USDA Animal and Plant Health Inspection Service
U.S. DEPARTMENT OF AGRICULTURE

2022–2023 Highly Pathogenic Avian Influenza Outbreak

Summary of Depopulation Methods and the Impact on Lateral Spread

Key Points:

- Reported observations are subject to biases due to data availability and quality. Associations reported are based on descriptive evaluation of the data available from a subset of infected commercial premises (69 percent; 221/325) and are not supported by any statistical analyses. Available anecdotal reports have been incorporated where applicable.
- The median time to complete premises depopulation following a confirmed diagnosis has been substantially shorter during the 2022–2023 outbreak when compared to the 2014–2015 outbreak.
- The use of ventilation shutdown plus heat (VSD+) in the 2022–2023 outbreak has reduced the percentage of commercial turkey premises depopulated using foam and changed the primary depopulation method for commercial table egg premises from carbon dioxide (CO_2) to VSD+. VSD+ has been used in the 2022-2023 outbreak under constrained circumstances to meet the 24–48-hour depopulation goal established after the 2014-2015 outbreak.
- During the 2022–2023 outbreak, VSD+ was used alone, or in combination with other methods, on 49 percent of commercial turkey, 85 percent of commercial table egg, 44 percent of commercial broiler, and 29 percent of commercial duck premises.
- The choice of depopulation method was heavily associated with the States of the infected premises. State-level, production-system influences, and depopulation resource availability (i.e., people, supplies, equipment) should be considered when drawing conclusions about depopulation methods and lateral spread.
- House-level factors including bird age, infection status and/or observation of clinical signs were associated with the use of VSD+.
- A subset of States that initially used VSD+ in the depopulation response transitioned to other methods as the number of detections increased. This may reflect a change in resource availability.
- The percentage of premises that completed depopulation within 24 hours of starting were 83 percent (134/161) of commercial turkey, 86 percent (6/7) of commercial broiler, 79 percent (11/14) of commercial duck, and 38 percent (3/8) of commercial gamebird premises. Commercial table egg premises took substantially longer to depopulate (range: 1–17 days).
- For commercial turkey, broiler, and duck houses, the median time to complete depopulation using VSD+ was longer than foam. For commercial table egg houses, depopulation by CO_2 took substantially longer than depopulation by VSD+. These differences are attributable to the differences in logistics and requirements for implementing depopulation methods.

- None of the primary depopulation methods consistently achieved 100 percent mortality. Secondary depopulation methods were used for 38 percent (273/724) of commercial turkey, 59 percent (168/281) of commercial table egg, 35 percent (12/34) of commercial broiler, 29 percent (19/66) of commercial duck, and 14 percent (3/21) of commercial gamebird houses.

OVERVIEW

The current 2022–2023 outbreak of highly pathogenic avian influenza (HPAI) is the largest and longest outbreak in the history of the United States. The previous record-breaking outbreak occurred in 2014–2015, with 225 poultry premises containing more than 50.5 million infected birds. The outbreak lasted over six months, with the first and last infections confirmed on 11 December 2014 and 22 June 2015, respectively. The first detection of HPAI in the current 2022–2023 outbreak occurred on 8 February 2022, and as of 31 August 2023, the National Veterinary Services Laboratory (NVSL) confirmed 839 cases impacting nearly 58.8 million birds. Among the 850 HPAI cases, 325 cases occurred on commercial poultry premises and included 227 commercial turkey, 37 commercial table egg, 27 commercial broiler, 17 commercial duck, 16 commercial gamebird, and 1 commercial goose breeder premises. One critical component of the outbreak response is the rapid identification and depopulation of infected premises to prevent lateral spread. During the 2015 outbreak, various factors related to the methods used caused multiple delays in the depopulation of premises. Concern that delayed depopulation may have contributed to the lateral spread of HPAI in 2015 led to the United States Department of Agriculture (USDA) implementing a 24- to 48-hour goal for depopulation following a confirmed detection.[1]

While multiple methods exist to depopulate commercial poultry premises, the 2022–2023 outbreak response used ventilation shutdown plus heat (VSD+) to help achieve the 24- to 48-hour depopulation goal. As implied, VSD+ involves shutting down barn ventilation systems, adding heat, and allowing heat, humidity, and CO_2 to accumulate, ultimately leading to the deaths of the animals. Available data for this depopulation method suggests barns should reach a temperature of 104° F to 110° F within 30 minutes and maintain this temperature range for a minimum of 3 hours. While VSD+ is permitted by the American Veterinary Medical Association (AVMA) under constrained circumstances,[2] use of the method has received scrutiny. Since VSD+ has been a critical tool in the 2022–2023 outbreak response, the purpose of this analysis is to look at the impact of VSD+ on the current outbreak, including the factors contributing to the use of VSD+ and the impact on response timelines, animal welfare, and lateral spread.

[1]https://www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/ventilationshutdownpolicy.pdf
[2]https://www.avma.org/sites/default/files/resources/AVMA-Guidelines-for-the-Depopulation-of-Animals.pdf

APPROACH

The USDA uses the Emergency Management Response System (EMRS)as the official system of record for recording foreign animal disease investigations, surveillance and control programs, State-specific disease outbreaks, and national animal health emergency responses. In an HPAI outbreak event, data can be entered and maintained during the active response and then archived. While EMRS existed in 2015, the amount of data recorded and maintained in EMRS has substantially improved during the 2022–2023 outbreak. Data in EMRS used for this analysis includes premises investigation and disease statuses, laboratory testing submissions, monitoring depopulation reports, and appraisal data. Data can be reported at the premises and house levels, with premises-level information capable of being queried, and house-level data uploaded in the form of PDFs. Field responders and analysts can query and view data of interest using default or customized data views and the data in these views can then be downloaded for analysis. Regarding depopulation and disposal, customized view creation is available to report premises-level details, including the depopulation start and stop times, depopulation methods used, the number of animals depopulated, and associated comments.

