Exercise Follow-up:
Policy toward Dairy Farms with Swine
in the
New England Secure Milk Supply (SMS) Project

by

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SUMMARY

The focus of this document is policy on permitting dairy farms with swine to ship milk during an FMD outbreak, a concern that arose during the 2013 exercise of the New England SMS Plan.

Given the exercise scenario (a simulated FMD outbreak in New England), the chief animal health officials for the six states decided to withhold eligibility for milk pick-up permits for farms that were reported to raise pigs as well as dairy cattle. A justification for this standard was to reduce the possibility that tanker service to farms with pigs would distinctly increase the risk of spreading disease, especially given the capacity of swine to "multiply FMD virus" and of service traffic to transmit it. Also during the exercise, officials decided to accept a slightly lower minimum Readiness Rating for farms without pigs, in order to keep more milk moving within the region.

As with many elements in plans for responding to a highly contagious livestock disease, the aim was a "sweet spot" between tactical alternatives that can, in practice, conflict even as they advance a common goal of returning to disease-free operations. In this case, officials put farms with pigs and farms without pigs on different sides of the sweet spot, favoring disease control for one and continuity of operations for the other. As suggested in the 2013 New England SMS Exercise AAR/IP, this paper explores the consequences and rationale for that decision.

Judging from reviews to-date, pigs themselves need not be considered crucial to the economic viability of dairying in New England. The vast majority of dairy farms in the region (nearly 90%) have no pigs, and the remainder have very few. The largest swine herd has barely fifty head, and the average has only six. These herds could not generate enough income to sustain a commercial dairy farm.

More crucial for continuity of these operations is dairying itself. Although the share of regional agriculture directly related to dairy operations with swine may seem small, the absolute number of farms and livestock and the amount of food at-risk are striking. Withholding milk-movement permits from regional dairy farms with pigs would likely interrupt commerce for about 200 dairy farms, with approximately 1,200 pigs, that milk 18,000 cows, produce 870,000 pounds of milk per day, and care for 50,000 head of livestock in all. So, among the greatest challenges in withholding permission for shipments from dairy farms with pigs would be lost revenue to those particular farms, the integrity of their link in the food supply chain, the welfare of tens of thousands of animals, and about a million pounds of additional food-turned-waste each day.

Judging from premises reviewed to date (about 60% of all licensed dairy farms in New England), farms with pigs are just as prepared – as ready to implement SMS-mandated biosecurity – as those without them. As a group, they are actually slightly more "Ready" in five of the six states as well as the region as a whole. So in SMS permitting, greater continuity of operations in New England may be achieved – even with a bit greater overall disease protection – by including rather than excluding dairy farms with swine.

A remaining issue, though, is the possibility that swine are otherwise, so uniquely powerful as "amplifiers" of FMD contagion that permitting milk pickups from premises with pigs would be more hazardous than from pig-free neighbors. However, according to most recent research on conditions required for the availability, distribution, and reception of FMD virus, the threat of contagion in New England from dairy farms with pigs should not be expected to be greater than from dairy farms without them. So, depopulation of these particular, disease-free herds of swine or isolation of their dairy premises may be not only impractical but also unnecessary.

These findings suggest that in SMS permitting the same minimum Readiness Rating should be required of New England dairy farms with and without pigs.

BACKGROUND

This document was prepared for the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS) and the New England Animal Agricultural Security Alliance (NESAASA) to advance the New England Secure Milk Supply (SMS) Project.[1]

The project is intended to develop uniform principles and procedures among the six New England states to promote continuity of dairy operations, in the event of an animal-disease emergency, such as an outbreak of Foot-and-Mouth Disease (FMD). To date, the main focus has been preparing to help Incident Command identify farms that would be eligible for a permit to ship milk safely to market, even in a FMD Control Area. Eligibility for a permit chiefly depends on a farm's epidemiological status (e.g., disease-free rather than infected, contact, or suspect), and its ability to resist infection by maintaining:

- A secure perimeter,
- A clean route from the perimeter to the bulk tank, and
- A wash station to decontaminate traffic (e.g., a milk tank truck) as it enters and leaves.

The chief instrument for assessing that ability is a Readiness Review of all dairy farms in the region. Elements of the review (now about 60% complete) are assigned weights by consensus of the chief animal public-health officials and integrated in a "Readiness Rating" for each farm. The Information Technology group of the Texas Center for Applied Technology in association with National Center for Foreign Animal and Zoonotic Disease Defense (FAZD) maintains this NESAASA database, including complete results of the review and a summary Readiness Rating for each farm. On-line access is restricted to State Veterinarians, but they can grant access to other officials in an emergency as well as in training and exercises.[2]

The most recent training and exercise of this part of the New England SMS Plan was held in Concord, New Hampshire on May 9, 2013. (Full documentation is on-line with NESAASA reports.) Among the results was an After-Action Report and Implementation Plan (AAR/IP) that includes several recommendations for improving regional preparedness. This document is among the efforts to implement those recommendations. (Relevant "Select Recommendations from the 2013 New England SMS Exercise AAR/IP" are appended.)

The focus of this document is SMS policy on milk-movement permits for dairy farms with swine.

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See the Appendix for relevant state- and region-level statistics drawn from the latest (January 2014) Readiness Reviews of dairy farms in New England.

[1] "Support for the Project to 'Revise, Expand, and Exercise Regional FAD Emergency Continuity of Operation Planning,'" Cooperative Agreement Number 13-9644-1245CA (FFY 2013) between the Division of Agriculture/Animal Health in the Rhode Island Department of Environmental Management and USDA-APHIS Veterinary Services on behalf of NESAASA (October 4, 2013 to August 31, 2014). Credit is also due Simon Barteling, Raul Casas Olascoaga, Jim Roth, and Paul Sutmoller for reviewing a draft of this document.

[2] Richard P. Horwitz, Assessing Farm Readiness for Emergency Milk Movement in New England (NESAASA, 2012).

SWINE ON DAIRY FARMS IN NEW ENGLAND

The 2013 exercise of the New England SMS Plan identified a special concern for dairy farms that keep swine. Participants (including the chief animal health officials in the six states) said that they could use better information about such operations than was handy at the time.

The concern first arose in selecting a precise biosecurity standard for milk-movement permits (i.e., a minimum Readiness Rating. Farms with that score or higher could be recommended to Incident Command as eligible to receive a permit to have their milk picked up. They would be considered "safe enough" for tanker service.)

