness of how veterinarians contribute to public health is a deterrent to FAV entering these fields. Adequate funding to support the training and hiring of FAV in public health fields is also important.

Finally, robust training is needed for FAV to remain relevant to and meet the demands of animal agriculture. Training also fosters competence and employability, which are important to recruitment and retention.

Introduction

The predicted continued growth of the world population and subsequent global food insecurity is a looming threat to human health. Access to affordable and

safe animal source foods will play a role in mitigation of this problem (Henchion et al. 2017; Nelson et al. 2010). Food animal veterinarians (FAV) safeguard the health and welfare of livestock, poultry, and aquatic food animals and food safety and quality along the entire "farm to fork" continuum. In doing so they help to ensure the financial sustainability of producers and worldwide food security (Alders et al 2017; NRC 2013). FAV are trained in multispecies comparative medicine and as a result can provide a link between agriculture and human medicine and advance One Health initiatives.

Of particular importance is the role veterinarians play in preparation for and mitigation of disease outbreaks including emerging and transboundary (foreign animal) disease outbreaks. An outbreak of a highly contagious transboundary disease in the United States is expected to cause severe economic consequences. A 2015 study estimated that the total economic impact of an outbreak of the transboundary disease foot-and-mouth disease in the United States would range from $16 to $140 billion. Much of this is from direct impact to agricultural communities, food production, domestic demand, international trade, and tourism (Pendell et al. 2015). Indirect impacts for which the economic toll are difficult to measure include loss of consumer trust and confidence in the food supply, and perhaps even loss of faith in government agencies entrusted with food safety. Social and psychological impacts from livestock producers and veterinarians losing their livelihoods and dealing with mass euthanasia would also be expected (Govindaraj et al. 2017; O'Rourke 2003; Peck 2005; Pendell et al. 2015).

Animal agriculture is constantly changing. Consolidation and vertical integration, globalization of the food supply and food safety systems, technological advances, emerging disease and bioterrorism threats, environmental pressures, and consumerism have and will continue to reshape animal agriculture (Barrington and Allen 2010; Delgado et al. 2001; Hoblet, Maccabe, and Heider 2003; NRC 2013; Prince, Andrus, and Gwinner 2006).

The veterinary needs of animal agriculture have changed as the structure of animal agriculture has changed. Food supply veterinary medicine (FSVM) has evolved from an almost exclusive focus on individual animals as recently as the 1950s to modern practice which also focuses on the population as a whole (Barrington and Allen 2010). FAV currently serve animal agriculture via a variety of employment avenues in private and public practice (industry, government, and academia) (Table 1) (White et al. 2010).

The species of food animal as well as the segment of the industry that each FAV serves varies from a narrow focus (e.g., feedlot veterinarians) to any number of combinations. Poultry veterinarians work almost exclusively for companies that grow and market poultry, whereas beef, dairy, and small ruminant veterinarians work almost predominantly for private veterinary practices. Swine veterinarians work for a mixture of private practice and industry.

Many private practice FAV live and work in rural communities where food animals are raised. Veterinarians in rural practice may be exclusively full-time FAV, or mixed FAV and companion animal practitioners. The food animal portion of mixed animal practices are increasingly limited to cattle, especially the cow-calf segment of the beef industry (NRC 2013).

The veterinary profession has struggled with a central workforce related question—why is it difficult to recruit

Table 1. Food animal veterinarian practice types.

Type of Practice	Sub Types	Integrated Activities
Private Practice	▪ FSVM exclusive ▫ Aquaculture ▫ Beef ▫ Dairy ▫ Poultry ▫ Small Ruminant ▫ Swine ▪ Mixed species FSVM ▪ Mixed FSVM and companion animal	▪ Clinical diagnosis, treatment, and control of disease ▪ Herd investigation of disease and suboptimal animal performance ▪ Control and prevention of infectious and zoonotic diseases ▪ Animal identification, records, and records analysis ▪ Integration of animal handling, nutrition, genetics, housing, and environmental factors into animal health programs ▪ Producer education ▪ On farm food safety and animal welfare programs and audits ▪ Food safety ▪ Foreign animal disease preparedness and response ▪ Education, Research, Extension ▪ Epidemiology and disease ecology especially in population medicine ▪ Policy and regulation formulation and implementation
Industry	▪ Pharmaceutical ▪ Nutrition ▪ Diagnostic testing	
Government	▪ USDA ▪ State Animal Health Agencies ▪ FDA ▪ CDC ▪ Homeland Security ▪ Diagnostic Laboratories	
Academia	▪ Education ▪ Research ▪ Extension	

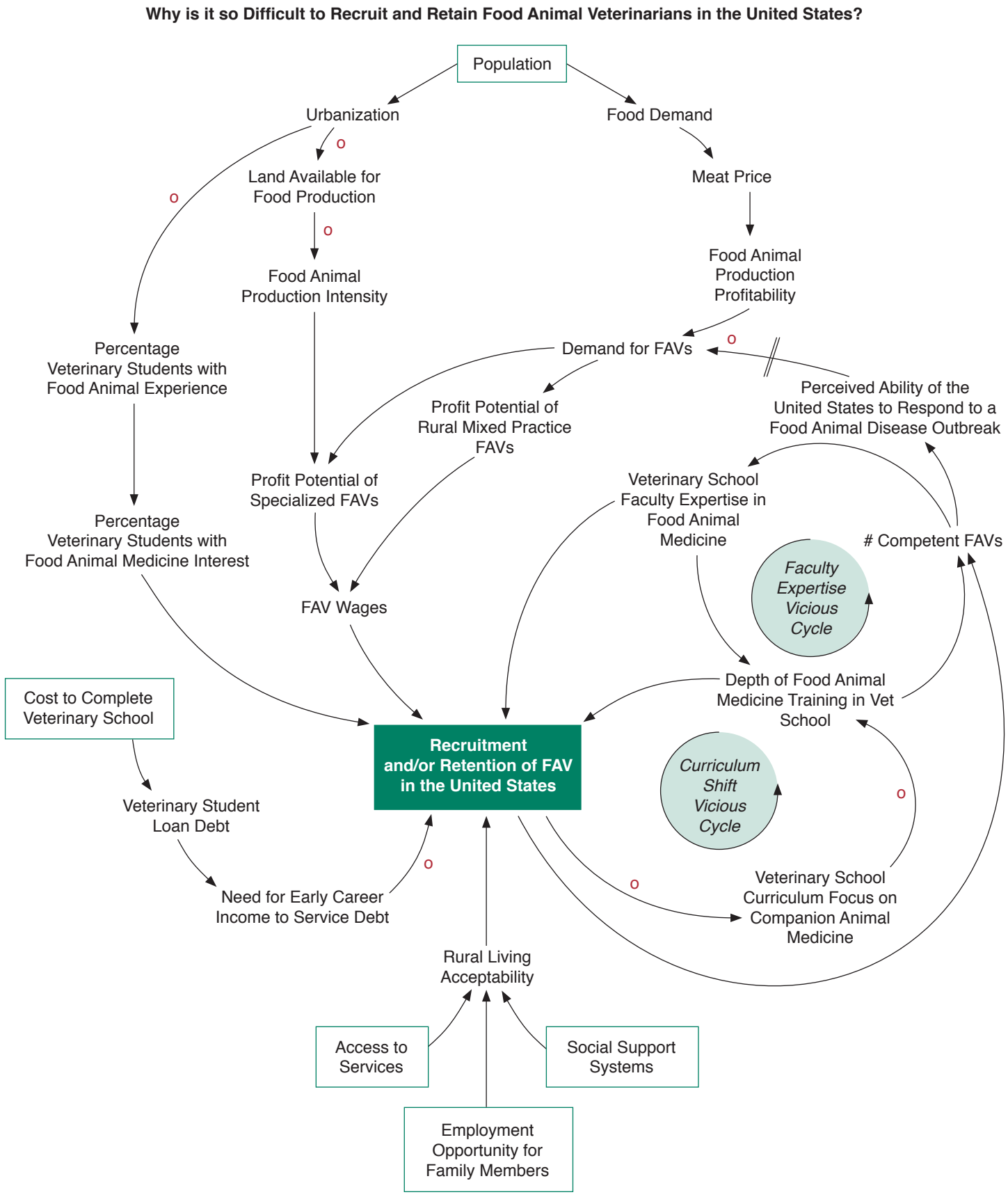

Figure 1. Causal Loop Diagram of factors influencing the recruitment and retention of food animal veterinarians (FAV) in the U.S. (O = opposite relationship; i.e., an increase in one variable causes a decrease in the subsequent variable).

and retain FAV in the United States? This issue paper will address the many factors which impact recruitment and retention of FAV. The interactive relationship of these factors is summarized in a causal loop diagram (Figure 1).

Underlying factors impacting recruitment and retention of FAV include food demand and food animal production intensity, both of which are driven, in part, by population growth. Population growth is paralleled by urbanization, which reduces land available for food production and necessitates an increase in production intensity to feed a growing global population. These changes influence demand for and wages of FAV as well as the specialization and training needs of FAV (Dicks et al. 2016). If FAV wages increase, the ability to recruit and retain FAV in the United States could be positively impacted. On the other hand, with increasing production intensity, the percentage of veterinary students with food animal experience and interest could decline, impacting supply of FAV. Shifting focus of veterinary school curriculums away from FSVM does not allow for recruitment and creates a void in training of FAV. This lack of training not only impacts the ability of FAV to serve private practice and public health needs, but impacts training of future FAV faculty, creating a vicious cycle that further erodes FSVM curriculums.

The availability of FAV in *rural* areas has been a particular point of discussion which extends to livestock producers, rural communities, and veterinary colleges, even reaching national news media and warning of risks to livestock and the food supply (Honig 2018). So widely recognized are the economic, social, community, and health/safety risks of a lack of FAV that public funding and grants have evolved to attempt to mitigate these risks by incentivizing practitioners into rural areas (Carrozza 2018).