Analysts at the USDA Center for Epidemiology and Animal Health (CEAH) used the house-level HPAI Monitoring Depopulation Report forms uploaded into EMRS for each poultry house depopulated on an infected premises to assess the rationale behind method selection, the impact on depopulation timelines, and potential lateral spread. Each report included the setup and preparation activity information and time, the primary depopulation method, and if secondary depopulation was required. The forms also contained several comment sections for responders to provide additional information. It is important to note that these forms were developed at the start of the 2022–2023 HPAI outbreak to assist field responders in their oversight of premises depopulation. These forms were not originally intended to be used for a technical analysis of depopulation methods and were not formally monitored for data quality; because of this, the quality of these forms varied substantially. When available, report PDFs were downloaded for each premises, and the available information was extracted. Additionally, other data in EMRS, including lab submissions, epidemiological interviews, and appraisal forms, were manually obtained to identify house-level variables of interest.

DATA

This report includes commercial premises confirmed infected by the NVSL on or before 31 August 2023. Premises considered backyard producers or non-poultry premises[3] by the World Organisation for Animal Health were excluded from the analysis since VSD+ was only used on commercial premises. As of 31 August 2023, individual house-level HPAI monitoring depopulation reports were available for 69 percent (221/325) of commercial detections. For the remaining 104 detections, reports were not available, were not in a standard format, or were combined. Combined reports included single-page summary reports that outlined dates and methods used per house, and single house-level HPAI monitoring depopulation reports describing multiple houses. Commercial detections included a total of 17 commercial

[3] https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id=169&L=1&htmfile=glossaire.htm#terme_volailles

production types. For analysis, production types were grouped by their production species (e.g., turkey, egg layer, broiler, duck, and gamebird).For example, commercial table egg layer, table egg breeder, and table egg pullet farms were all grouped together into the table egg species. By production group, individual house reports were available for 77 percent (174/227) of commercial turkey, 62 percent (23/37) commercial table egg, 26 percent (7/27) commercial broiler, 76 percent (13/17) commercial duck, and 19 percent (3/16) commercial gamebird premises. When possible, data was extracted from non-standard or combined reports and included in the analysis. Analysts transcribed data from the reports to produce a dataset for the analysis of the depopulation conducted during the 2022–2023 HPAI outbreak response. For ease of analysis, house-level primary depopulation methods were grouped into four categories: foam, VSD+, CO_2, and individual. The CO_2 category included CO_2 carts and CO_2 tenting. The individual category included cervical dislocation, captive bolt, turkey euthanasia device (TED), Koechner Euthanizing Device (KED), and gunshot.

RESULTS

The following results are based on patterns observed in the descriptive data. These observations are not currently supported by formal statistical analysis. All inferences made are subjective and do not necessarily reflect the full rationale behind depopulation method choices. Analysis was conducted on the available data, and the quality of data from house-level reports varied significantly. In most cases, analysts did not further verify the data on the forms. Additionally, the exclusion of premises without individual house-level depopulation reports may bias the analysis. Analysts made efforts to clean data and verify outlier observations when reports were transcribed into a working dataset and analyzed.

A. Overview of Depopulation Methods Used

House-level depopulation reports included responses for both primary and secondary depopulation methods. The primary method refers to the main method of depopulation, while the secondary method refers to the method used to depopulate birds that did not succumb to the primary method. The primary depopulation methods used in the 2022–2023 outbreak included water-based foam, VSD+, CO_2, and individual depopulation via cervical dislocation, captive bolt, and KEDS and/or TEDS (Table 1). Combinations of multiple primary depopulation methods were frequently used to achieve depopulation of all houses on infected premises. At the premises-level, foam alone was the most frequently used method for the depopulation of commercial turkey, broiler, and duck premises; only VSD+ was the most frequent method for commercial table egg premises; and CO_2 and individual depopulation were used for commercial gamebird premises. Foam was used to some extent on 80 percent and VSD+ was used on 49 percent of commercial turkey premises. For commercial table egg premises, VSD+ was used on 85 percent while CO_2 was used on 33 percent of premises. Among the other production species, which contributed fewer observations to the dataset, foam was used in some capacity on 67 percent of commercial broiler, 47 percent of commercial duck, and 25 percent of commercial gamebird premises, while VSD+ was used to some degree for 44 percent of commercial broiler and 29 percent of commercial duck premises.

Table 1. Reported primary depopulation methods by commercial production species at the premises and house levels.