As with many elements in plans for responding to highly contagious livestock disease, the aim was a "sweet spot" between tactical alternatives that can, in practice, conflict even as they advance a common goal of returning to normal, disease-free operations.

Tradeoff in Setting the Level of Farm Biosecurity Required for a Permit to Ship Milk

Tactic	Higher Minimum Readiness Rating	Lower Minimum Readiness Rating
Strategy	Restrict Commerce	Continue Commerce
Objective (near-term)	Control Infection	Sustain Operations
Vulnerability (near-term)	Increased risk to food supply, farm survival, and environmental protection	Increased risk to animal health and international trade

Following detection, the main aim of any control policy is to achieve disease-free status as quickly as possible (allowing exports to resume), with the minimum of impact on the livestock community. Unfortunately, these two motivating ideals of minimizing the time and minimizing the disturbance are often in conflict. Determining what is the correct balance between these two elements is a critical decision that must be taken by the appropriate stakeholders and government agencies. Without such guidance, it is meaningless to talk about optimal strategies, or even whether one policy is 'better' than another.

– Matt J. Keeling (2005) [3]

[3] Keeling, Models of Foot and Mouth Disease, *Proceedings of the Royal Society B: Biological Sciences* 272:1569 (June 22, 2005), p. 1195.

Anticipating effects from the exercise scenario and NESAASA data, authorities agreed to require a minimum Readiness Rating of 0.4. That standard was lower than the minimum (0.5) anticipated in the Action Plan drafted for the exercise. Participants explained that the increase in disease-spread risk associated with awarding permits to lower-rated farms (with Readiness Ratings of 0.4 to 0.5) seemed more tolerable than the increase in risks to waste-management, food-supply, and business-continuity in denying permits to those farms. Given also the large number of premises that had yet to be reviewed and hence awaiting inspection, authorities judged that they should initially keep more milk moving to market, even if on-farm preparations were short of ideal.

The only across-the-board exception to this standard was for farms with pigs, a condition monitored in the Readiness Review but not at the time included in the calculation of each farm's Readiness Rating. Participants decided to remove from eligibility or at least postpone permit decisions for all farms that were reported to raise pigs as well as dairy cattle. A justification for this stricter standard was to reduce the possibility that tanker service to farms with pigs would distinctly increase the risk of spreading disease, especially given the capacity of swine to "multiply" FMD virus and of service traffic to transmit it.

Although authorities were unanimous in support of this exception (i.e., excluding dairy farms with swine from the list of eligible premises, before screening by Readiness Rating), they also said that it would be worth reconsidering in light of a more thorough assessment of the potential consequences and rationale. The following is intended to help fill that gap.

STAKES IN EMERGENCY MILK-SHIPMENT PERMITS FOR FARMS WITH PIGS

Judging from reviews to-date, the vast majority of dairy farms in New England (nearly 90%) have no pigs, and the remainder have very few. The largest swine herd has barely fifty head, and the average has only six. Just a half-dozen farms have fewer cows to milk than pigs to feed, and they tend to be very small operations (milking fewer than ten cows). Neither the smallest nor largest of these swine herds could generate enough income to sustain a commercial operation. So, pigs themselves need not be considered crucial to the economic viability of dairying in New England.

> **Pigs themselves need not be considered crucial to the economic viability of dairying in New England. More crucial for continuity of their operations is dairying itself.**

More crucial for continuity of their operations is dairying itself. Reviewed farms that keep pigs also milk an average of 85 cows. That is about a quarter less than the regional mean (114). So, emergency permitting decisions for dairy farms with pigs may be expected to affect a small share of farms (about 10%) and an even smaller share of the milk produced in the region.

By these simple measures, withholding emergency milk-shipment permits from farms with pigs should not in itself significantly endanger the sustainability of regional dairying. Direct effects would be confined to a little over 1,000 swine on about 200 dairy farms accounting for less than 10% of regional production.

It is worth emphasizing, however, that revenue from shipped milk sustains not only cows, farm families and communities but also a significant number of other sorts of livestock. Among dairy stock alone, there is more than one dry cow, heifer, calf, or bull for every cow that is milked. (See also the appended state-level counts of livestock by type and species.)

Livestock on New England Dairy Farms with Swine:

	Population on 123 Reviewed Farms	Average Number per Farm	Estimated Total for All Dairy Farms with Swine
Dairy Cattle	21,676	176.2	38,642
Milking cows	10,195	85	17,700
Dry cows	1,764	14.7	3,063
Bred heifers	2,929	24.4	5,085
Heifers	3,638	30.3	6,316
Calves (< 500 lbs.)	2,955	24.6	5,130
Bulls	195	1.6	339
Non-Dairy Livestock	7,687	62.5	13,346
Beef Cattle	581	4.8	1,009
Swine	703	5.9	1,220
Sheep	687	5.7	1,193
Goats	120	1	208
Llamas	13	0.1	23
Farmed Deer	0	0	0
Poultry	4,820	40.2	8,368
Horses	189	1.6	328
Other species	574	4.8	997
Total Livestock	29,363	239	50,979

In short, although the share of regional agriculture directly related to dairy operations with swine may seem small, the absolute number of farms and livestock and the amount of food at-risk are striking: over 50,000 individual animals and nearly a million pounds of milk per day

Estimated Impact of Restricted Commerce for Regional Dairies with Swine, January 2014

~ 200 Dairy Farms, with ~ 1,200 pigs, that:

- **Milk ~ 18,000 cows**
- **Produce ~ 870,000 pounds of milk per day**
- **Care for ~ 50,000 head of livestock.**

PREVENTIVE DEPOPULATION OF PIGS AS A BIOSECURITY MEASURE

Among the greatest challenges in withholding permission for shipments from dairy farms with pigs would be lost revenue to those particular farms, the integrity of their link in the food supply chain, the welfare of tens of thousands of animals, and about a million pounds of additional food-turned-waste each day.

A farm or Incident Command might aim to work around this problem by elevating biosecurity and "getting rid of the pigs," as was imagined during the 2013 NESAASA exercise. Such "depopulation" is a controversial but also common tactic to control highly contagious livestock disease, but doing it preventively, even with such small herds, could be tough, especially given poor support for recent precedent.[4]

NESAASA has agreed that, during a FMD outbreak in the region, all livestock shipments (e.g., among farms or to packing plants) should be suspended. There is widespread and growing consensus that a stop-movement order, coupled with increased surveillance, is the most effective first step in arresting an epidemic. Incident Command may be reluctant to approve an exception for shipments of live, FMD-susceptible animals (such as scattered small herds of hogs to slaughter) in a Control Area, even when they seem healthy. If those hogs happened to be "infected but undetected" (a possibility that was high enough to put them in the Control Area in the first place), risks of disease spread could be greatly increased along a path to commercial slaughter. So, that route to depopulation is apt to be closed.