Often discussed from a *supply* perspective are the drivers of why, or why not, individuals may choose to practice veterinary medicine in rural areas of the country. Multiple social and economic factors can be identified in driving the recruitment and retention of rural veterinarians (both FAV and companion animal), including comparative wage rates, lifestyle preferences, social and community support systems, access to services (e.g., childcare, schooling, and employment opportunities for spouses), and veterinary practice infrastructure.

Demand for veterinary services in rural areas is much less often discussed but cannot be ignored. The demand influences on FSVM are numerous and interrelated, and many are out of the control of the livestock industry and veterinarians (e.g., consolidation and vertical integration of animal agriculture) (U.S. Dairy Export Council 2019; U.S. Meat Export Federation 2019). The rural nature of many of the FAV practices is a disincentive for veterinarians that seek greater access to services, employment opportunities for family members, and a more robust social support system than many smaller communities can provide. Salaries for rural mixed practices are generally lower than for specialized, exclusive FAV, and companion animal veterinarians and when added to a very high student debt load poses further challenges for rural mixed FAV (AVMA 2019a).

FAV Workforce Studies

In an economics framework both the supply and demand for FAV are important to the functionality of the FSVM marketplace. However, quantifying the supply and demand in order to predict future needs of the profession so that resources can be properly allocated has proven challenging. Previous FAV workforce studies have shown conflicting results. (Brown and Silverman 1999; Dicks 2013; Little 1978; NRC 2013; PNVEP 1988; Prince, Andrus and Gwinner 2006; Tack et al. 2018; Wise and Kushman 1985). For example, a study from 1999 predicted an increase in supply and decrease in demand while a study a few years later in 2006 predicted the opposite (Brown and Silverman 1999; Prince, Andrus, and Gwinner 2006). Changes in supply and demand could have occurred in this time period but different methodology and beginning assumptions may also account for some of the discrepancies (Loyd and Smith 2000). Supply and demand studies that focus on low market salaries and the need for tuition subsidies and public funding may perceive a surplus of FAV while studies that focus on unmet societal needs may see a deficit of FAV. (Wang, Hennessy, and O'Connor 2010).

Accurate employment data are needed to project supply. The American Veterinary Medical Association (AVMA) membership database is often used to quantify the supply of FAV in the United States. This database is quite robust in that it represents 82% of the veterinarians in the United States and has more descriptive data on employment type than other sources of profession-wide statistics. (AVMA 2019b, c). However, 20% of veterinarians do not declare their practice type and, for those that do, the self-declaration may be years old and no longer accurate. Also, some practice type categories, especially public practice can include both FAV and non-FAV. Data from organizations specifically representing FAV or public practice veterinarians would be helpful but are not readily available.

On the demand side, the United States Department of Agriculture (USDA) census of county livestock numbers are often used. One assumption made when applying these data is that larger livestock densities equate to the need for more veterinary services. But identifying the true "demand" for veterinary services is complicated. Is demand driven by the total number of head, number of farms without adjustment for farm size, or adjusted for management intensity and/or total animal units?

Two studies have attempted to compare databases and methods used to predict FAV workforce needs. Wang and colleagues (2012) found that the two methods they compared were in agreement and counties with fewer FAV, more livestock, further from a veterinary college and more rural (defined by a rurality index) were designated shortage areas. In contrast, Tack and colleagues (2018) compared three different methods to identify FAV shortage areas. In total, 728 counties were identified as shortage areas among the three methods. However, only 47 counties were identified by at least two methods and only one county was identified by all three methods as having a shortage area.

FAV workforce studies are also fraught with confusing terminology. The definition of a FAV is not consistent and may account for conflicting results (Villereal et al. 2010). The terms "food animal veterinarian," "food supply veterinarian," "large animal veterinarian," and "rural veterinarian" are often used interchangeably but have different meanings to different people and groups. FAV employed in public practice are often neglected in these studies and while their numbers are comparatively small, they have very important roles in FSVM (AVMA 2019b, c).

Another term used frequently in FAV workforce discussions that has different meanings for different stakeholders is "shortage." The term "shortage" is often equated with "lack of supply of veterinarians" implying that training more FAV will fix the problem. There may be a lack of veterinarians working in food production—especially in rural areas—but if there is insufficient demand to make veterinary practices in these areas financially sustainable or the rural community is not attractive to veterinarians, then these areas will have difficulty recruiting and retaining FAV. As noted by the National Academy of Sciences report in 2013: "Regions that formerly supported a veterinarian can no longer do so. This is not a sign of a shortfall in the supply of veterinarians but rather of a shortfall in employment opportunities (AVMA 2013). What are frequently termed "shortage" areas in rural communities—implying a lack of available veterinarians to fill the jobs—are really underserved areas" (NRC 2013).

This brief history of FAV workforce studies points out the need for development of more objective measures of demand for FAV and early warning indicators of imbalances between supply and demand (AVMA 2013). This will provide guidance on how to address the needs to better use resources, and avoid training too few or too many FAV for the demand.

Drivers of Demand

Private Practice

The majority of FAV are in private practice (AVMA 2019b, c). True demand for FAV in the private sector is less often discussed than supply issues. Fluctuations in farm profitability, and in particular prolonged periods of financial stress, create unstable demand for veterinary services. Arguably, fluctuations in demand for veterinary (or other) medical services exist in all marketplaces/geographies. However, in rural areas where demand is dependent on a few large producers and/or originates largely from farming one species, (e.g., pork producers in Iowa or dairy producers in Wisconsin) the financial stresses are even more acutely felt by their service providers, including veterinarians.

U.S. livestock markets remain cyclical and volatile, impacted by feed prices, labor/wage rates, land prices, capital markets, export markets, and various other business factors. (U.S. Meat Export Federation 2019; U.S. Dairy Export Council 2019). Recent disruptions to key markets due to ongoing trade wars and disruptions to trading have introduced further uncertainty (USDA 2019).

The concentration of livestock production in specific regions, coupled with financial challenges, introduce the potential that input suppliers—including veterinarians—face uncertainties in demands for their services. While concentration of livestock operations yield changes in market structure and the demand for veterinary services (i.e., larger farms having on-staff veterinarians), financial stress of an entire production system offers the potential to shift the demand curve for veterinary services entirely if farms exit a geography. The dairy industry, for example, has faced recent extended periods of financial stress, marked by tightening margins with farms facing shortfalls in cash flow to meet financial obligations. This has resulted in many dairy farms going out of business and poses future sustainability problems for supporting businesses including veterinary practices (Program on Dairy Markets and Policy 2019; Wokatsch 2018). FAV participating in the American Association of Bovine Practitioners (AABP) veterinary practice analysis workshops in the spring of 2019 reported that the recent downturn in the dairy industry has affected their practices. Practices are responding by increasing allocation of resources for companion animal services, the addition of new services (including consultation) related to the dairy industry, and in a few cases the reduction in staff size (Welch, D. 2019. Personal communication).

In the long run, all inputs are variable. In the short run, fixed costs must be considered, and in particular for early career veterinarians, the added uncertainty about demand for services may add to the challenges of building practices and careers in rural areas—and dependent on increasingly volatile livestock markets. In this uncertain climate, FAV must continue to remain relevant or risk losing their presence in animal agriculture (Chenowith 1996; Getz 2012; NRC 2013; Prince, Andrus, and Gwinner 2006).

> *"Opportunities for FAV to remain relevant do exist, even in highly vertically integrated segments of animal agriculture such as the poultry industry. Poultry companies for example must manage complex and interrelated issues such as food safety and quality, animal welfare, and compliance with environmental and trade regulations. The broad training of veterinarians makes them uniquely qualified to address these issues, which opens up non-traditional job opportunities."*
> (Glisson and Hofacre 2006)

Public Practice

There is an unquestionable need for FAV in public practice, particularly government practice, for disease surveillance, food safety, etc. (NRC 2013; Prince, Andrus and Gwinner 2006). From a demand perspective, there may be a need for public practice FAV, but the impetus and funds to increase FAV capacity may be lacking. A common thread in veterinary workforce studies discussed previously is the balance between market pressures—what consumers of veterinary services are willing to pay and societal needs—what is typically paid by government (Dicks 2013; JCVE 1964; Little 1978; NRC 1982; Wise and Kushman 1985). Dicks (2013) explains:

> *"The literature clearly defines the need for an expanded role for veterinarians in the areas of public health and related sectors but offers no measure of the willingness to pay for the needed services by specific public or private entities."*

The value of FAV to the private animal agriculture sectors and society are different but overlapping. What a farmer is willing to pay for (driven by farm economics) and what is socially optimal (e.g., transboundary disease detection) are not necessarily the same.

The number of public practice veterinarians as a whole appears to be stable or increasing, but the trends in specific subcategories (industry, academia, government) are different. Uniformed services make up the majority of new veterinarians entering public practice but their numbers have declined over the past decade (AVMA 2019c).

There are other non-traditional, public health roles arising that need to be filled by veterinarians. The number of non-commercial or "backyard" food animals, especially poultry, is increasing in urban and peri-urban areas. This poses zoonotic disease and food safety risks to people and animal disease risks to commercial livestock and poultry industries. The majority of urban and peri-urban veterinarians are likely focused on companion animals and may be unfamiliar with the medical and welfare needs of food animals as well as regulations and legalities associated with treating animals designated by the Food and Drug Administration as food producing animals. They may also not operate optimally as the first line of defense for recognizing transboundary disease in "backyard" food animals that are a risk to commercial animal agriculture (Pires et al. 2019; Wang, Hennessy, and O'Conner 2010).

Drivers of Supply

Assuming that sufficient demand for FAV exists, several questions about an ample, well-trained labor supply arise. If veterinarians do not enter and remain in FSVM jobs, then government, non-governmental organizations, industry, and agribusiness will employ non-veterinarians to fill their needs (Hoblet, Maccabe, and Heider 2003). Multiple social and economic factors can be identified as impacting the supply of FAV. Characterizing these factors is confounded by the diverse nature of FAV as described in the introduction. According to Walker (2009), this "identity crisis" dilutes and complicates attempts to characterize the problems and fill voids. Veterinary colleges, for example, are trying to recruit and train students to fill a need that is not clearly defined. Most of the discussion of the supply of FAV surrounds recruitment and retention of FAV to rural communities.