Premises-level Primary Depopulation Methods					
Depopulation Method(s)	Turkey	Table Egg	Broiler	Duck	Gamebird
Foam	43.6% (79/181)	0.0% (0/27)	55.6% (5/9)	35.3% (6/17)	12.5% (1/8)
VSD+	17.7% (32/181)	63.0% (17/27)	22.2% (2/9)	17.6% (3/17)	0.0% (0/8)
CO_2	0.6% (1/181)	14.8% (4/27)	0.0% (0/9)	11.8% (2/17)	37.5% (3/8)
Individual	2.2% (4/181)	0.0% (0/27)	0.0% (0/9)	17.6% (3/17)	37.5% (3/8)
Foam, VSD+	24.9% (45/181)	0.0% (0/27)	11.1% (1/9)	5.9% (1/17)	0.0% (0/8)
Foam, CO_2	0.6% (1/181)	0.0% (0/27)	0.0% (0/9)	0.0% (0/17)	12.5% (1/8)
Foam, Individual	3.9% (7/181)	0.0% (0/26)	0.0% (0/9)	5.9% (1/17)	0.0% (0/8)
VSD+, CO_2	0.0% (0/181)	18.5% (5/27)	0.0% (0/9)	0.0% (0/17)	0.0% (0/8)
VSD+, Individual	0.0% (0/181)	3.7% (1/27)	11.1% (1/9)	5.9% (1/17)	0.0% (0/8)
Foam, VSD+, Individual	6.6% (12/181)	0.0% (0/27)	0.0% (0/9)	0.0% (0/17)	0.0% (0/8)
Total	100% (181/181)	100% (27/27)	100% (9/9)	100% (17/17)	100% (8/8)
House-level Primary Depopulation Methods					
Depopulation Method	Turkey	Table Egg	Broiler	Duck	Gamebird
Foam	60.1% (435/724)	0% (0/281)	61.8% (21/34)	45.5% (30/66)	28.66% (6/21)
VSD+	34.1% (247/724)	71.2% (200/281)	35.3% (12/34)	16.7% (11/66)	0% (0/21)
CO_2	1.2% (9/724)	28.5% (80/281)	0% (0/34)	28.8% (19/66)	52.4% (11/21)
Individual	4.6% (33/724)	0.4% (1/281)	2.9% (1/34)	9.1% (6/66)	19.0% (4/21)
	100% (724/724)	100% (281/281)	100% (34/34)	100% (66/66)	100% (21/21)

B. Factors Influencing Method Selection

The selection of depopulation methods can be complex and influenced by State-level response, resource availability and constraints, disease burden, and company structures or management systems. Acknowledging that nuances are not always reflected in static data, CEAH analysts were interested in identifying any factors or patterns associated with depopulation method selection. Premises-level factors of interest included the State of premises location, the number of previous detections in the State, the number of premises pending depopulation, and the number of commercial poultry premises located within the control area (10-km radius) at the time of detection. House-level factors of interest were the number of birds in the house, the age of the birds, and the house infection status. All house-level factors were manually matched to house-level depopulation reports using data available in the USDA EMRS database. To determine the house infection status, laboratory accession data was matched to house-level depopulation reports. Matched houses that tested positive for HPAI were considered "confirmed infected" for analysis; all other houses were not. Frequently, only the index house on each premises was tested, leaving the infection status of other houses unknown. It is possible some houses were misclassified as "not infected."

The premises State may influence the depopulation method choice since the outbreak response is managed at the State level, and outbreak response preparedness and resources may vary across States. Figure 1 depicts the premises-level depopulation method(s) by commercial production species and State. The premises-level method(s) was obtained by combining methods reported within individual house-level reports for each premises.

For commercial turkey premises, depopulation method(s) appears to be influenced by the State. For example, Minnesota typically used a single primary depopulation method, with foam being the most common. In contrast, South Dakota frequently used a combination of foam and VSD+ to depopulate infected turkey premises. Iowa and Utah also frequently used a single primary depopulation method, with VSD+ followed by foam being the most common. With the exception of North Dakota, which mirrored the methods of South Dakota, the remaining States that contributed commercial turkey observations to the dataset predominantly used foam as the primary method of depopulation.

For commercial table egg premises, VSD+ was the primary depopulation method for analyzed premises in Iowa, Maryland, Nebraska, and Pennsylvania. Colorado, South Dakota, Utah, and Wisconsin used CO_2 in some capacity.

The remaining production species contributed fewer premises to the analyzed dataset. Four States contributed commercial broiler premises; Arkansas used foam, whereas California, Pennsylvania, and Tennessee used both foam and VSD+. The methods used for depopulation of commercial duck premises varied across the four States that contributed observations to the analysis: Pennsylvania depopulated commercial duck premises using various combinations of foam, VSD+, and individual methods; California used either CO_2 or foam; Indiana only used individual depopulation methods; and Wisconsin used a combination of foam and individual methods. For depopulation of commercial gamebirds, California, Colorado, and Idaho used CO_2. South Dakota used

either foam or individual depopulation methods, while Wisconsin used a combination of foam and individual methods.