Furthermore, the ethics and procedure for sacrificing healthy animals in such a situation is "the one area identified as needing additional guidance" in the latest Guidelines for Euthanasia from the American Veterinary Medical Association. The AVMA is still developing recommendations on appropriate conditions and humane methods for depopulation of swine in particular.[5]

Among the lessons of the much-studied 2001 FMD outbreak in the U.K. is that preventive contiguous culling and carcass disposal may be more than an ethical and logistical challenge. Depopulation will likely be resisted by farmers as well as the public and challenging or even impossible as a practical matter, especially when, as in the U.S., full indemnification cannot be assured and response resources (e.g., for enforcement and carcass disposal) are apt to be strained.

Depopulation will likely be resisted by farmers as well as the public and challenging or even impossible as a practical matter.

[4] Convery, *et al.*, *Animal Disease and Human Trauma: Emotional Geographies of Disaster* (Palgrave, 2008). See also, for example: *Fields of Fire*, edited and self-published by Quita [Jacquita Allender] (2002) or Nick Green's video deconstruction of BBC coverage of FMD response in Cumbria, FMD 2001 Inside Out Feb 2011 and FMD2001 Countryfile Propoganda!! (YouTube, 2011).

[5] "AVMA Guidelines for the Depopulation of Animals" are under development. AVMA Guidelines for the Euthanasia of Animals: 2013 Edition (AVMA, 2013), pp. 5-6, 82. See also USDA-APHIS-VS, National Animal Health Emergency Management System, NAHEMS Guidelines: Mass Depopulation and Euthanasia (May, 2011) and FAD PReP / NAHEMS Tactical Topics: Mass Depopulation and Euthanasia (November 2013).

DISEASE CONTROL AND SPECIES IN PERMITTING

In recent outbreaks, the value of large-scale depopulation – especially over a broad terrain of "contiguous premises" (CP) rather than just specific "infected premises" and their "dangerous contacts" (IP and DC) – has been much disputed. In general, preventive depopulation has not proven to be a particularly palatable or effective way to stop the spread of FMD. It has spread anyway, apparently most often when infected animals were moved into uninfected herds, in violation of stop-movement orders or before they were issued.

Clearly, during an outbreak, every farm that is depopulated or otherwise isolated represents a reduction in the risk of transmitting infection. However, isolation also poses an increase in risk for the survival of the farm, the wellbeing of its owner, employees and families, the care of its livestock, the supply of food, and the protection of its surroundings, where waste milk would likely be dumped. That is why the best way to control disease cannot be "just shut everything down." If the "patient" (in this case, New England dairying) is to survive the "treatment," continuity of commerce must be, in some manner, both limited and maintained. As in dealing with marginal Readiness Ratings, the challenge is deciding whether a type of operation falls above or below "a sweet spot" between diverging objectives: control infection and sustain operations.

So, should dairy farms with and without pigs fall on the same or different sides of that sweet spot? Would, in fact, milk tanker service to New England farms with swine be sufficiently more likely to spread disease (when compared to farms without swine) to justify withholding permits to them as a group?

One reason to answer "yes" would be if farms with swine were significantly more likely to have an insecure perimeter, to contaminate vehicles on the way to the bulk tank, or to fail to clean them as they enter and leave. As it turns out, at least on average according to NESAASA reviews to date, they are not. Farms with pigs are just as prepared – as ready to implement SMS-mandated biosecurity – as those without them. As a group, they are actually slightly more "Ready" in five of the six states as well as the region as a whole.

Readiness Ratings of New England Dairy Farms by Presence of Swine

	Average Readiness Rating
Dairy Farms with Pigs	0.613
Dairy Farms with No Pigs	0.590
All Dairy Farms	0.593

These figures suggest that, by treating dairies with pigs the same as those without, authorities could help sustain more farms with the same or even slightly better on-the-ground barriers to infection.

In the 2013 NESAASA exercise, for example, if participants had not first excluded dairy farms with swine, they could have kept more milk moving without resorting to a lower minimum Readiness Rating. So in SMS permitting, greater continuity of operations in New England may be achieved – even with a bit greater overall disease protection at the farm gate – by including rather than excluding dairy farms with swine.

In permitting milk pick-up during an animal-disease emergency, greater continuity of operations in New England may be achieved – even with a bit greater overall disease protection at the farm gate – by including rather than excluding dairy farms with swine.

A remaining issue, though, is the possibility that swine are, as a species, uniquely hazardous in a FMD outbreak, so innately powerful as "amplifiers" of contagion that permitting milk pickups from premises with pigs would be more hazardous than from pig-free neighbors.

Under conditions that prevail in New England, is it likely that FMD in swine would be harder to detect, last longer, spread faster, be carried longer or blow farther than FMD in cattle? Recent relevant research, reviewed below, suggests that the answer to all of these question is, "No."

SWINE AS AMPLIFIERS OF FMD CONTAGION AMONG DAIRY FARMS

There is a great deal of evidence that infected livestock can often shed huge amounts of FMD virus, even before, if ever, they seem sick. If enough active virus reach naive, susceptible animals, they are almost certain to become infected, though with variable effects. Symptoms differ greatly depending on the species involved, the conditions surrounding exposure, and the strain of the virus. For example, some strains may particularly afflict swine (e.g., O Taiwan 1997), while others seem better attuned to cattle or sheep, even as these species remain susceptible to yet other strains with or without symptoms of their own. It matters a great deal if the source of the virus has hosted it for more than a day or two, if the newly exposed animals are crowded together, and if virus reaches sufficiently vulnerable cells in adequate concentration.

But it is hard to see how such complexity conditions contagion beyond a biosecure site. As long as farmers stop movement of susceptible animals, minimize contamination of traffic on-site and effectively decontaminate everything at the farm gate, pathogens would seem to be corralled. Nevertheless, in the past FMD has spread in surprising directions, even jumping many miles from one apparently isolated herd to another. Indeed, that is what seems to have happened in some infamous cases, and pigs have been implicated in analyses that these cases attract.