Recruitment and Retention

An adequate supply of FAV starts with getting students interested in FSVM (either before or after acceptance into veterinary college), getting them adequately trained and employed in FSVM jobs, and finally, keeping them in those FSVM jobs. Many of the recruitment factors such as student debt, rural living, gender, and generation influences are also retention factors that lead to career or job switching by FAV. There are others, specifically certain practice attributes (application of business and human resource best practices), which are especially important to retention.

Nationally, career switching (starting out with one interest and switching to another) during veterinary school is low but when it happens, either towards or away from FSVM, it is due to exposure to new fields in veterinary school coursework (Andrus, Gwinner and Prince 2006; Saltman et al. 2004). Having strong FSVM curriculum and strong FAV faculty and practitioner role models to attract new students to FSVM and retain those already interested in FSVM might be effective.

The magnitude of career switching in FAV after graduation is debatable. Some reports indicate that fewer than 30% of those who entered FSVM at graduation remained in FSVM practice by five years' post-graduation; (Lissmore and Stowe 1989; Osborne 2003; Radostits 2004; Schmitz et al. 2007). More recently however, Andrus, Gwinner, and Prince (2006) reported that career switching was uncommon in both early and late career FAV and report high career satisfaction compared to other areas of the profession. The minority that did switch had lower job satisfaction and switched because they wanted more life-work balance and more social activities.

Student Debt

High student debt is arguably the biggest issue facing the veterinary profession. When asked about issues important to the veterinary profession, veterinary students as a whole—and FAV interested students in particular—ranked debt highest (Prince, Andrus, and Gwinner 2006; Volk et al. 2018). In the 2018 Merck Animal Health Wellbeing Study, student debt was strongly associated with lower levels of wellbeing. Wellbeing decreased as student debt increased and there was a significant difference in wellbeing in respondents with and without student debt (Volk et al. 2018).

Colleges of veterinary medicine have shifted from majority state funded to funding by tuition and competitive grants (Getz 2012; NRC 2013). Student debt load has increased dramatically in recent years while starting salaries have failed to keep pace. The educational debt accumulated during veterinary school to starting salary ratio (debt to income ratio or DIR) for the class of 2018 was 2.3:1 (AVMA 2019a). This is up from 1.8:1 in 2004 and above what is considered the upper acceptable boundary of 1.4:1 (AAVMC 2018; Larkin 2018; Shepard 2004, 2005, 2008; Veterinary Business Advisors, Inc. 2017).

While the average DIR is admittedly high, and has grown over time, the precise DIR from any given subset (e.g., FAV) varies widely depending on both the debt incurred and postgraduate career plans. FAV taking jobs in food animal exclusive practices generally have lower debt and higher salaries, and thus lower DIR, than mixed or companion animal veterinarians. Veterinarians employed in all public practice types combined had the lowest debt but there is quite a range depending on specific type of public employment (e.g., industry versus government) (AAVMC 2019b; AVMA 2019a; Dicks et al. 2016). The reason for the significant difference in the debt load and DIR of new graduates based on post-graduation plans is unknown and while investigating debt load and practice type seems a natural way to study student debt across professional focus areas, the lack of causation and simple associative nature of the comparison should be noted. It is hard to quantify if whether income is because of a chosen career path or if a career path is chosen based on poten-

tial income and a student's debt load. Nonetheless, significant heterogeneity in DIR is seen across veterinarians which contributes to difficulty in incentivizing individuals to pursue specific veterinary career opportunities (AAVMC 2019b; AVMA 2019a).

A recent trend in student debt data is that the percentage of veterinary students graduating with zero debt is increasing (AAVMC 2018). One hypothesis as to the cause of this trend is that more students of means are applying and being accepted into veterinary school. The impact this may have on the diversity of the profession as a whole or to FAV recruitment and retention is unknown.

Solutions to high veterinary student debt have focused on mitigating the problem after the fact. Public funding, scholarships, and grants have evolved to incentivize FAV to practice in rural areas. The Veterinary Medical Loan Repayment Program (VLRMP) is the longest standing loan repayment program for FAV (USDA 2019b). The VMLRP was established by the National Veterinary Medical Services Act in 2003 and distribution of awards was started in 2010. Veterinarians selected for the program practice for three years in a designated underserved area in exchange for $25,000 in loan repayment for each year of service. In 2018, the VMLRP awarded $7.1 million in loan assistance to 74 food animal and public practice veterinarians. In order to expand the program's reach without the need of additional funding, the VMLRP Enhancement Act has been introduced to both the U.S. Senate and House of Representatives. This bill would lift a 39% income withholding tax that the USDA pays on the program's awards. (U. S. Congress 2017, 2019).

Other federal programs not necessarily specific to FAV include the Public Service Loan Forgiveness Program, Army Active Duty Health Professions Loan Repayment Program, Army Specialty Pay, Armed Forces F. Edward Hebert Armed Forces Health Professionals Scholarship Program, and the Federal Faculty Loan Repayment Program. In addition to these programs, as of 2017, there were 19 states with some type of loan forgiveness programs, many targeting FAV (AVMAc).

The private sector is also developing debt relief programs. Banfield Pet Hospital, which has more than 900 veterinary practices in the United States, has started the Veterinary Student Debt Relief Pilot Program for their employees. It includes a monthly contribution of $150 paid by Banfield directly on qualifying student loans, a low-interest refinancing option from a third-party financial institution, and a $2,500 payment for each qualifying Banfield student program the doctor participates in before graduating—up to $10,000 (Banfield Pet Hospital 2019). Banfield practices are exclusively small animal, but similar programs may work for food animal practices.

Veterinary organizations also have debt mitigation efforts. The Veterinary Debt Initiative is a partnership between American Association of Veterinary Medical Colleges, American Veterinary Medical Association, and Veterinary Medical Association Executives to raise awareness and provide access to resources that will enable pre-veterinary students, veterinary students, and veterinarians to make highly informed financial decisions (AAMC 2019). The AVMA has several financial management tools for students and graduates at: https://www.avma.org/About/SAVMA/StudentFinancialResources/Pages/default.aspx.

The obvious "elephant in the room" is how to decrease the actual student debt load. Several looming questions related to student debt load ask how the debt load will impact number of applications, if veterinary schools will go out of business, or how to solve the problems of rising tuition costs. High student debt has implications for recruitment but it may or may not be a factor in long term retention. An Australian study (Buykx et al. 2010) of retention efforts for healthcare workers in rural areas showed that the most commonly implemented retention strategy was financial incentives. However, they also stated that there was very little long-term effectiveness of any retention strategy implemented, including financial incentives. In contrast, a survey of VMLRP awardees 3 years' post-contract indicated that 76% of respondents were still practicing in the same location and seeing the same species as they did under VMLRP (VMLRP Program Office, 2019. Personal communication). It's unknown how this retention rate compares to new graduates in rural FAV underserved areas not supported by the VMLRP.

Rural Life

The challenges of a rural life have been implicated as an issue in recruitment and retention of FAV to rural practices. Many students interested in FSVM come from rural communities and have experience in animal agriculture and these students are thought to be an important pool of future FAV (Lenarduzzi, Sheppard, and Slater 2009; Prince, Andrus, and Gwinner 2006; Schmitz et al. 2007). It's hypothesized that the number of students interested in FSVM is diminishing over time but data to support strong trends are lacking and even contradictory. Recent data show that 1 in 5 U.S. veterinary students comes from a rural community and many of these are interested in FSVM, so a diminished student pool may not be an issue (AAVMC Annual Report 2019).

Olfert and colleagues (2012) showed that the attractiveness of a rural community was more about human population size and dynamics than livestock concentrations. Lack of social and cultural opportunities, support systems, suitable career opportunities for spouses, access to services such as childcare and schools, veterinary practice infrastructure, combined with high student debts and low starting salaries are also implicated in discouraging new graduates from entering rural practice (Brown and Silverman 1999; Prince, Andrus and Gwinner 2006; Wang, Hennessy, and O'Conner 2010). Consolidation of animal agriculture may make FAV gravitate towards more consulting roles providing some flexibility in where FAV actually reside.

Some of the above recruitment issues are also retention issues. Stress from long workdays, on-call hours and lack of time off are consistently highly ranked as reasons why veterinarians leave rural practice. Other reasons are family concerns, lack of mentorship, opportunities for higher salary and benefits, and lack of continuing education opportunities (Andrus, Gwinner, and Prince 2006; Schmitz et al. 2007).

Other medical professions face similar

problems with recruitment and retention in rural communities. Besides those listed above, factors such as professional isolation, gaining acceptance and trust within communities, and a lack of medical equipment make working in rural communities uniquely challenging for healthcare providers (Henry, Hooker, and Yates 2011; Hooker, Cawly, and Everett 2017; Humphreys et al. 2002; Larson et al. 2016).

Humphreys and colleagues (2002) suggested that no single incentive will improve retention of rural healthcare workers and that a multi-faceted approach is required—maintaining adequate and stable staffing; adequate infrastructure; realistic and competitive compensation; recognizing and rewarding individuals making significant contributions to the practice; and ensuring social, family and community support. It would be reasonable to assume that a similar multi-faceted approach would be applicable to rural FAV.