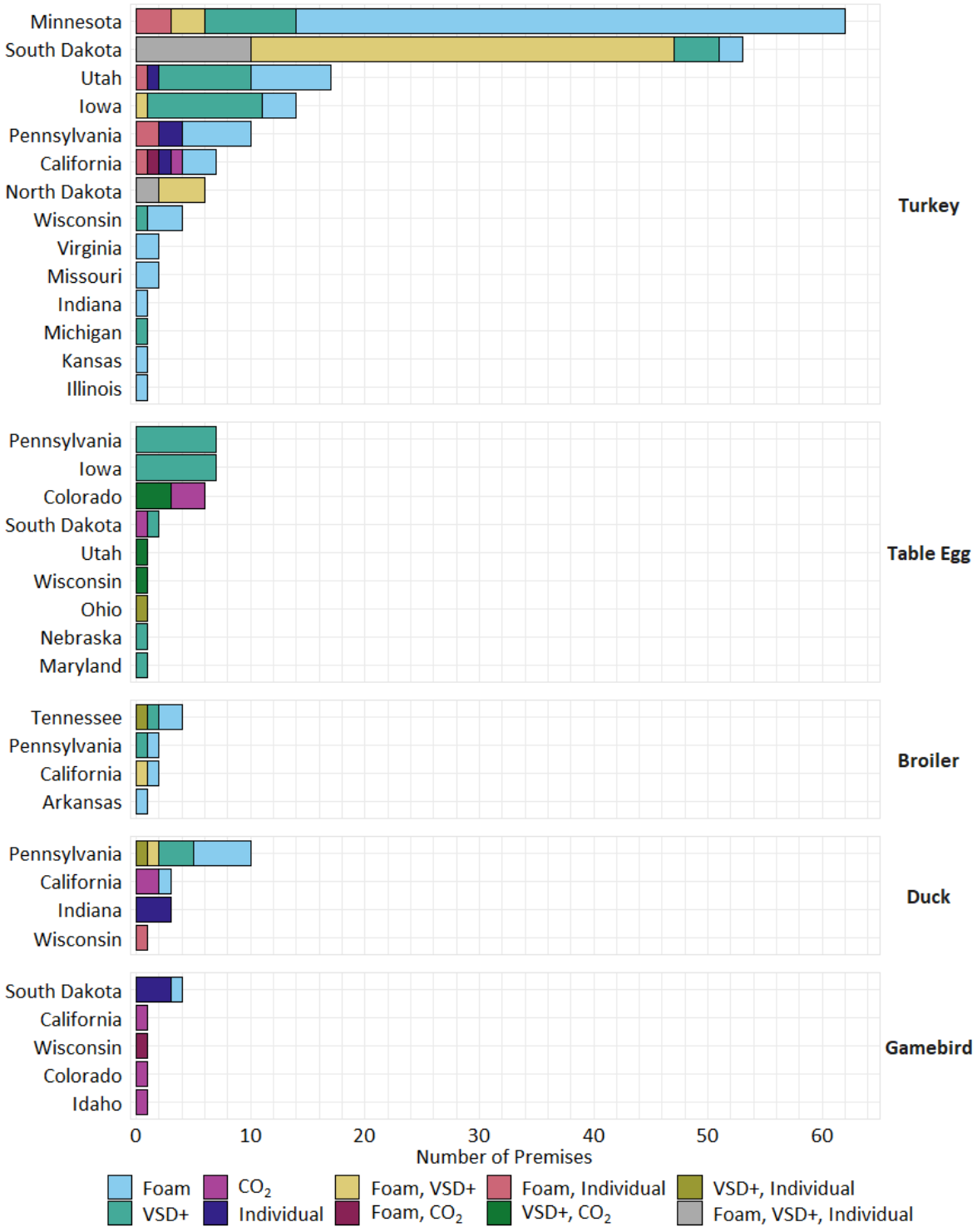

Figure 1. Premises-level depopulation methods for analyzed premises by commercial production species and State. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

Examining premises-level depopulation methods by the number of previous detections in the State or relative order of detection can potentially provide insight to resource availability. Figure 2 uses color to indicate premise-level depopulation methods and reflects a relative detection timeline for States contributing four or more premises to the dataset. Various patterns can be observed for each State, and for some States, such as Iowa, Minnesota, North Dakota, and South Dakota, method choice does not seem to be impacted by the relative time of detection. Each of these States appear to have had a predominate response method, with deviations from this method occurring randomly across the relative detection timeline. Other States, such as Colorado, Pennsylvania, and Utah, appear to have initially used VSD+ in some capacity and then transitioned to other methods of depopulation as the relative number of detections increased. This may reflect changes in resource availability.