Investigation of exactly how FMD spreads has progressed along many lines for several decades. Hope for applying lessons of that research has always been high, to better anticipate the course of contagion and to allocate resources accordingly. Emergency managers want to be able to trust that "the" research, more than conventional or wishful thinking, will help them choose "the" best course to prevent or control disease next time. Delivery on that promise necessarily depends on the capacity of different lines of inquiry to converge in recommending a clear, consistent course.

Unfortunately, progress toward such useful integration has been less pronounced than the production of freestanding findings, with do-it-yourself implications for emergency managers. A large and diverse cottage industry has arisen for the study of factors that help explain past epidemics and for the development of Disease Spread Models (DSM) for use in the future. However, models and data to run them in the U.S. still seem to be inadequate for managing an outbreak. So far, research advances have been incremental and uneven – greatest at the level of the virus, cell, organ, and organism; less so, at the level of whole herds or terrains.

Such variation in research may be inevitable. Exploration of chemical or microbial interactions are relatively easy to justify, control, and finance, while experiments with animals are more ethically suspect, difficult, and expensive. Intentionally infecting whole herds with pathogenic FMD virus (e.g., to see how disease spreads among them) may be useful to imagine or simulate but utterly unreasonable to do.

Relevant data from prior, "natural" outbreaks are understandably inconsistent and incomplete. In the midst of an outbreak, investing resources to track the origin of each wave in a flood of new herd infections must be a lower priority than caring for survivors and sandbagging the dikes. Even if the source of all those particular infections could be detailed, the circumstances for each may well be too unique to yield portable lessons, anyway.

Reports of "purer," lower-level, controlled experiments invariably include a warning, in effect, to avoid generalizing from this one study to other circumstances, least of all, direct to field application. Disease-spread modelers hence face the challenge of integrating many unique, caveat-filled studies into a set of harmoniously calibrated parameters with algorithms that yield predictions in circumstances for which few of the contributing studies were designed.

Nevertheless, a great deal has been learned about how FMD is more or less likely to spread from one herd or premises to another. Unfortunately, though too, the lessons of each outbreak tend to be clear more in hindsight than in time to help with the emergency at hand. What's worse, each new outbreak seems to confound the lessons of the last.

For example, a key lesson taken from an outbreak of FMD in the U.K. in 1967-68 was the potential for airborne transmission of the virus. At least in that instance and again in France in 1981, disease surely seemed to blow with the wind. So, a substantial line of research in anticipation of future outbreaks focused on modeling relationships among the availability, distribution, and reception of aerosolized virus (a subfield of aerobiology).

Promising models directed their attention to the number and kind of livestock on infected farms, the distance and direction to uninfected farms, the topography of the terrain between them, and the weather, such as the force and direction of the wind. With such data and a decent DSM (e.g., a traditional SIR model, the FMD-oriented "Imperial" or "Cambridge-Edinburgh" variants, or the more general-purpose simulator, InterSpread), they hoped to design Control Areas in a way that would maintain separation between farms where livestock could best be sacrificed inside and protected outside a predictable plume of infection.

Important for nearly all models of disease transmission was the discovery that certain species – pigs in particular – can shed extraordinarily large amounts of virus, but they also are quite resistant to infection, if they inhale it. Conversely, cattle shed much less virus, but they also need to inhale much less of it (or at least to take fewer breaths containing it) to get sick.

These contrasting roles in infection were established wisdom by 1970. Ever since, veterinarians have been taught a rule of thumb for anticipating infection dynamics, one species per function: "**Sheep act as maintenance hosts, pigs as amplifiers and cattle as indicators**."[6] This triptych does, indeed, counsel concern that pigs can be an engine of contagion and cattle their victims, no matter what you do at the farm gate.

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[6] Sellers and Parwer. "Airborne Excretion of Foot-and-Mouth Disease Virus," *Journal of Hygiene* 67:4 (December, 1969), p. 676.

Unfortunately, the next, “good” opportunity to apply that wisdom (2001 in the U.K.) proved disappointing, both in that an outbreak happened at all and that the latest hard-won wisdom did not much help. Responders quickly learned that airborne virus and swine had little to do with the course of the epidemic (though it likely started from improperly garbage-fed hogs).

Maybe most tragically, disease-control measures informed by DSM runs and related research proved unpopular and staggeringly costly, especially for the farms and communities that they were designed to help. By many estimates, they made matters worse. More than 6.5 million animals were sacrificed, the majority of them apparently disease-free, to protect the remainder from risk that may have been reduced with much less deadly measures (e.g., with rapid vaccination, as applied in the Netherlands, also in 2001). Opponents remember the U.K. effort as “culling by the numbers” and “carnage by computer.”

There are a number of reasons that researchers or modelers should not be blamed. In fact, from the outset DSM developers clearly warned that wind-blown virus could account for only a small share of disease spread from farm to farm. Ordinarily and specifically in the case of the U.K. in 2001, modelers themselves advised, there should be no need to target “contiguous premises” as broadly as the path of prevailing winds would project under most-favorable conditions.

As they geared up alternative models, they also well knew that values for parameters would have to be calculated from data that were far short of ideal. Instead, they would have to run models based on presumptions of, not the most likely of observed values for those parameters, but fallible “expert opinion” or simply the worst they could imagine, a hypothetical perfect storm.

Insofar as there were miscalculations, then, even in 2001, it was not researchers so much as emergency managers, under intense pressure from diverse sources, who decided to accept the “necessity” of massive depopulation and great damage to farms, the environment and the way of life that they supported. They choose a “sweet spot” that greatly favored control of infection over sustaining operations to avoid risks that were, by design, unlikely to happen. They decided to err on the “safe side” of only one of two sets of risks in FMD. When forced to choose between near-term priorities, they opted for infection control over farm continuity.

Still, regardless of priority and time-frame, even without attending to aerosolized virus (“atmospheric dispersion models”), common sense as well as disease-spread models since the 1920s presume that virus can spread over the terrain surrounding an infected premises by any of a large number of carriers (i.e., “mass action” or “random-mixing” transmission). Rather than in droplets in the air, virus can move with bits of dust or muck on the lane, the feet of birds or rodents, the shoes of kids who share a school bus, or the tires of service vehicles that ply the neighborhood. Obviously the density of virus would decline with the proximity and intensity of related traffic (again, no matter how the wind blows), and the greater the total amount of virus, the greater the risk. Whatever mistakes may have been made in crafting Control Areas in the U.K. in 2001, it remains worth remembering that contagion does have a geography amenable to analysis and spatially-oriented management measures.