Research on recruitment and retention of physicians and physician's assistants to rural areas consistently finds that the rural background of individuals is important for residential intentions and remaining in a rural community. Community attachment, place identity, and proximity to family were key factors that predicted which students were likely to return to and stay in a rural community (Brooks et al. 2002; Demi, McLaughlin and Snyder 2009; Eacott and Sonn 2006; Foster and Main 2018; Frieze, Hansen and Boneva 2006; Jones, Bushnell, and Humphreys 2014; Larson et al. 2018; Morse and Mudgett 2018; Petrin et al. 2014; Rabinowitz and Paynter 2000; Walker et al. 2012; Ulrich-Schad, Henley, and Safford 2013). These studies point out that rural "returners" are a substantial proportion of the people that migrate to rural areas. In Canada, return migration accounts for 31% of the immigration to rural communities (Niedomysl and Amcoff 2011). Moreover, return migrants have been characterized as the "best and brightest," bringing higher qualifications and higher incomes (Foster and Main 2018; Petrin, Schafft, and Meece 2014; Stockdale 2004). Based on this work looking at physician and physician assistants, a mitigating first step for the veterinary profession may be to take advantage of community ties and concentrate recruitment efforts towards potential veterinarians from a particular rural area in need (Brooks et al. 2002; Demi, McLaughlin and Snyder 2009; Eacott and Sonn 2006; Foster and Main 2018; Frieze, Hanson, and Boneva 2006; Jones, Bushnell, and Humphreys 2014; Larson et al. 2016; Morse and Mudgett 2018; Petrin et al. 2014; Rabinowitz and Paynter 2000; Ulrich-Schad, Henley, and Safford 2013; Walker et al. 2012).

Solving issues of long work hours and emergency duty are also key. Practices can educate producers to do routine procedures and employ technicians to assist and improve after-hours working conditions. Cooperation between and consolidation/regionalization of practices to cut down on hours worked and share after-hours duties between more people is another solution (Humphreys et al. 2002). The tradeoff is that clients and veterinarians may have to travel longer distances, which may yield additional challenges associated with travel costs, added working hours due to lengthened commutes, and potential challenges of access to timely care.

Childcare is a particular concern of young veterinarians. Practices can consider contracting with local daycare centers to extend hours to meet needs. One group of practitioners in Texas hired their own daycare provider and help each other out in times of need (Fears 2018).

One factor that may attract veterinarians to rural areas is the lower cost of living. While salaries may be lower for practices in rural areas compared to non-rural areas, the lower cost of living of rural areas will allow for more buying power (AVMA 2019a).

A case can be made for cooperation between veterinarians and physicians especially in "hard to reach populations" to improve recruitment and retention. Examples include vaccination clinics for both animals and humans in rural areas or sharing equipment (Schelling et al. 2005). The idea could be extended, especially in the context of high-income counties, by considering ways that physicians and veterinarians can support each other personally and professionally through shared conferences, networking, and intentional communications between the professions (Zinnstag et al. 2005).

FAV Demographics

Good data are lacking but from what is available, it appears that the demographics of FAV may be different from the general population of veterinarians in the United States. Bovine veterinarians specifically are older, male, and have less diversity of race and ethnicity than the general veterinary population in the United States (Dicks et al. 2016). A better understanding of the reasons for these differences may foster recruitment and retention efforts for FAV.

The current generation of students has a strong push for 40-hour workweeks and flexible work hours to allow for work-life balance. This is true for students interested in both mixed and food animal veterinary medicine. Rural practices often have smaller staff, fewer veterinarians to share on-call duties, and do not often have emergency clinics for large animals nearby to refer current and after-hour cases. This makes recruitment, and retention, of young veterinarians difficult (AVMA 2019).

Exaggerated generational differences in practices may lead to conflict between employers and new graduates. Unarticulated assumptions and unconscious criteria may lead employers to try to fit employees into a preconceived "good employee" ideal (Zemke, Raines, and Filixzak 2000). For example, the older practitioner who is used to working 80 or more hours per week may think the young associate who only wants to work 40 hours per week is lacking work ethic. Older generation employers in rural practices must be aware of the generation gap that exists as they hire and try to retain new veterinarians. Different generations have different values and therefore define success differently.

Training employers to understand the attributes of particular generations and how to manage the generational differences may help (Zemke, Raines, and Filixzak 2000). Employers can recognize that the new veterinarian brings an array of new ideas, technologies, and skill sets that can contribute to the success of individuals and to the practice. Zeeshan and Iram (2012) describe this as "reverse

mentoring" and point out the mutual benefits of loyalty and trust.

Gender may also play a role in recruitment and retention of FAV. Women make up half of all veterinarians, but less than one third of FAV (Dicks et al. 2016; Schmitz. et. al. 2007). About 30% of all bovine veterinarians are female but there is a shift as 60% of bovine practitioners less than 35 years of age are now female. The reasons for this discrepancy are not known, nor is it known if this is true of other FAV subgroups (e.g., swine and poultry veterinarians) as gender of membership has not always been collected. Results from surveys indicate that men were more likely to come from smaller communities and had a more positive attitude towards rural life (Hashizume, Woloschuk and Hecker 2015; Lenarduzzzi, Sheppard and Slater 2009). Currently, approximately 80% of veterinary students are female (AAVMC 2019a) and this is unlikely to change since animal science programs, where a high percentage of veterinary students do their pre-veterinary education, are also approaching 80% female (Data USA 2019). Getting better data as to why these gender differences exist are necessary since the pool of future FAV is female.

There are also gender differences in salaries. Even after controlling for age, experience level, practice type, specialty, and hours worked, female veterinarians earn less than their male counterparts (AVMA 2019a; Cron 2000). Female students also graduate with more debt (AVMA 2019a). Employers that wish to recruit and retain new veterinarians in rural practice must be willing to provide market value compensation regardless of gender.

Female employees are more likely to cite more family time as being important than male counterparts (Schmitz et. al 2007). Practice owners located in rural areas should have policies in place to accommodate their employees' requests for family leave, including maternity leave and time off to take care of a newly adopted infant or ill family member. (Collings, Freeney, and van der Werff 2018).

A better understanding of the demographics of veterinarians who choose FSVM and those who don't may provide insight for recruitment and retention efforts. Generation, gender, race, ethnicity, and socioeconomic status likely all play roles in these choices but there is very little FAV specific data. Acquiring actual employment data as well as reasons behind the choices students make is the first step. Without this, recruitment and retention efforts may be misguided.

Practice Attributes

Certain practice attributes impact both recruitment and retention but are particularly important to retention. Practice atmosphere and location were ranked highest by new graduates looking for their first job, followed by caseload, concerns with time demands from being on-call, being able to make full use of their medical/surgical skills, mentorship, quality of facilities, and potential for practice ownership. Private practices need to be appealing, attractive, interesting, exciting, motivating, financially rewarding, and progressive to attract new veterinary graduates (Andrus, Gwinner, and Prince 2006; Elmore 2003, Radostits 2004; Saltman et al. 2004; Villarroel 2010).

Practices that create an environment where employed veterinarians feel appreciated, supported, and successful are likely to have higher retention rates. Such practices are operationally efficient and have practice owners that are business savvy, emotionally intelligent, and understand the importance of sound leadership. Ideally veterinary practices should have clear mission and vision statements which are known and embodied by practice staff. The way the practice operates, the systems, and procedures used should align with that mission and vision because it motivates behaviors toward common goals (Bart et al. 2001). The new veterinarian can then find ways to use their skills and capabilities to contribute and gain satisfaction in their personal and the practice's accomplishments.

Studies from the United States and Canada identified inadequate mentorship as a significant cause for veterinarians leaving rural practice (Andrus et al 2006; Jelinski 2009b; Lissemore and Stowe. 1989; Olfert et al. 2012). Establishing a clear plan for mentorship and following through on that plan provides an excellent return on investment through veterinary employee retention. Mentorship not only involves the transfer of technical knowledge and skills but a broader approach that involves the development of social skills and attributes. The technical component has been described as "competency", but a broader term "employability" is defined as "having a set of skills, knowledge, understanding and personal attributes that make a person more likely to choose and secure occupations in which they can be satisfied and successful." Bell, Cake, and Mansfield (2018) recommend veterinary educators consider focusing on employability rather than just competency. Similar efforts by employers through mentoring could enhance employability and the chance that new employees maintain a satisfying and successful career (Kogan, McConnell, and Schoenfeld-Tacher 2004).

Offering high value service for client operations will provide an economic platform to improve incomes, which should contribute to resolving future labor supply problems before they arrive (Prince, Andrus, and Gwinner 2006). Practice models may need to shift from a fee for service/task orientation to a fee for advice/information where costs are spread over the entire herd as opposed to individual animals.

The increased use of veterinary technicians/nurses is linked to higher practice efficiency and revenue (Salois 2019). Rural veterinary practices have a lower DVM to non-DVM staff ratio than other types of practice (Larkin 2012). Better use of veterinary technicians/nurses in food animal practices offers several advantages. These include expansion of the geographical practice area allowing veterinarians to service more clients and be located in less rural areas along with expansion of total services offered by having veterinary technicians perform technical tasks, granting veterinarians more time to offer expanded services and develop new skills. These advantages and others have the potential to increase revenue streams to increase FAV compensation as well as increase professional satisfaction, both of which may assist with retention (Remsburg, Galligan, and Ferguson 2007). Many state laws currently dictate that technicians must work under the direct supervision of a veteri-

narian. These would need to be amended to allow for technicians to work under indirect supervision or remote supervision and to define the scope of what procedures and/or diagnoses are allowed. It's important to note that the same factors that impact recruitment and retention of FAV to rural practices (e.g., low salaries, student debt, long work hours, etc.) also impact recruitment and retention of veterinary technicians/nurses.

Telehealth, or using technology to deliver health information, education, or care remotely, also presents opportunities for expanded scope and reach of services for rural practices. Telehealth is being increasingly used in human medicine in rural areas (Rural Health Information Hub 2019). FAV are already routinely using digital photographs, real time video, electronic record keeping systems, and more to gather and share information with clients (Navarre, C. 2019. Personal communication). The AVMA is currently exploring ways to develop telehealth services that could expand these services further for FAV.

A significant contributor to the economic success of individual veterinarians and veterinary practices is effective use of business knowledge and skills (Cron 2000; Jackson and Houser 2016). Business skills are even more important to FAV as their recommendations have economic implications for their client's businesses (Kansas State University Research and Extension 2014).