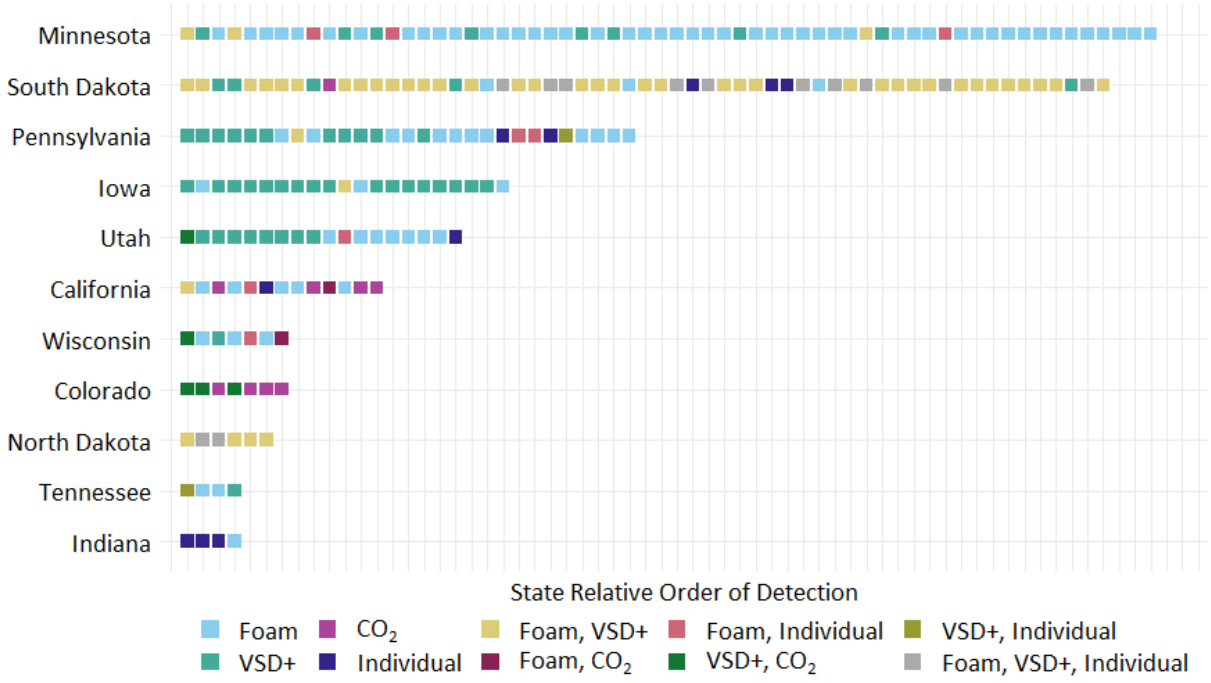

Figure 2. Premises-level depopulation methods by State and relative order of detection.

CEAH analysts also examined the premises-level depopulation method by the number of premises pending depopulation (Figure 3). An increase in the number of premises awaiting depopulation may reflect a rapid increase in a State's detections and could represent a burden on their depopulation resources, which could influence depopulation method choice. When analysts examined States that contributed five or more premises to the dataset, no apparent trends were observed across the States.

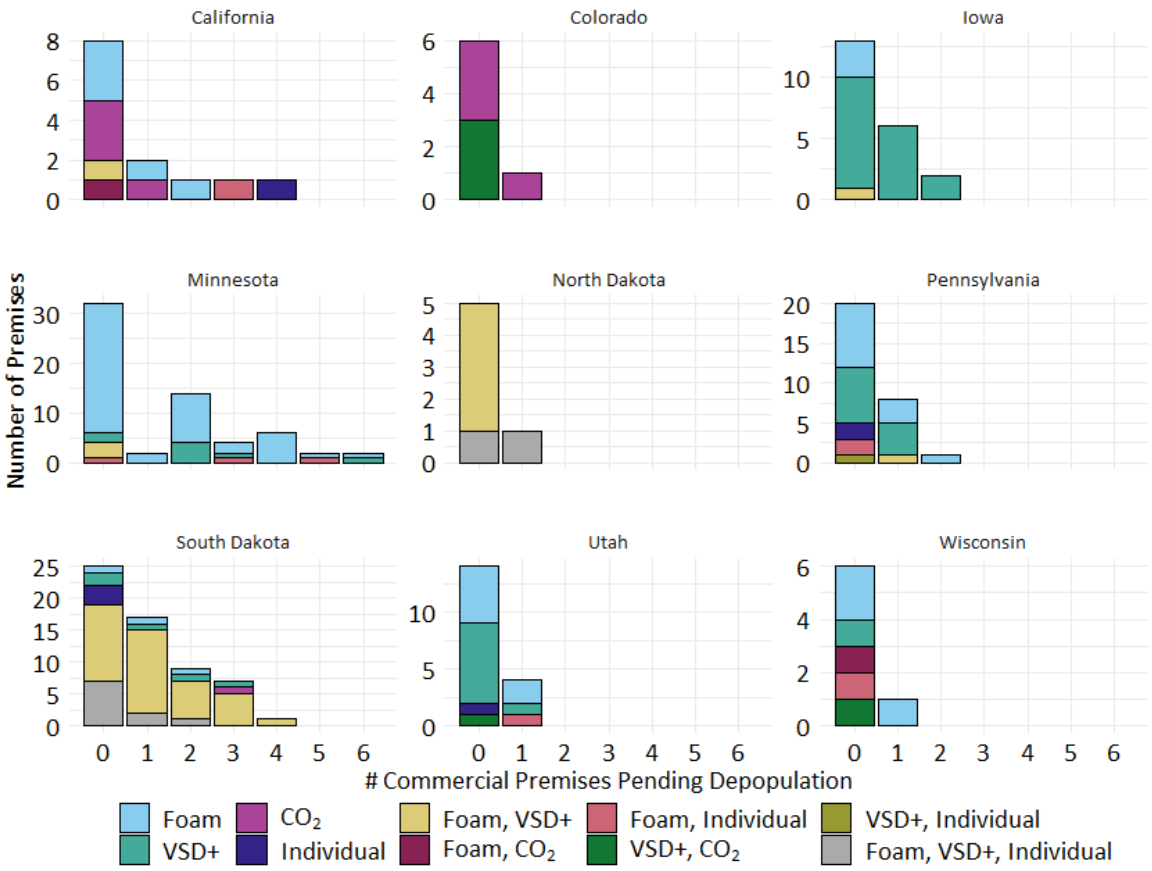

Figure 3. Primary depopulation method(s) used by State and number of premises pending depopulation (includes States with 5 or more detections).

Analysts were also interested in whether the local density of commercial poultry premises influenced the choice of depopulation method(s). In high-density areas, the desire to rapidly depopulate infected premises to prevent virus amplification and local spread may have influenced method choice. To analyze the potential association of commercial poultry premises density and depopulation method(s) choice, the number of commercial poultry premises within the infected premises control area (10-km radius) was examined. Figure 4 provides distribution summaries of the number of premises in the control area by commercial production species and depopulation method(s). For commercial turkey premises, the top three depopulation methods were foam, VSD+, and a combination of foam and VSD+. Within these categories, the median number of

premises in the control area was the greatest for foam depopulation (median: 15, range: 1–201 premises) followed by VSD+ (median: 6.5, range: 1–49 premises), and foam and VSD+ (median: 2, range: 1–57 premises). When evaluating this comparison, it is important to consider how the observed associations are influenced by the State-level depopulation response and how commercial poultry density varies by State. For example, Minnesota, the top commercial turkey-producing State, predominantly used foam in their depopulation response and accounted for a substantial portion of premises analyzed. For commercial table egg premises, VSD+ was the predominant method of depopulation and had the greatest number of commercial poultry premises in the control area when used (median: 8, range: 1–75 premises). Associations for the remaining commercial production species can be observed in Figure 4.