Modelers also readily acknowledge the need for more complete and reliable data and better calibrated parameters. They regret having to fill the void with unproven and perishable, albeit expert prognostication. Not surprisingly, advances in experimental research and refinements of DSM since 2001 have helped reduce the buffer – the margin for error around doomsday harbingers – that has been, by default, built into beta versions of DSM.

On the risk that swine might transmit FMD to off-premises cattle, recent studies have shown that:[7]

- The pace of infection, transmission, and development of clinical signs of FMD is similar in cattle and swine. Both species can become infected and begin shedding virus very soon after exposure to a sufficient dose under a wide range of conditions. The incubation period (between initial infection and development of clinical signs) for both can be as short as 24 hours, but it is normally 2-4 days. (Erring on the safe side, OIE stipulates that the incubation could be as long as 14 days.) From then on, cattle and swine tend to show obvious symptoms of disease, after which their shedding of infective virus rapidly declines. So, there is little reason to think that adult swine should be considered more likely to be "infected but undetected" than cattle on the same farm.

- "Carriers" of FMD virus (animals that are free of overt symptoms but that still host the virus) are not necessarily capable of spreading disease. In fact, pigs "clear" FMD infection much faster than cattle. For example, unless re-infected, pigs will be free of FMD virus in less than three weeks following infection. They will not be carriers. But cattle are apt to host and shed virus for six months, and some may remain carriers for more than three years. Furthermore, once free of symptoms, neither species has been strongly implicated in the direct spread of infection to naïve herds. So, the presence of FMD virus in "carriers" (e.g., positive tests for the presence of FMDv antigens, RNA, or structural proteins) should not be equated with a capacity to develop symptoms or to spread disease.

[7] The following points are abstracted from publications cited in the Bibliography, especially: Alexandersen *et al.,* Aspects of the Persistence of Foot and Mouth Disease Virus in Animals – The Carrier Problem, *Microbes and Infection* 4:10 (August, 2002), pp. 1099-1110; Alexandersen *et al.,* "The Pathogenesis and Diagnosis of Foot-and-Mouth Disease," *Journal of Comparative Pathology* 129:1 (July, 2003), pp. 1-36; Alexandersen *et al.*, "Studies of Quantitative Parameters of Virus Excretion and Transmission in Pigs and Cattle Experimentally Infected with Food-and-Mouth Disease Virus," *Journal of Comparative Pathology* 129:4 (November, 2003), pp. 268-282; Donaldson and Alexandersen, Predicting the Spread of Foot and Mouth Disease by Airborne Virus, *Revue Scientifique et Technique, OIE* 21:3 (2002), pp. 569-575; Hagenaars, *et al.*, Estimation of Foot and Mouth Disease Transmission Parameters, Using Outbreak Data and Transmission Experiments, *Revue Scientifique et Technique, OIE* 30:2 (2011), pp. 467-481; Keeling, Models of Foot and Mouth Disease, *Proceedings of the Royal Society B: Biological Sciences* 272:1569 (June 22, 2005), pp. 1195-1202; Kitching, Clinical Variation in Foot and Mouth Disease: Cattle, *Revue Scientifique et Technique, OIE* 21:3 (December, 2002), pp. 499-504; Kitching and Alexandersen, Clinical Variation in Foot and Mouth Disease: Pigs, *Revue Scientifique et Technique, OIE* 21:3 (December, 2002), pp. 513-518; Mansley *et al.,* Destructive Tension: Mathematics Versus Experience – The Progress and Control of the 2001 Foot and Mouth Disease Epidemic in Great Britain, *Revue Scientifique et Technique, OIE* 30:2 (2011) pp. 483-498; Mason and Grubman, "Vaccines to Control Foot-and-Mouth Disease," in *Vaccines for Biodefense and Emerging and Neglected Diseases*, ed. Barrett and Stanberry (Elsevier, 2009), Chapter 22, pp. 361-377; Sellers and Gloster, Foot-and-Mouth Disease: A Review of Intranasal Infection of Cattle, Sheep and Pigs, *Veterinary Journal* 177:2 (August, 2008), pp. 159-168; Sutmoller *et al.,* Review: Control and Eradication of Foot-and-Mouth Disease, *Virus Research* 91:1 (2003) pp. 101-144; Sutmoller and Olascoaga, The Successful Control and Eradication of Foot and Mouth Disease Epidemics in South America in 2001, Evidence for the Temporary Committee on Foot-and-Mouth Disease of the European Parliament (September 2, 2002); Sutmoller and Barteling, Points to Consider in the Prevention, Control and Eradication of FMD (2002).

> *Experiments were carried out in attempts to show that carriers could indeed initiate disease. However, close contact exposure of susceptible animals (cattle and pigs) to carriers failed to transmit disease . . . even under circumstances where the carrier cattle and the susceptible contacts were stressed in various ways.*
>
> – Paul Sutmoller *et al*. (2003)[8]

- Swine should not be expected to "multiply" virus and "amplify" disease as radically as has been cited for most of the past forty years. The peak amount of disease-causing virus (in a 50% Tissue Culture Infective Dose, $TCID_{50}$, excreted via respiration per pig in 24 hours) was first reported to be as high as $10^{8.6}$, but no one has been able to replicate that result or even a small fraction of it since 1982. More recent counts – depending on the strain – now put the maximum closer to 10^{6}, still higher than cattle but less singularly so.[9] Pigs will excrete that maximum dose about the time that clinical signs first appear (e.g., lesions on the snout, tongue, and feet, most likely within 18-72 hours of infection), but again in the absence of reinfection, shedding will decline to near-zero over the next three to five days.[10] So, infected pigs do, in fact, greatly multiply virus and represent a distinct threat to naïve cattle, but at least hundreds and perhaps thousands of times less intensely and for a much shorter period of time than has been feared. Insofar as environmental contamination and long-distance transmission is at issue, cattle may well be the greater hazard.

> *Although pigs are major producers of virus aerosols, cattle produce several magnitudes more virus. Cattle are probably the main source of environmental FMD contamination. . . . Excretion by cattle can easily surpass 10^{14} virus particles per cow per day, representing approximately 10^{10} IU [*Infectious Units*]. These quantities of virus behave like a very fine dust that spreads over the infected premises and sticks to all materials, animals, and people.*
>
> – Paul Sutmoller *et al*. (2003)[11]

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[8] Sutmoller *et al.*, Review: Control and Eradication of Foot-and-Mouth Disease. *Virus Research* 91:1 (2003), p. 119.