Active development and enhancement of business knowledge and human resource skills among veterinary practice owners and managers are a key element for improving the retention of veterinarians in rural practice (Cron 2000; Dicks et al 2016). Cron (2000) identified three human resource related business practices that accounted for the largest difference between low and high-income practices and all three focused on employee job satisfaction and retention—active strategies to promote employee longevity, measuring employee satisfaction, and employee reward programs tied to client satisfaction or client loyalty.

Public Practice

Recruitment and retention of public practice FAV is equally as important as private practice FAV. Lack of awareness of how veterinarians contribute to public health and research by students, veterinarians, and the general public is a key barrier to recruitment and retention. Lack of training opportunities as well as the extra time and expense of acquiring post-DVM training are major barriers to recruitment (AVMA 2019a; Freeman 2005; Jarman, et. al., 2011). If there is a lack of a supply of public practice veterinarians, positions will be filled by non-DVMs which represents a significant loss of FSVM clinical and animal production as well as food safety expertise. Adequate funding to increase awareness of what public practice veterinarians do, increasing training opportunities, and addressing salary inequities is necessary to ensure that veterinarians continue to be involved in public practice (Freeman 2005).

Summary of Recruitment and Retention Solutions

Many FAV supply issues can be mitigated, although some are easier than others. Table 2 outlines strategies and tactics for recruitment and retention of FAV. The relative importance of these recommended solutions differs between studies (Lenarduzzi, Sheppard and Slater, 2009; Prince, Andrus, and Gwinner 2006; Villarroel 2010a; Villeroel 2010b) but each tactic can have some impact.

Training

To maintain the relevance of FAV to animal agriculture it is necessary to ensure that the workforce is trained to meet demands (Gilbert 2002; Radostits 2004). Training also affects recruitment and retention. Bell, Cake, and Mansfield (2018) contend that in veterinary medicine competence—gained through training—is an important component of employability and that "employability is a useful and important educational goal, since it encapsulates the vital objectives of professional success, satisfaction, and well-being."

The steady increase in companion animal education opportunities and erosion of food animal education in veterinary colleges leaves students interested in FSVM at risk of being inadequately trained (Barrington and Allen 2010; Elmore and White 2010; Walker 2009). It also plays a factor in attracting and maintaining students' interest in FSVM and rural life (Hashizume, Wololschuk, and Hecker 2015; Schmitz et al. 2007). Financial resources available to veterinary schools are limited and with shrinking budgets and pressure to curtail student debt, are unlikely to improve. Careful and informed decisions at several levels are needed to make sure opportunities to train FAV to benefit both society and the veterinary profession are not lost (Hoblet, Maccabe, and Heider 2003).

One of the strengths veterinarians bring to public health is their multispecies training and there is currently still a need for some rural FAV to be trained in "all creatures great and small" (Hoblet, Maccabe, and Heider 2003). The beef cow-calf industry as well as backyard and hobby food animal owners are most often serviced by rural FAV or mixed animal practitioners. However, omni-competence in veterinary medicine is becoming more difficult to attain both because of a lack of financial resources and the breadth of knowledge required. This poses a challenge for students without livestock experience to gain the necessary background knowledge of an industry while in veterinary school.

Limited resources and highly variable training needs for FAV often lead to the recommendation of "centers of excellence" or "centers of emphasis" at veterinary schools to avoid having many weak programs as each school tries to do everything (Chenowith 1996; Hoblet, Maccabe, and Heider 2003; NRC 2013; PNVEP 1988; Prince, Andrus and Gwinner 2006; Willis et al. 2007). In 2013, the National Research Council supported the concept of "centers of excellence/emphasis." Requirements for the success of this type of program are formidable and include funding, marketing, leadership, communication, coordination, integration, and dedicated people with the time to make it work. Integration of funding across universities is very difficult and likely the largest barrier to overcome to make these types of programs possible.

Table 2. Strategies and tactics to increase recruitment and retention of FAV.

Strategy	Tactics
Expose veterinary students to the benefits of careers in FSVM	▪ Paid summer externship opportunities ▪ Increased number of FAV faculty ▪ Increased numbers of courses on FSVM ▪ Regional centers of excellence including public practice agencies
Increased involvement of professional veterinary associations, industry, and government	▪ Scholarships ▪ Mentoring ▪ Externship opportunities ▪ Develop educational materials about FSVM that accurately reflect the duties and benefits of various careers in FSVM ▪ Communicate job opportunities to veterinary students ▪ Provide educational materials to help new graduates establish FSVM practices ▪ Provide financial assistance in the form of student loan debt relief ▪ Provide networking opportunities for new graduates with common interests
Veterinary students increase involvement	▪ Take advantage of externship opportunities, scholarships ▪ Attend national FSVM species association meetings to better connect with prospective employers and future colleagues
High school, pre-veterinary, and veterinary programs develop specific educational opportunities	▪ Provide early educational opportunities to increase exposure and interest ▪ Educate students on proper handling of large animals to overcome concerns about physical aspects of FSVM careers ▪ Target students from rural backgrounds with experience in food production ▪ Dedicated admissions programs for FSVM interested students ▪ Active recruitment of students from rural backgrounds ▪ Dedicated admissions programs for FSVM interested students and underrepresented students
Student debt reduction	▪ Scholarships ▪ Federal and state sponsored programs ▪ Financial literacy education ▪ Employer based programs ▪ Curtail the rise in tuition
Community involvement	▪ Identify potential FAV from a community and provide resources and support ▪ Foster connections between different medical professionals
Veterinary practice involvement	▪ Creative solutions to long hours, emergency duty ▪ Increase use of technology ▪ Develop sound business and human resource practices including mentorship and family leave policies

It will likely be the animal agriculture industries themselves that will take on specialized training. Glisson and Hofacre (2006) described the current educational environment for poultry medicine as one in which a small consolidated group of veterinary colleges have maintained robust poultry medicine programs and the commercial poultry industry has developed private and independent post-graduate, in-house training programs. Advanced training programs add to educational costs and efforts should be taken to minimize impacts to already burdensome debt loads on students.

However, there are successes. The Swine Medicine Education Center (SMEC) at Iowa State University is an example of a center of excellence focused on training swine veterinary students from all over the United States, Canada, and other countries. Since its inception in 2011, SMEC has trained veterinary students from 17 U. S. schools and 27 countries through both on-farm and distance learning modules. Recently, with the help of funding from the Bill and Melinda Gates Foundation, two U.S. and one New Zealand veterinary school have begun to collaborate on a project to develop and populate a digital platform with teaching resources for food animal faculty worldwide (Feedstuffs 2019).

Training veterinary technicians/nurses to have skills specific to food animal practices should also be considered. They are also becoming more specialized as there are currently 16 veterinary technician specialty groups but only two offer a sub-specialty in production animals: The Academy of Internal Medicine Veterinary Technicians—Production Animal Internal Medicine; and the Academy of Veterinary Technicians in Clinical Practice: Production Animal (NAVTA 2019).

Conclusion

The complex interaction of multiple factors (Figure 1) that impact recruitment and retention of FAV makes predicting the future of FSVM and enacting change very difficult. The issues are multifactorial and interrelated and will require multifaceted solutions. The challenge of consolidation and vertical integration of animal agriculture must be viewed as an opportunity. Use of technology, improving practice management skills, and focusing on emerging areas with high-demand needs will maintain demand (Prince, Andrus, and Gwinner 2006). Ensuring an adequate supply of FAV will require adequate recruitment, retention and training. Recruitment efforts should be aimed at increasing the likelihood of FAV interested students entering veterinary college and retention efforts should be aimed at providing ongoing support for both employers and employees to prevent FAV from switching careers. Successfully increasing the recruitment and retention of FAV in the United States will require training interventions that break the viscous cycles of curriculum shift and declining food animal expertise among veterinary school faculty.

Literature Cited

Alders, R. J. de Bruyn, K., Wingett, and J. Wong. 2017. One Health, veterinarians and the nexus between disease and food security. *Aust Vet J* 95 (12): 451–453.

American Veterinary Medical Association (AVMA). 2009. USDA awards $7M for loan repayment to address shortage areas. 16 Feb 2009. https://www.avma.org/News/JAVMANews/Pages/190201l.aspx.

American Veterinary Association (AVMA). 2013. 2013 U.S. Veterinary Workforce Study: Modeling Capacity Utilization. AVMA, Schaumburg, Illinois.

American Veterinary Medical Association (AVMA). 2018. 2018 Veterinary Economic Report. AVMA, Schaumburg, Illinois.

American Veterinary Medical Association (AVMA). 2019a. 2019 Economic State of the Veterinary Profession. AVMA, Schaumburg, Illinois.

American Veterinary Medical Association (AVMA). 2019b. Market Research Statistics: AVMA Membership 2018. https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-AVMA-membership.aspx.

American Veterinary Medical Association (AVMA). 2019c. Market Research Statistics: Market Research Statistics: U.S. Veterinarians 2018. https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-veterinarians.aspx.

American Veterinary Medical Association (AVMA). 2019d What is FSVM?. https://www.avma.org/resources-tools/food-supply-veterinary-medicine/what-is-fsvm.

American Veterinary Medical Association (AVMAa). Financing Your Veterinary Medical Education. https://www.avma.org/About/SAVMA/StudentFinancialResources/Pages/default.aspx.

American Veterinary Medical Association (AVMAb). Scholarship, Loan Repayment and Forgiveness for Veterinary Medical Student Loans https://www.avma.org/About/SAVMA/StudentFinancialResources/Pages/Scholarship-Loan-Repayment-and-Forgiveness-Programs.aspx.

American Veterinary Medical Association (AVMAc). State veterinary loan-repayment program summary. https://www.avma.org/Advocacy/StateAndLocal/Pages/State-veterinary-loan-repayment-programs.aspx.

Andrus, D.M, K. P Gwinner, and J. B. Prince. 2006. Job satisfaction, changes in occupational area, and commitment to a career in food supply veterinary medicine *J Vet Med Educ* 228 (12): 1884–93.