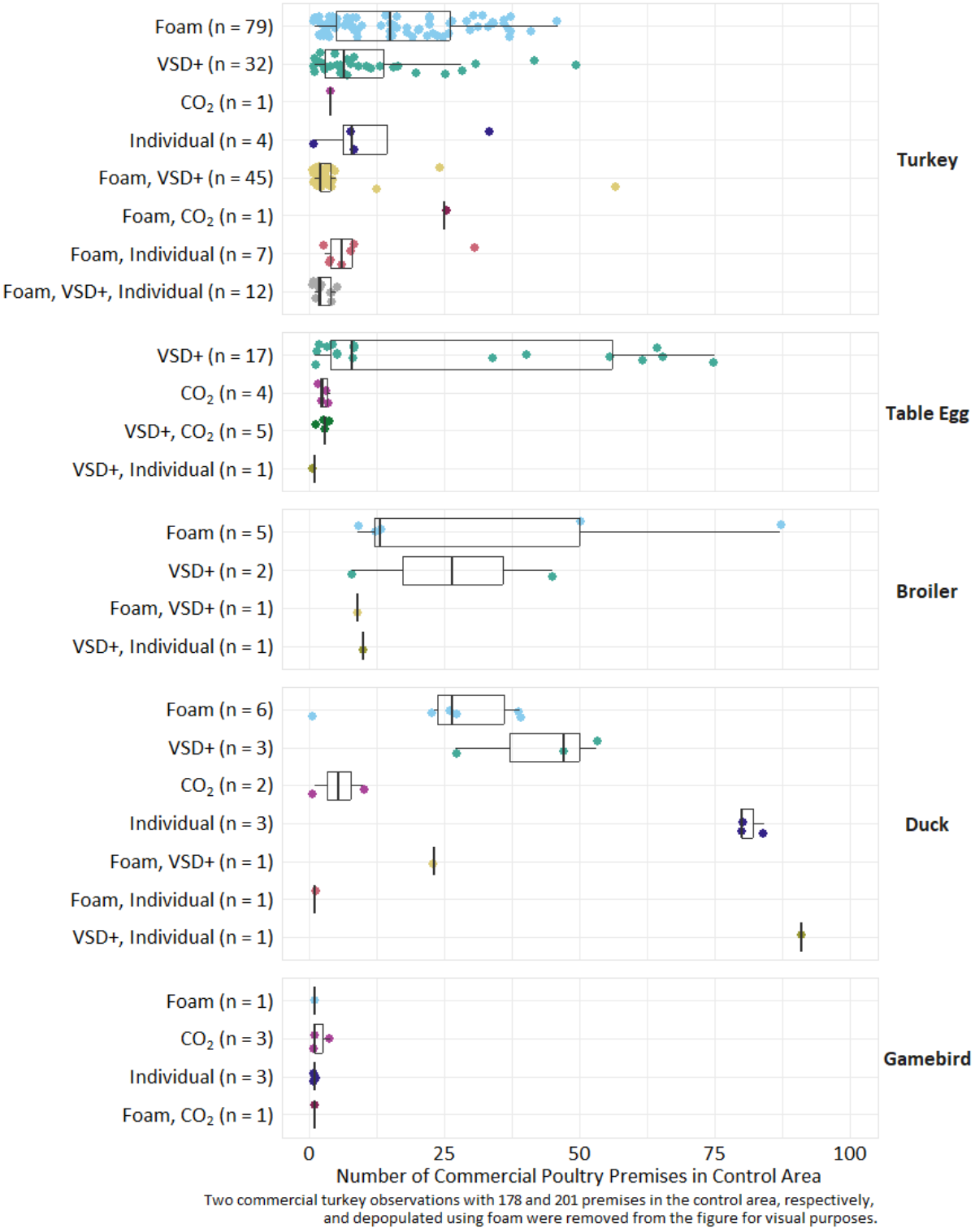

Figure 4. Distributions of the number of commercial poultry premises in the control area (10-km radius) of infected premises by commercial production species and premises-level depopulation method(s) (*n* = number of houses contributing to the summary boxplot distribution, shown here as individual points). Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

House-level factors examined included the number of birds in the house, the age of the birds, and whether the house was confirmed infected. Table 2 provides house-size summary distributions by commercial production species and the house-level depopulation method. Discrepancies between house numbers in Table 1 and Table 2 reflect data availability. For commercial turkey premises, the number of birds per house had little variation across house-level depopulation methods. Further investigation of the houses on commercial turkey premises depopulated using individual methods indicated that most of these houses either contained laying chickens for personal use, breeder flocks, or were houses in which the majority of the birds succumbed to disease prior to depopulation. Some variation in house size by method was observed for commercial table egg, commercial broiler, and commercial duck houses. For these production species, the median sizes of houses depopulated using VSD+ was greater than other depopulation methods. The one commercial table egg house depopulated using individual depopulation methods reported greater than 90 percent disease-associated mortality prior to depopulation. Use of VSD+ over CO_2 can reflect resource availability or method feasibility since CO_2 may be a more time- and resource-intensive method on large table egg layer houses.