[9] Depending on the FMDv strain, $TCID_{50}$ ranges from about $10^{5.6}$ to $10^{7.6}$ for swine vs. $10^{5.1}$ for cattle. Note also that respiration is the main route of infection for cattle, but it is ingestion for swine, and the quantity of virus is apparently inversely related to its stability in aerosols.

[10] "For all species, the excretion of airborne virus lasts for 4-5 days. . . . Two periods of aerosol production from exposed animals have been identified The first period, from 30 minutes to 22 hours after exposure, probably corresponds to virus trapped on the bristles, hair, wool and in the lumen of the upper respiratory tract, with virus dislodged by mechanical movement and airflow. The second phase, two to seven days after exposure, follows replication of the virus in the upper respiratory tract." Garner *et al.*, Potential for Wind-Borne Spread of Foot-and-Mouth Disease Virus in Australia, Report prepared for the Australian Meat Research Corporation (1995), p. 10.

[11] Sutmoller *et al.*, Review: Control and Eradication of Foot-and-Mouth Disease, *Virus Research* 91:1 (2003), pp. 107 and 132.

- Shed virus does not necessarily cause infection. As antigens stimulate antibody production in a host, the virus that the host sheds becomes less infectious. "Co-excreted immunologically active components" reduce the risk that normal contact with susceptible livestock will make them sick. So, timing is crucial, although difficult to capture in DSM. The shedding of large amounts of virus should not be equated with direct transmission of disease (e.g., from pigs to cattle), although risks of indirect, delayed transmission may remain. That potential remainder is an important justification for elevated biosecurity at the farm gate.

> *A sharp decline in viral excretion and load occurs during days 4-5 of clinical disease, when a significant antibody titre can be detected. However, it is important to note that although all secretions and excretions . . . are free of detectable infectivity at 10-14 days post-infection, virus already excreted during the preclinical and acute clinical phases can survive in the environment for weeks or even months.*
>
> – Soren Alexandersen *et al.* (2003)[12]

- Exposure to the very small amount of virus in a standard "infective dose" (e.g., the least amount of virus necessary to produce infection among 50% of experimental subjects, MID_{50}) is unlikely to cause infection in most susceptible livestock under normal real-world conditions. Natural transmission, even to naïve cattle in a barnyard, apparently requires much larger, more concentrated, sustained, or repetitive exposure than nearly all the infections that have been induced in laboratory-confined animals or tissue experiments to date. So, the generation and delivery of an "infective dose" should not be equated with the spreading of infection, much less disease.

> *Convalescent or vaccinated pigs have never been shown to be persistently infected. Nor have convalescent pigs been incriminated as a cause of outbreaks.*
>
> – Paul Sutmoller *et al*. (2003)[13]

- FMD virus is too unlikely to blow significant distance with wind to warrant consideration in all but very exceptional circumstances. Unless the infected herd is large, the virus strain amenable, the relative humidity and temperature in the right range, the wind steady, the topography flat and featureless, and the uninfected herd entirely naïve and packed together, directly in the wind's path, virus will probably spread no farther by wind than by the flight path of starlings or the range of local traffic. So, wind-blown virus is among the least likely of causes for what appear to be large "plumes" of infection. The presence or

[12] Alexandersen *et al.,* "The Pathogenesis and Diagnosis of Foot-and-Mouth Disease," *Journal of Comparative Pathology* 129:1 (July, 2003), p. 13.
[13] Sutmoller *et al.*, Review: Control and Eradication of Foot-and-Mouth Disease. *Virus Research* 91:1 (2003), p. 116.

absence of pigs has proven so insignificant a factor in indirect disease transmission that, for better or worse, some standard disease-spread models developed since 2001 no longer even count swine proximity as a parameter.[14]

> *In most epidemiological models aerogenic spread in the pre-clinical stage – especially from pigs – is over-emphasised. The main control effort should be on the prevention of all virus escape from infected premises, and of establishing bio-security precautions for all farms at risk to reduce the possibilities of virus entry.*
>
> – Paul Sutmoller *et al*. (2003)[15]

- Small, scattered herds of pigs are distinctly unlikely to be a source of airborne infection beyond the farm. The longest overland instance on record was 60 KM, at the beginning of the 1967 outbreak in the U.K. Even under simulated conditions that are extraordinarily conducive to wind-borne contagion (i.e., where all else is imagined to be worst-case), recent models place the outer limit of risk for aerosolized disease spread at 20-300 KM for a 1,000-head herd and 6-90 KM for a 100-head herd of swine. So, with an average swine herd-size of just 6 and a maximum of 50, New England dairy farms with pigs are very unlikely to be the source of airborne infection beyond their nearest neighbors. Even under worst-case conditions, ten infected hogs would at most project risk about the same short distance (less than 1 KM) as a hundred infected cattle. So, in terms of potential for airborne infection beyond the farm gate, there is little reason to distinguish farms in New England with pigs and without them.

In short, according to most recent research on conditions required for the availability, distribution, and reception of FMDv, the threat of off-premises contagion from dairy farms with pigs should not be expected to be greater than from dairy farms without them.

> **According to most recent research on conditions required for the availability, distribution, and reception of FMDv, the threat of off-premises contagion in New England from dairy farms with pigs should not be expected to be greater than from dairy farms without them.**

[14] For example: "Pigs . . . were very underrepresented amongst the affected species in the 2001 epidemic [in the U.K]. Subsequent investigations showed that, although the virus spread readily *within* populations of pigs, local spread *between* pig herds was much more limited because of the resistance of pigs to infection by aerosols, the much better biosecurity on pig farms, and legislation unrelated to FMD that regulated the movement of swine from farm to farm. We assume that conditions [for developing a DSM] in Pennsylvania are similar enough to warrant excluding pigs from our model." Tildesley *et al.*, "Modeling the Spread and Control of Foot-and-Mouth Disease in Pennsylvania Following Its Discovery and Options for Control," *Preventive Veterinary Medicine* 104:3-4 (May, 2012), p. 226. See also: Tildeseley *et al.*, Optimal Reactive Vaccination Strategies for a Foot-And-Mouth Outbreak in the UK, *Nature* 440:7080, p. 86.

[15] Sutmoller *et al.*, Review: Control and Eradication of Foot-and-Mouth Disease. *Virus Research* 91:1 (2003), p. 132.