Association of American Veterinary Medical Colleges (AAVMC). 2018. Annual Report 2018. AAVMC, Washington, D. C. https://www.aavmc.org/publications/annual-report.

Association of American Veterinary Medical Colleges (AAVMC). 2019a. Veterinary Debt Initiative. https://www.aavmc.org/additional-pages/veterinary-debt-initiative.aspx (Accessed 4 June 2019)

Association of American Veterinary Medical Colleges (AAVMC). 2019b. Annual Data Report 2018-2019. Association of American Veterinary Medical Colleges, Washington, D.C. https://www.aavmc.org/assets/site_18/files/data/2019%20aavmc%20annual%20data%20report%20(id%20100175).pdf.

Bain, B., and M. Salois. 2019. Employment, starting salaries, and educational indebtedness of year-2018 graduates of US veterinary medical colleges. *J Am Vet Med Assoc* 254 (9): 1061–1066.

Banfield Pet Hospital. 2019. Banfield Veterinary Student Debt Relief Program. https://www.banfield.com/about-us/community/wellness-our-people/veterinary-student-debt-relief (Accessed 4 June 2019).

Barrington, G.M. and J. A. Allen. 2010. Food Animal Veterinarians: Where We Came from and Where We Might Go. *Online Journal of Rural Research and Policy* 5:1–6.

Bart, C. K, N. Bontis, and S. Tagger. 2001. A Model of the Impact of Mission Statements on Firm Performance, Management Decision. *Mange Decis*. 39:19–35. doi:10.1108/EUM0000000005404.

Bell M. A., M. A. Cake, and C. F. Mansfield CF. 2018. Beyond Competence: Why We Should Talk About the Employability in Veterinary Education. *J Vet Med Educ* 45(1): 27–37.

Blake, A., M. T. Sinclair and G. Sugiyarto. 2003. Quantifying the impact of foot and mouth disease on tourism and the UK economy. *Tourism Economics* 9 (4): 449–465.

Bradley J. White. B. J., A. Brusk, and D. Goehl. 2010. Professional Services Offered in Rural, Mixed-Animal Veterinary Practices. Online Journal of Rural Research and Policy. 5 (7): 1–8.

Brooks R. G., M. Walsh, R. E. Mardon, M. Lewis, and A. Clawson. 2002. The roles of nature and nurture in the recruitment and retention of primary care physicians in rural areas: a review of the literature. *Acad Med* 77 (8):790–8.

Brown J. P. and J. D. Silverman. 1999. The current and future market for veterinarians and veterinary medical services in the United States. *J Am Vet Med Assoc* 215 (2):161–183.

Buykx, P., J. Humphreys, J. Wakerman, and D. Pashen. 2010. Systematic review of effective retention incentives for health workers in rural and remote areas: Towards evidence-based policy. *Aust J Rural Health* 18:102–109.

Car, P. and M. J. Kefalis. 2009. Hollowing out the middle: The rural brain drain and what it means for America. Beacon Press, Boston, Massachusetts.

Carrozza, A. 2018. $2.4M in grants aim to address rural veterinarian shortage. *American Veterinarian*. https://www.americanveterinarian.com/news/24m-in-grants-aim-to-address-rural-veterinarian-shortage.

Chenowith, P.J. 1996. Food Animal Veterinary Education: Whither or Wither? *J Vet Med Educ* 23 (2): 34–38.

Chieffo, C., A. M. Kelly, and J. Ferguson. 2008. Trends in gender, employment, salary, and debt of graduates of US veterinary medical schools and colleges *J Am Vet Med Assoc* 233 (6): 910–917.

Collings, D., Y Freeney, and L. van der Werff. 2018. "How Companies Can Ensure Maternity Leave Doesn't Hurt Women's Careers." Harvard Business Review, September 11.

Committee on Veterinary Medical Sciences, Commission on Life Sciences, National Research Council. Specialized veterinary manpower needs through 1990. 1982. National Academy Press, Washington, D.C.

Cron, W. L. 2000. Executive summary of the Brakke management and behavior study *J Am Vet Med Assoc* 217 (3): 332–338.

Data USA. 2019.General Animal Sciences. https://datausa.io/profile/cip/010901/#enrolled_gender (Accessed 4 June 2019).

Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 2001. Livestock to 2020: The Next Food Revolution. *Outlook on Agriculture* 30 (1): 27–29. https://doi.org/10.5367/000000001101293427.

Demi, M. A., D. K. McLaughlin, and A. R. Snyder. 2009. Rural youth residential preferences: Understanding the youth development-community development nexus. *Community Development* 40 (4): 311–330.

Department of Agriculture, Fisheries and Forestry-Australia. 2003. Review of Rural Veterinary Services Report. Commonwealth of Australia. https://www.ava.com.au/siteassets/advocacy/veterinary-workforce/frawley-report.pdf.

Dicks, M. R. 2013. A short history of veterinary workforce analyses. *J Am Vet Med Assoc* 242 (8): 1051–1060 https://doi.org/10.2460/javma.242.8.1051.

Dicks, M. R., F. B. Ouedraogo, R. Knippenberg, and B. Dutton. 2016. American Association of Bovine Practitioners Economic Report. American Veterinary Association, Schaumburg, Illinois. https://www.avma.org/Practice-Management/BusinessIssues/Pages/State-and-Allied-Group-Reports.aspx.

Eacott, C. and C. C. Sonn. 2006. Beyond education and employment: Exploring youth experiences