Table 2. Distribution of house number of birds by commercial production species and house-level primary depopulation method.

Commercial Turkey Houses						
Depopulation Method	# Houses	Min.	p25	Median	p75	Max.
Foam	430	240	6,498	10,127	14,667	52,262
VSD+	229	1,091	8,734	10,275	14,264	27,556
CO_2	9	6,403	7,729	7,773	7,818	24,724
Individual	33	27	250	500	2,864	13,680
Commercial Table Egg Houses						
Depopulation Method	# Houses	Min.	p25	Median	p75	Max.
VSD+	151	1,357	78,292	94,352	186,393	425,000
CO_2	70	14,444	20,569	26,696	52,640	204,165
Individual	1			228,715		
Commercial Broiler Houses						
Depopulation Method	# Houses	Min.	p25	Median	p75	Max.
Foam	21	893	10,929	11,667	27,800	40,744
VSD+	12	9,958	25,000	33,226	33,865	34,224
Individual	1			11,000		
Commercial Duck Houses						
Depopulation Method	# Houses	Min.	p25	Median	p75	Max.
Foam	25	636	2,966	5,229	6,882	26,211
VSD+	11	5,531	9,090	14,300	18,708	39,600
CO_2	19	39	1,431	1,722	2,544	6,768
Individual	6	501	3,119	4,061	6,042	8,749
Commercial Gamebird Houses						
Depopulation Method	# Houses	Min.	p25	Median	p75	Max.
Foam	4	13,100		45,475		59,350
CO_2	4	3,500		5,000		14,700
Individual	4	174		512		800

Min. = minimum; p25 = 25th percentile; p75= 75th percentile; Max. = maximum

Figure 5 presents summary distributions of house-level bird age by commercial production species and primary depopulation method. The age of birds in commercial turkey houses depopulated by VSD+ (median: 109, range: 4–350 days) appears to be slightly older than in houses depopulated by foam (median: 76, range: 1–385 days). Age distributions by depopulation method appear similar for commercial table egg premises. For commercial broiler houses, the age of birds in houses depopulated by foam (median: 112, range: 24–427 days) is greater than in houses depopulated by VSD+ (median: 35, range: 26–273 days). A similar pattern was observed for commercial duck houses where the median age for foam was 273 days (range: 7–609 days), compared to 39 days (range: 11–51 days) for VSD+. Further investigation of these differences in age distribution identified the use of foam on breeder premises, compared to VSD+ on commercial meat bird premises. This suggests specific premises types within commercial production categories may have influenced method choice.