SUMMARY RECOMMENDATIONS

> *This and other* [post-epidemic] *field analyses also indicated that, even for contiguous premises, the most likely route of infection was by carriage on fomites entering through the farm gate, rather than across the contiguous farm boundary, and was therefore susceptible to control by good enforcement of biosecurity.*
>
> – Leonard Mansley *et al*. (2011)[16]

Both farms with and without pigs should be considered highly at-risk during a FMD outbreak and should elevate biosecurity, both for their own protection and for the protection of the farms with which they may be in contact. Clearly, the spread of disease among livestock on a single premises would be easier to control if it had fewer animals and fewer species, but the spread of disease over longer distances, between separated premises, presents a different and more controllable challenge, especially insofar as continuity of operations is an objective.

Pigs are less vulnerable to inhaled (vs. ingested) virus than cattle. So, unless feed is FMD-contaminated, cattle represent a greater risk to pigs than pigs do to cattle. In just hours following infection, even before clinical signs of disease, both pigs and cattle are likely to spread disease directly to other susceptible livestock that share a premises. After a just a few days following incubation, swine-shed virus may no longer be a direct source of infection, but the huge amounts of virus that they previously shed to the environment (e.g., in secretions and excretions of all sorts or anything they touch) can remain hazardous for a much longer time. These are precisely the contaminants that can be most easily transmitted via service traffic and that should be the target of remediation efforts for farms with FMD-susceptible livestock.

Heightened surveillance and elevated biosecurity at the farm gate are most likely to reduce the risk of spreading FMD from one farm to another, no matter what the mix of species. The same minimum Readiness Rating should be equally, albeit imperfectly effective for both.

> **These findings suggest that the same biosecurity and hence minimum Readiness Rating should be required for permitting milk pickup from New England dairy farms with and without pigs.**

[16] Mansley *et al.,* Destructive Tension: Mathematics Versus Experience – The Progress and Control of the 2001 Foot and Mouth Disease Epidemic in Great Britain, *Revue Scientifique et Technique, OIE* 30:2 (2011) p. 493.

APPENDIX

Select Recommendations from the 2013 New England SMS Exercise AAR/IP[17]

4.1 Further development and refinement of the criteria used in the Readiness Model should be considered.
4.4.1 Roadblocks to completing Readiness Reviews and entering info into database should be evaluated and corrected.
4.4.2 State agricultural support and mechanisms for continuing the Farm Readiness Review process need to be confirmed.
4.4.3 Clarify how would prioritize farms that do not participate in review and their impact on validity of Readiness Rating.
4.5.1 Re-evaluate and revise the Readiness Model and Weighing of Readiness Criteria based on discussions during the workshop.

Reviewed vs. Unreviewed Dairy Farms by State, January 2014[18]

	CT	MA	ME	NH	RI	VT	New England
Number of Dairy Farms in NESAASA Database	138	170	297	130	17	970	1,722
Number of Farms Reviewed, as of 1/27/2014	46	116	210	78	16	525	991
Share of Farms Reviewed, as of 1/27/2014	33.3%	68.2%	70.7%	60.0%	94.1%	54.1%	57.6%
Average Readiness Rating of Reviewed Farms	0.568	0.587	0.671	0.578	0.608	0.568	0.593
Number of Farms Not Yet Reviewed	92	54	87	52	1	445	731
Milking Cows Not Counted (If average is the same as for reviewed farms)	12,494	3,553	8,567	5,903	64	57,850	88,431
Milk Production Per Day on Unreviewed Farms (assuming 49 lbs per day per cow)	612,206	174,097	419,783	289,247	3,136	2,834,650	4,333,119

[17] These recommendations are relative to exercise "Objective 4: Practice Implementing Permitting Plan." Appendix A: Improvement Plan, New England Secure Milk Supply Exercise AAR/IP (September 27, 2013), pp. 26-28.
[18] This table, like all of those that follow, are based on reports generated at the end of January, 2013, from the NESAASA database on New England dairy producers. The data belong to their respective New England state and are maintained on a server by the Information Technology group of the Texas Center for Applied Technology in association with National Center for Foreign Animal and Zoonotic Disease Defense (FAZD).

FMD-Susceptible Livestock on Reviewed Dairy Farms by State, January 2013

Dairy Cattle

	CT	MA	ME	NH	RI	VT	New England
Number of Milking Cows (among dairy stock) on Reviewed Farms	6,247	7,632	20,678	8,855	1,089	68,050	112,551
Largest Number of Milking Cows on a Reviewed Farm	1,030	427	1,640	1,047	260	1,750	1,750
Average Number of Milking Cows on Reviewed Farms	136	66	98	114	68	130	114
Number of Other Dairy Cattle (dry, heifer, calf, bull) on Reviewed Farms	7,869	7,925	24,698	9,744	920	60,372	111,528
Average Number of Other Dairy Cattle on Reviewed Farms	171	68	118	125	56	115	113
Largest Number of Other Dairy Cattle on a Reviewed Farm	1,174	316	2,155	1,545	145	1,290	2,155
Total Number of Dairy Cattle on Reviewed Farms	14,116	15,557	45,376	18,599	2,009	128,422	224,079
Average Number of Dairy Cattle on Reviewed Farms	307	134	216	238	126	245	226
Largest Number of Dairy Cattle on a Reviewed Farm	2,204	675	3,795	2,592	405	2,512	2,592

Beef Cattle

	CT	MA	ME	NH	RI	VT	New England
Total Number of Beef Cattle on Reviewed Farms	404	170	1,333	342	65	986	3,300
Number of Reviewed Farms with Beef Cattle	17	22	57	28	5	123	252
Number of Reviewed Farms with More Beef Cattle Than Milking Cows	2	2	4	0	0	2	
Share of Reviewed Farms with Beef Cattle	37.0%	19.0%	27.1%	35.9%	29.4%	23.4%	25.4%
Largest Number of Beef Cattle on a Reviewed Farm	150	27	350	150	50	70	350
Average Number of Beef Cattle per Reviewed Farm with Beef Cattle	24	8	23	12	13	8	13