of their communities, place attachment and reasons for migration. *Rural Society* 16 (2): 199–214.
Elmore, R. G. 2003. Recruitment and retention of veterinary student for food animal practices. *J Am Vet Med Assoc* 222 (12): 1697–1699.
Elmore, R.G. and B.J. White. 2010. Recruitment of Veterinarians for Rural Communities through Education: The Veterinary Training Program for Rural Kansas" *The Online Journal of Rural Research and Policy* 5 (7): 1–5.
Fears, R. 2018. The pink vets of Texas rewrite stereotypes. *Beef* https://www.beefmagazine.com/business/pink-vets-texas-rewrite-stereotypes. Accessed 29 May 2019.
Feedstuffs. 2019. Vet colleges partner to improve vet education, 3 July 2019. https://www.feedstuffs.com/news/vet-colleges-partner-improve-vet-education. (Accessed 23 July 2019.)
Freeman, L. C. 2005. Rx for Recruitment and Retention of Veterinarian Scientists: Money, Marketing, Mentoring. *J Vet Med Educ* 32(3): 328–336.
Foster, K., and H. Main. 2018. Finding a place in the world: understanding youth outmigration from shrinking rural communities. Dalhousie University, Halifax, Nova Scotia.
Frieze, I. H., S. B. Hansen, and B. Boneva. 2006. The migrant personality and college students' plans for geographic mobility. *J Environ Psychol* 26 (2): 170–177.
Getz, M. 2012. Education and earnings in the health professions. *J Vet Med Educ* 39:247–256.
Gilbert, R. O. 2002. Editorial: In-House Caseload and Education of Veterinary Students in Production Animal Medicine. *J Vet Intern Med* 16:5–6.
Glisson, J. R. and C. L. Hofacre. 2006. The Future of Veterinary Medicine in Poultry Production. *J Vet Med Educ* 33 (4): 492–495.
Govindaraj, G., B. Ganeshkumar, K. R. Nethrayini, R. Shalini, V. Balamurugan, B. Pattnaik, and H. Rahman .2017. Farm Community Impacts of Foot-and-Mouth Disease Outbreaks in Cattle and Buffaloes in Karnataka State, India. *Transbound Emerg Dis* 64: 849–60.
Hashizume, C. T., W. Woloschuk, K. G. Hecker. 2015. Changes in Veterinary Students' Attitudes Toward the Rural Environment and Rural Veterinary Practice: A Longitudinal Cohort Study. *J Vet Med Educ* 42 (2): 112–119, https://doi.org/10.3138/jvme.1014-101R.
Henchion, M., M. Hayes, A. M. Mullen, M. Fenelon, and B. Tiwari. 2017. Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods* 6 (7): 53 doi:10.3390/foods6070053.
Henry, L. R., R. S. Hooker, K. L. Yates. 2011. The role of physician assistants in rural health care: a systematic review of the literature. *The Journal of Rural Health* 27 (2): 220–9.
Hoblet K. H., A. T. Maccabe, and L. E. Heider. 2003. Veterinarians in population health and public practice: Meeting critical national needs. *J Vet Med Educ* 30:287–294.
Honig, E. 2018. Shortage Of Rural Veterinarians Puts Farmers, Food Supply At Risk. *Harvest Public Media*. https://www.npr.org/sections/thesalt/2018/06/16/620387349/shortage-of-rural-veterinarians-puts-farmers-food-supply-at-risk.
Hooker, R. S., J. F. Cawley, and C. M. Everett. 2017. Physician assistants: policy and practice (Fourth ed.). F.A. Davis Company, Philadelphia, Pennsylvania.
Humphreys, J. S., M. P. Jones, J. A. Jones, and P. R. Mara. 2002. Workforce Retention in Rural and Remote Australia: Determining the Factors That Influence Length of Practice. *Med J Aust* 176 (10): 472–6.
Jackson, E. L. and S. Hauser, 2016. The Evidence Base for Developing a Veterinary Business Management Curriculum. Veterinary Evidence 1 (2).
Jarman, D. W., J. L. Liang, R. R. Luce, J. G. Wright, G. M. Stennies, and K.M. Bisgard. 2011. Veterinary Public Health Capacity in the United States: Opportunities for Improvement. Public Health Rep 126 (6): 868–874.
Jelinski, M. D., J. R. Campbell, J. M. Naylor, K.L. Lawson, and D. Derkzen. 2009a. Demographic survey of veterinarians employed in western Canada. *Can Vet J* 50 (6): 621–629.
Jelinski, M. D., J. R. Campbell, J. M. Naylor, K.L. Lawson, and D. Derkzen. 2009b. Factors associated with career path choices of veterinarians in western Canada. *Can Vet J* 50 (6): 630–636.
Joint Committee on Veterinary Education (JCVE). 1964. *Manpower in veterinary medicine: a report on the status of veterinary manpower in the US*. American Veterinary Medical Association, Chicago Illinois.
Jones, M. P., J.A. Bushnell, and J. S. Humphreys. 2014. Are rural placements positively associated with rural intentions in medical graduates? *Med Educ* 48 (4): 405–416.
Kogan, L., S. L McConnell, and R. Schoenfeld-Tacher. 2004. Gender Differences and the Definition of Success: Male and Female Veterinary Students' Career and Work Performance Expectations. *J Vet Med Educ* 31 (2):154–60.
Larkin, M. 2012. "Where to draw the line Rural practitioners debate role of veterinary technicians." *JAVMAnews* 19 Sept. 2012 https://www.avma.org/javma-news/2012-10-01/where-draw-line.
Larkin, M. 2018. "Salaries, debt for new graduates continue to increase." *JAVMAnews* 28 Nov. 2018 https://www.avma.org/News/JAVMANews/Pages/181215f.aspx.
Larkin, M. 2019. "Efforts evolve on how to address educational debt." 27 Feb. 2019. *JAVMAnews* https://www.avma.org/News/JAVMANews/Pages/190315b.aspx.
Larson, E. H., C. H. A. Andrilla, C. Morrison, S. Ostergard, and A. Glicken. 2016. Which Physician Assistant Training Programs Produce Rural PAs? A National Study. Policy Brief #154. University of Washington WWAMI Rural Health Research Center, Seattle, Washington.
Lissemore, K. and J. Stowe. 1989. Farm practice in a cross-fire. *Can Vet J* 30:857–862.
Little, Authur D. 1978. Summary of US Veterinary Medical Manpower Needs-1978-1990. *J Vet Med Educ* 173(4): 369–72.
Lenarduzzi, R., G. A. Sheppard, and M. R. Slater. 2009. Factors Influencing the Choice of a Career in Food-Animal Practice among Recent Graduates and Current Students of Texas A&M University, College of Veterinary Medicine. *J Vet Med Educ* 36 (1): 7–15.
Lloyd. J. W. and D. M. Smith. 2000. Is there an oversupply of veterinarians? *J Am Vet Med Assoc* 216 (11): 1726–1728.
Kansas State University Research and Extension. 2014. The business-minded veterinarian. *ScienceDaily*, www.sciencedaily.com/releases/2014/12/141223113819.htm (Accessed 2 December 2019).
Moore, D. A. 2006. Veterinary school consortia as a means of promoting the food-supply veterinary medicine pipeline. *J Vet Med Educ* 33:539–542.
Morse, C. E., and J. Mudgett. 2018. Happy to Be Home: Place-Based Attachments, Family Ties, and Mobility among Rural Stayers. *The Professional Geographer* 70 (2): 261–269.
National Association of Veterinary Technicians in America (NAVTA). 2019. Specialties. https://www.navta.net/page/specialties (Accessed 7 Jan. 2020).
National Research Council (NRC). 1982. *Specialized veterinary manpower needs through 1990.* National Academy Press, Washington, D. C.
National Research Council (NRC). 2013. Workforce needs in veterinary medicine. National Academies Press Washington, D.C.
National Rural Health Association (NRHA). 2008. Recruitment and Retention of Quality Health Workforce in Rural Areas: A Series of Policy Papers on the Rural Health Careers Pipeline, Paper #12. NHRA, Washington, D.C.
Nelson, G. C., M. W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, T. Zhu, T. B. Sulser, C. Ringler, S. Msangi, and L. You. 2010. Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options. International Food Policy Research Institute, Washington, D. C. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/127066/filename/127277.pdf
Niedomysl, T. and Amcoff, J. 2011. Why return migrants return: Survey evidence on motives for internal return migration in Sweden. *Popul Space Place* 17(5): 656–673. https://doi.org/10.1002/psp.644.
North American Veterinary Medical Educational Consortium (NAVMEC). (2011) Roadmap for Veterinary Medical Education in the 21st Century: Responsive, Collaborative, Flexible. NAVMEC, Washington, D.C.
Novakovic, A. and C. Wolf. 2018. Disorderly Marketing in the Twenty-First Century U.S. Dairy Industry. *Choices* 33 (4). https://ageconsearch.umn.edu/record/279867/files/cmsarticle_659.pdf.
O'Rourke, K. 2003. Food animal veterinarian shortage causing growing concern. *JAVMAnews* Accessed 19 May 2019. https://admin.avma.org/News/JAVMANews/Pages/030115a.aspx?mode=mobile.
Olfert, M. R., M. Jelinski, D. Zikos, and J. Campbell. 2012. Human capital drift up the urban hierarchy: veterinarians in Western Canada. *Ann Reg Sci* 49:551–570.
Osborne, D. 2003. Demographic survey forecast. *Focus* (Ontario Veterinary Medical Association). 22:16–17.
Peck, D. F. 2005. Foot and Mouth Outbreak: Lessons for Mental Health Services. *BJPsych Adv* 11:270–76.
Pendell, D. L., T. L. Marsh, K. H. Coble, and J. L Lusk. 2015. Economic Assessment of FMDv Releases from the National Bio and Agro Defense Facility. *PLoS ONE* 10 (6): e0129134 doi: 10.1371/journal.pone.0129134.
Petrin, R. A., K. A. Schafft, J. L. and Meece. 2014. Educational Sorting and Residential Aspirations Among Rural High School Students:

What Are the Contributions of Schools and Educators to Rural Brain Drain?. *Am Educ Res J* 51(2): 294–326.

Pew National Veterinary Education Program (PNVEP). 1988. Future directions for veterinary medicine. Institute of Policy Sciences and Public Affairs, Durham, North Carolina.

Pires, A. F. A., A. Peterson, J. N. Baron, R. Adams, B. Martínez-López, and D. Moore 2019. Small-Scale and Backyard Livestock Owners Needs Assessment in the Western United States. *PLoS ONE* 14 (2): e0212372 doi: 10.1371/journal.pone.0212372.

Prince J. B., D. M. Andrus, K. P. Gwinner. 2006. Future demand, probable shortages, and strategies for creating a better future in food supply veterinary medicine. *J Am Vet Med Assoc* 229 (1): 57–69.

Program on Dairy Markets and Policy. 2019. Dairy Input Prices. https://dairymarkets.org/Tools/Inputs.html (Accessed 4 June 2019).

Rabinowitz, H. K., and N. P. Paynter. 2000. The role of the medical school in rural graduate medical education: pipeline or control valve? *The Journal of Rural Health* 16 (3): 249–253.

Radostits, O. M. 2004. Bovine Practice: Successes of the Past and Challenges and Opportunities in the Future, In *Proceedings of the 23rd World Buiatrics Congress,* Quebec, Canada, 11–16 July 2004 https://pdfs.semanticscholar.org/ce97/ab4b63236c3610a057a2c001df386d1d1096.pdf (Accessed July 2019).

Remsburg, D. W., D. T. Galligan, and J. T. Ferguson. 2007. A proposed novel food animal health care delivery system. *J Am Vet Med Assoc* 231 (6):854–60.

Renner, D. M., J. M. Westfall, L. A. Wilroy, and A. A. Ginde. 2010. The influence of loan repayment on rural healthcare provider recruitment and retention in Colorado. *Rural and Remote Health* 10 (4): 1605.

Riddle C., H. Mainzer, and M. Julian. 2004. Training the Veterinary Public Health Workforce: A Review of Educational Opportunities in US Veterinary Schools *J Vet Med Educ* 31 (2): 161–167.

Rural Health Information Hub. 2019. Telehealth Use in Rural Healthcare. https://www.ruralhealthinfo.org/topics/telehealth (Accessed 7 Jan. 2020)

Saltman, R., D. M. Andrus, K. P. Gwinner, and J. B. Prince. 2006. The Future of Food Supply Veterinary Medicine: What the FSVMC-Bayer Study Tells us and How Can AABP Use this Information?. Paper presented at the 39th Annual Convention of the American Association of Bovine Practitioners, Saint Paul, Minnesota, 21-23 September.

Schelling, E., K. Wyss, M. Béchir, D. D. Moto, and J. Zinsstag. 2005. Synergy between public health and veterinary services to deliver human and animal health interventions in rural low income settings. *Bmj 331* (7527): 1264–1267.

Shepherd, A. J. 2004. Employment, starting salaries, and educational indebtedness of year-2004 graduates of US veterinary medical colleges. *J Am Vet Med Assoc* 225:1677–1679.

Shepherd, A. J. 2005. Employment, starting salaries, and educational indebtedness of year-2005 graduates of US veterinary medical colleges. *J Am Vet Med Assoc* 227:1084–1086.

Shepherd, A.J. 2008. Employment, starting salaries, and educational indebtedness of year-2008 graduates of US veterinary medical schools and colleges *J Am Vet Med Assoc* 233:1067–1070.

Schmitz, J. A., R. J. Vogt. G. P. Rupp, B. W. Brodersen, J. M. Abel, A. R. Wohlers, D. B. Marx. 2007. Factors Associated with Practice Decisions of Nebraska Veterinarians Regarding Type of Practice and Community Size. *J Vet Med Educ* 34 (3): 7–15.

Salois, M. 2019. "AVMA: More veterinary technicians, higher practice efficiency" *DVM360* 8 Sept. 2019. https://www.dvm360.com/view/avma-more-veterinary-technicians-higher-practice-efficiency.

Stockdale, A. 2004. Rural out-migration: Community consequences and individual migrant experiences. *Sociologia Ruralis* 44(2): 167–194. doi:10.1111/j.1467-9523.2004.00269.x.

Sullivan, S. E. 1999. The Changing Nature of Careers: A Review and Research Agenda. *J Manage* 25 (3): 457–84. http://journals.sagepub.com/doi/10.1177/014920639902500308 (Accessed 5 July 2019).