Swine

	CT	MA	ME	NH	RI	VT	New England
Number of Reviewed Farms with Swine	5	15	30	17	1	55	123
Number of Reviewed Farms with More Pigs Than Milking Cows	0	3	1	0	0	2	6
Share of Reviewed Farms with Swine	10.9%	12.9%	14.3%	21.8%	5.9%	10.5%	12.4%
Total Number of Milking Cows on Reviewed Farms with Pigs	205	928	1,673	1,317	44	6,085	10,252
Average Number of Milk Cows Per Reviewed Farm with Pigs	41	62	56	77	44	111	83
Average Readiness Rating of Reviewed Farms with Pigs	0.627	0.600	0.662	0.595	0.612	0.595	0.613
Average Readiness Rating of Reviewed Farms with No Pigs	0.560	0.585	0.673	0.573	0.608	0.564	0.590
Total Number of Pigs on Reviewed Farms	31	159	142	89	11	274	706
Largest Number of Pigs on a Reviewed Farm	20	40	51	22	11	43	51
Average Number of Pigs per Reviewed Farm with Pigs	6	11	5	5	11	5	6
Milk at-Risk Per Day if Farms with Swine Stopped Shipping (assuming 49 lbs per day per cow)	10,045	45,472	81,977	64,533	2,156	298,165	502,348

Sheep

	CT	MA	ME	NH	RI	VT	New England
Total Number of Sheep on Reviewed Farms	143	66	222	68	1	677	1,177
Number of Reviewed Farms with Sheep	5	8	9	7	8	20	57
Number of Reviewed Farms with More Sheep Than Milking Cows	2	1	2	0	0	1	6
Share of Reviewed Farms with Sheep	10.9%	6.9%	4.3%	9.0%	47.1%	3.8%	5.8%
Largest Number of Sheep on a Reviewed Farm	97	25	101	28	8	400	400
Average Number of Sheep per Reviewed Farm with Sheep	29	8	25	10	0	34	21

Goats

	CT	MA	ME	NH	RI	VT	New England
Total Number of Goats on Reviewed Farms	194	488	102	20	14	1,681	2,499
Number of Reviewed Farms with Goats	4	18	16	5	4	41	88
Number of Reviewed Farms with More Goats Than Milking Cows	1	6	1	2	0	10	20
Share of Reviewed Farms with Goats	8.7%	15.5%	7.6%	6.4%	23.5%	7.8%	8.9%
Largest Number of Goats on a Reviewed Farm	169	203	50	7	6	300	300
Average Number of Goats per Reviewed Farm with Goats	49	27	6	4	4	41	28

Llamas

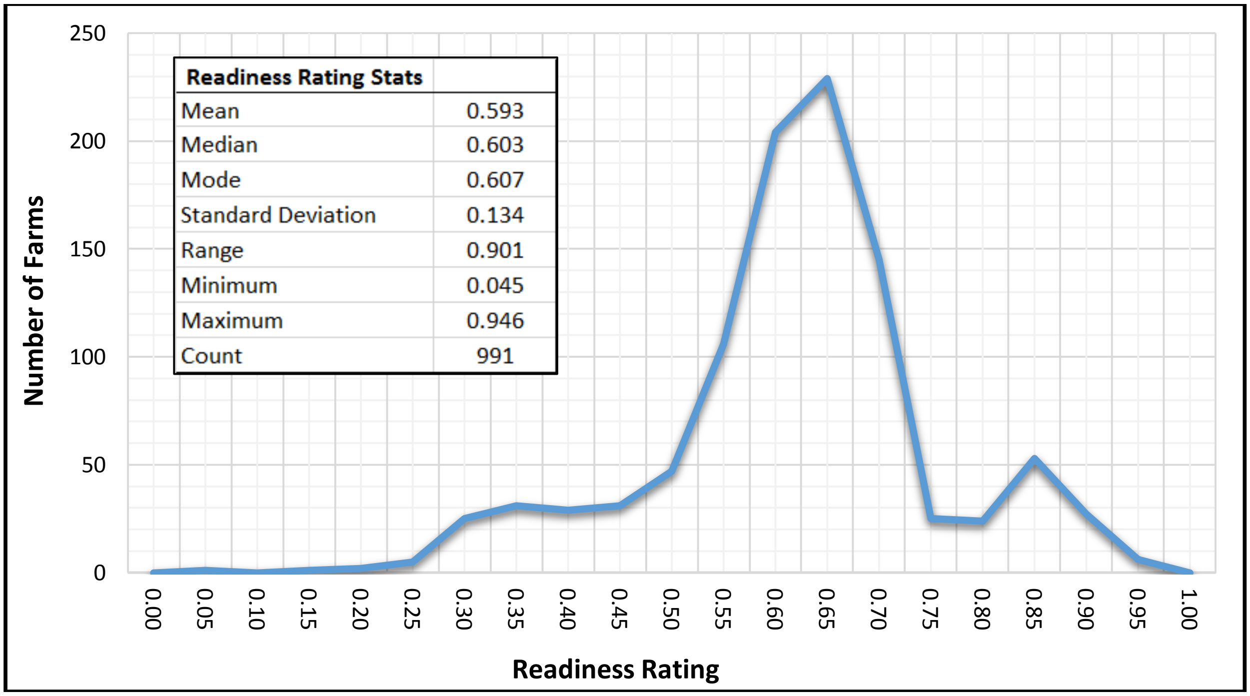
	CT	MA	ME	NH	RI	VT	New England
Total Number of Llamas on Reviewed Farms	2	7	3	1	1	43	57
Number of Reviewed Farms with Llamas	2	2	1	1	1	12	19
Number of Reviewed Farms with More Llamas Than Milking Cows	0	0	0	0	0	2	2
Share of Reviewed Farms with Llamas	4.3%	1.7%	0.5%	1.3%	5.9%	2.3%	2.0%
Largest Number of Llamas on a Reviewed Farm	1	5	3	1	1	18	18
Average Number of Llamas per Reviewed Farm with Llamas	1	4	3	1	1	4	2

Farmed Deer

	CT	MA	ME	NH	RI	VT	New England
Total Number of Farmed Deer on Reviewed Farms	0	0	0	0	0	0	0
Share of Reviewed Farms with Farmed Deer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Number of Reviewed Farms with Farmed Deer	0	0	0	0	0	0	0
Number of Reviewed Farms with More Farmed Deer Than Milking Cows	0	0	0	0	0	0	0
Largest Number of Farmed Deer on a Reviewed Farm	0	0	0	0	0	0	0
Average Number of Farmed Deer per Reviewed Farm with Farmed Deer	0	0	0	0	0	0	0
Total Number of Farmed Deer on Reviewed Farms	0	0	0	0	0	0	0

Readiness Ratings of Reviewed Farms, January 2014

Number of Farms by Readiness Rating



Number of Farms over a Minimum Readiness Rating (Cumulative Frequency)

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