Swine Medicine Education Center (SMEC). 2019. What is SMEC? *Swine Medicine Education Center.* https://www.smec.iastate.edu/mission/ (Accessed 23 July 2019)

Tack, D. M., M. J. McCool-Eye, C, R. Kizer, D. A. Dargatz, A. M. Turzillo. 2018. Exploration of Veterinary Shortages in the Wake of the Veterinary Feed Directive. *J Am Vet Med Assoc* 253 (10): 1334–41.

Ulrich-Schad J. D., M. Henly, and T. G. Safford. 2013. The role of community assessments, place, and the great recession in the migration intentions of rural Americans. *Rural Sociology* 78 (3): 371–98.

United Kingdom Parliament. 2003. Select Committee on Environment, Food and Rural Affairs: Sixteenth report. www.publications.parliament.uk/pa/cm200203/cmselect/cmenvfru/703/70304.htm. (Accessed May 20, 2019)

United State Department of Agriculture (USDA). 2019. Livestock, Dairy, and Poultry Outlook LDP-M-297. USDA, Economic Research Service. 14 March, 2019. https://www.ers.usda.gov/webdocs/publications/92609/ldp-m-297.pdf?v=7042.8.

United States Department of Agriculture (USDA). 2019a. The Veterinary Medicine Loan Repayment Program. https://nifa.usda.gov/program/veterinary-medicine-loan-repayment-program.

United States Department of Agriculture (USDA). 2019b. VMLRP General Information. https://nifa.usda.gov/vmlrp-general-information.

U.S. Congress. 2017. Veterinary Medicine Loan Repayment Program Enhancement Act, HR 1268, 115th Congress, 1st Session, Introduced in House Mar. 1, 2017. https://www.congress.gov/116/bills/hr4881/BILLS-116hr4881ih.pdf.

U.S. Congress. 2019. Veterinary Medicine Loan Repayment Program Enhancement Act, S 1163, 116th Congress, 1st Session. Introduced in Senate April. 11, 2019. https://www.congress.gov/116/bills/s3016/BILLS-116s3016is.pdf.

U.S. Dairy Export Council. 2019. 2011–2018 Export Trade Data. http://www.usdec.org/research-and-data/market-information/us-export-data/historical-data.

U.S. Meat Export Federation. 2019. FAQ. https://www.usmef.org/about-usmef/faq/.

Veterinary Business Advisors, Inc. 2017. The State of Student Debt. https://veterinarybusinessadvisors.com/the-state-of-student-debt/ (Accessed 9 July 2019)

Villarroel, A., S. R. McDonald, W. L. Walker, L. Kaiser, R. D. Dewell, and G. A. DeWell. 2010b. A survey of why veterinarians leave rural veterinary practice in the United States. *J Am Vet Med Assoc*. 238:859–867.

Villarroel, A., S. R. McDonald, W. L. Walker, L. Kaiser, R. D. Dewell, and G. A. Dewell. 2010c. Shortage of Rural Veterinarians: Real or Perceived? *The Online Journal of Rural Research and Policy* 5 (7): 1–17.

Volk, J. O., U. Schimmack, E. B. Strand, L. K. Lord, C. W. Siren. 2018. Executive summary of the Merck Animal Health Veterinary Wellbeing Study *J Am Vet Med Assoc* 252 (10): 1231–1238.

Walker, J. B. 2009. Food animal medicine in crisis. *J Am Vet Med Assoc* 235:368–374.

Walker, J. H., D. E. Dewitt, J. F. Pallant, and C. E. Cunningham. 2012. Rural origin plus a rural clinical school placement is a significant predictor of medical students' intentions to practice rurally: A multi-university study. *Rural and Remote Health* 12 (1): 1908.

Wang, T, D. A. Hennessy, and A. M. O'Connor. (2010) Where Are the Veterinarian Shortage Areas Anyway?. *Preventive Veterinary Medicine 104 (2012): 198–206.*

White, A., B. J. White, D. R. Goehl, and K. C. Dhuyvetter. 2010. Results of a survey to determine demographic and business management factors associated with size and growth rate of rural mixed-animal veterinary practices. *J Am Vet Med Assoc* 237 (12): 1386–1392.

White, B.J., A.M. Brusk, and D.R. Goehl. 2010. Professional Services Offered in Rural, Mixed-Animal Veterinary Practices. *Online J Rural Res Policy* 5 (7): 1–8.

Willis, N. G., F. A. Monroe, J. A. Potworowski, G. Halbert, B. R. Evans, J. E. Smith, K. J. Andrews, L. Spring, and A. Bradbrook. 2007. Envisioning the future of veterinary medical education: The Association of American Veterinary Medical Colleges Foresight Project, Final Report. *J Vet Med Educ* 34:1–41.

Wise, J. K., and J. E. Kushman. 1985. Synopsis of US veterinary medical manpower study: demand and supply from 1980 to 2000. *J Am Vet Med Assoc* 187:358–361.

White, A., B. J. White, D. R. Goehl, and K. C. Dhuyvetter. 2010. Results of a survey to determine demographic and business management factors associated with size and growth rate of rural mixed-animal veterinary practices. *J Am Vet Med Assoc* 237 (12): 1386–1392

Wokatsch, R. 2018. Dairy farm crisis grows critical for many. *Farm Progress* 30 April 2018. https://www.farmprogress.com/dairy/dairy-farm-crisis-grows-critical-many (Accessed 4 June 2019.)

Zeeshan A. and A. Iram. 2012. Generational Diversity: Strategies to Bridge the Diversity Gap. *IJEMS* 3 (3): 315–318.

Zemke, R., A. Raines, and B. Filixzak. 2000. Generations at Work: Managing the Clash of Veterans, Boomers, Xers. and Nexters in Your Workplace. American Management Association, New York, New York.

Zinsstag, J., E. Schelling, K. Wyss, and M. B. Mahamat. 2005. Potential of cooperation between human and animal health to strengthen health systems. *The Lancet* 366 (9503): 2142–2145.

CAST Member Societies, Companies, and Nonprofit Organizations

AGRICULTURAL AND APPLIED ECONOMICS ASSOCIATION ■ AMERICAN ASSOCIATION OF AVIAN PATHOLOGISTS ■ AMERICAN ASSOCIATION OF BOVINE PRACTITIONERS ■ AMERICAN BAR ASSOCIATION, SECTION OF ENVIRONMENT, ENERGY, & RESOURCES ■ AMERICAN DAIRY SCIENCE ASSOCIATION ■ AMERICAN FARM BUREAU FEDERATION ■ AMERICAN MEAT SCIENCE ASSOCIATION ■ AMERICAN METEOROLOGICAL SOCIETY, COMMITTEE ON AGRICULTURAL AND FOREST METEOROLOGY ■ AMERICAN SEED TRADE ASSOCIATION ■ AMERICAN SOCIETY FOR NUTRITION NUTRITIONAL SCIENCES COUNCIL ■ AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS ■ AMERICAN SOCIETY OF AGRONOMY ■ AMERICAN SOCIETY OF ANIMAL SCIENCE ■ AMERICAN SOCIETY OF PLANT BIOLOGISTS ■ AMERICAN VETERINARY MEDICAL ASSOCIATION ■ AQUATIC PLANT MANAGEMENT SOCIETY ■ BASF CORPORATION ■ BAYER CROP SCIENCE ■ CAL POLY STATE UNIVERSITY ■ CORTEVA AGRISCIENCE ■ CROP SCIENCE SOCIETY OF AMERICA ■ CROPLIFE AMERICA ■ ENTOMOLOGICAL SOCIETY OF AMERICA ■ INNOVATION CENTER FOR U.S. DAIRY ■ NATIONAL CATTLEMEN'S BEEF ASSOCIATION ■ NATIONAL CORN GROWERS ASSOCIATION/IOWA CORN PROMOTION BOARD ■ NATIONAL MILK PRODUCERS FEDERATION ■ NATIONAL PORK BOARD ■ NORTH CAROLINA BIOTECHNOLOGY CENTER ■ NORTH CENTRAL WEED SCIENCE SOCIETY ■ NORTHEASTERN WEED SCIENCE SOCIETY ■ POULTRY SCIENCE ASSOCIATION ■ RURAL SOCIOLOGICAL SOCIETY ■ SOCIETY FOR IN VITRO BIOLOGY ■ SOIL SCIENCE SOCIETY OF AMERICA ■ SYNGENTA CROP PROTECTION ■ THE FERTILIZER INSTITUTE ■ TUSKEGEE UNIVERSITY ■ TYSON FOODS ■ UNITED SOYBEAN BOARD ■ UNIVERSITY OF NEVADA–RENO ■ U.S. POULTRY AND EGG ASSOCIATION ■ WEED SCIENCE SOCIETY OF AMERICA ■ WESTERN SOCIETY OF WEED SCIENCE

The mission of the Council for Agricultural Science and Technology (CAST): *CAST, through its network of experts, assembles, interprets, and communicates credible, balanced, science-based information to policymakers, the media, the private sector, and the public. The vision of CAST is a world where decision making related to agriculture and natural resources is based on credible information developed through reason, science, and consensus building. CAST is a nonprofit organization composed of scientific societies and many individual, student, company, nonprofit, and associate society members. CAST's Board is composed of representatives of the scientific societies, commercial companies, nonprofit or trade organizations, and a Board of Directors. CAST was established in 1972 as a result of a meeting sponsored in 1970 by the National Academy of Sciences, National Research Council.*

ISSN 1070-0021

Additional copies of this Issue Paper are available from CAST, http://www.cast-science.org.

Citation: Council for Agricultural Science and Technology (CAST). 2020. *Impact of Recruitment and Retention of Food Animal Veterinarians on the U.S. Food Supply*. Issue Paper 67. CAST, Ames, Iowa.

The Science Source for Food,
Agricultural, and Environmental Issues

4420 West Lincoln Way
Ames, Iowa 50014-3447, USA
(515) 292-2125
E-mail: cast@cast-science.org
Web: www.cast-science.org