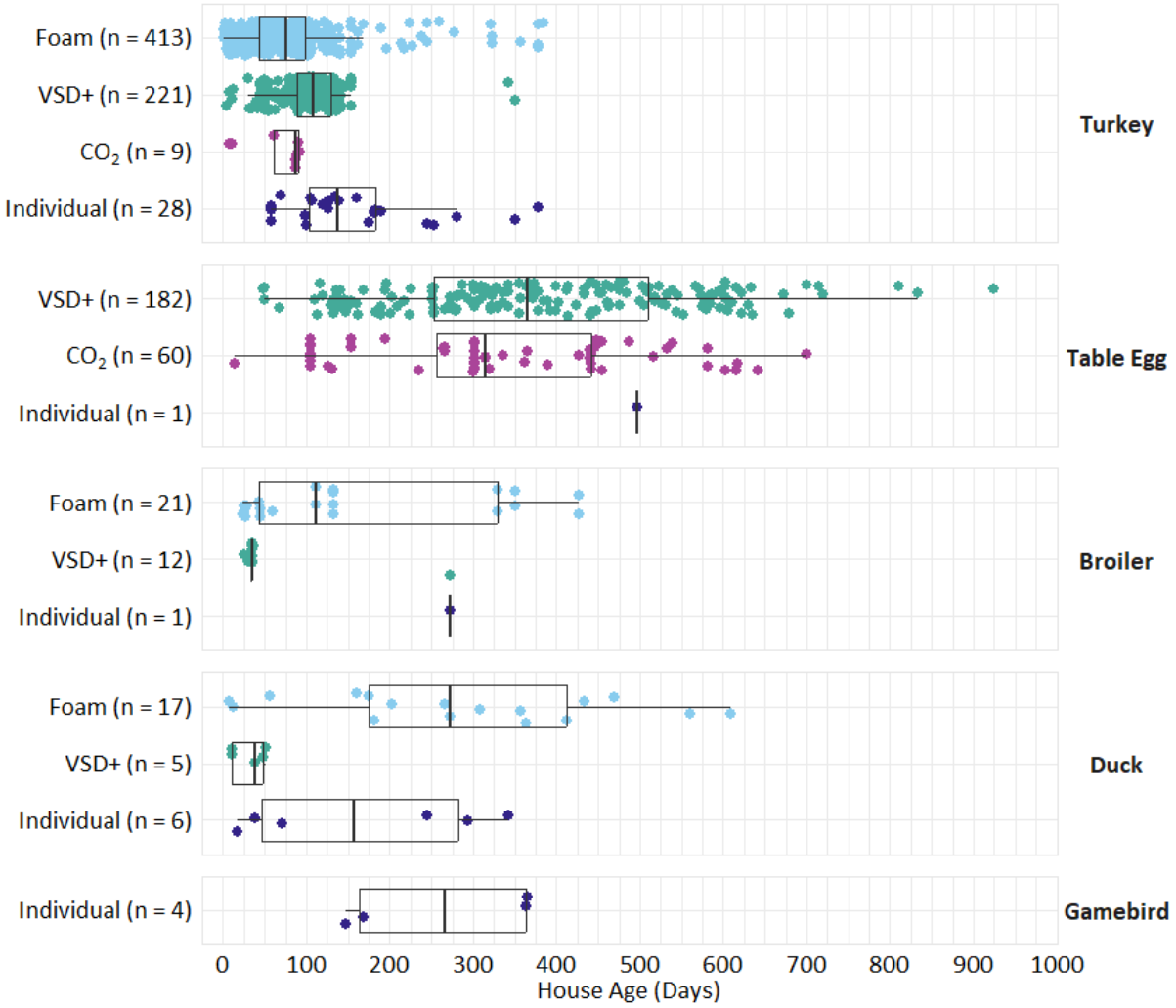

Figure 5. Distributions of house age by commercial production species and house-level primary depopulation method (*n* = number of houses contributing to the summary boxplot distribution, shown here as individual points). Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

Confirmation of HPAI in at least one house on a commercial premises resulted in depopulation of the entire premises. CEAH analysts were interested in whether the house-level infection status influenced the depopulation method, specifically on premises that used a combination of depopulation methods. Analysts reviewed laboratory accession data and manually matched test results to house-level depopulation data, when available. In many cases, when a premises was located outside of an outbreak response zone, laboratory testing was only performed for the index house that initially exhibited clinical signs. For the analysis of house infection status, the absence of matched test results was assumed to be a null response, meaning the house was assumed not infected. Table 3 shows the proportion of houses confirmed infected by house-level depopulation method on premises that used a combination of depopulation methods. For commercial turkey premises that used foam in combination with other depopulation methods, the proportion of houses confirmed infected was greater for the non-foam methods than the foam methods. This could indicate that known-infected houses were more likely to be depopulated using VSD+, CO_2, or individual depopulation methods. Input from the National Incident Coordinators (NICs) confirmed this observation and further indicated that additional barns exhibiting clinical signs were prioritized for depopulation.[4]

For floor-raised birds, several States implemented a method wherein only the clinically-affected barns on a premises were depopulated by VSD+, and all remaining barns were depopulated via foaming. This provided a swift depopulation method for clinically-impacted barns, thus limiting further spread to other barns on the same premises or to other premises in close geographic proximity. This method also limited VSD+ to a smaller number of birds and used an AVMA-preferred method for all other birds on the same premises. Additionally, there were instances where VSD+ was only used in a subset of barns on a floor-raised or cage-housed premises that met barn structure requirements for its effective implementation; additional depopulation methods were then used on the remaining barns that did not meet this requirement (e.g., older, damaged, or open-sided barns).

[4] National Incident Coordinators, personal communications, September 18, 2023, and September 21, 2023.

Table 3. Percentage of houses confirmed infected* by house-level depopulation method for only premises using a combination of primary depopulation methods.

	House-level Primary Depopulation Method			
Production Species	**Foam**	**VSD+**	**CO_2**	**Individual**
Turkey	12% (19/158)	51.50% (51/99)	100% (1/1)	61.50% (8/13)
Table Egg		7.40% (4/54)	5.5% (3/55)	0 (0/1)
Broiler	33.30% (1/3)	100% (2/2)		0.00% (0/1)
Duck	0% (0/7)	12.50% (1/7)		100.00% (1/1)

*House-level infection status was determined by manually matching lab accession data to house-level depopulation reports. A house was only considered to be “confirmed infected” when laboratory data could be matched to the depopulation data. Frequently, only the initial house on a premises exhibiting clinical signs was tested, and the infection status of other houses was unknown. Therefore, there is a data bias toward a “no” response.

C. Time to Start Depopulation of an Infected Premises

Figure 6 depicts the distribution of time in hours from a presumptive diagnosis to the start of premises-level depopulation by commercial production species and State. Presumptive diagnosis indicates the first detection of HPAI by a State's National Animal Health Laboratory Network (NALHN) lab. Following a presumptive diagnosis, samples were sent to the NVSL, which conducted additional tests and provided a confirmed diagnosis. The color of each datapoint reflects the depopulation method(s) used. Some variation is noted in the State-level response times and was situation dependent: once the outbreak was declared, response may be triggered with a presumptive diagnosis state by state; however, there are times when an NVSL-confirmed diagnosis is required first, and in compliance with USDA Authorization for Response and Associated Activities Policy[5]. Most States had a median time to start depopulation of less than 48 hours, reflecting a rapid response following the initial detection of disease.

Figure 7 shows the time from presumptive diagnosis to the start of premises-level depopulation by premises-level depopulation method(s). The number of contributing observations should be considered when comparing two or more depopulation method(s). It is important to acknowledge that these timelines are also impacted by the State-level response (see Figure 1 and Figure 6). For commercial turkey premises, median times from presumptive diagnosis to the start of depopulation were similar for premises that used only foam (median: 22.75, range: 0.62–48.92 hours) or VSD+ (median: 19.93, range: -16.22–51.87 hours). Negative time intervals resulted from a premises starting depopulation before a presumptive diagnosis, which occurred when a premises was identified as a dangerous contact—dangerous contacts being contact premises depopulated because of an epidemiological link to a known infected premises. For commercial table egg premises, the two premises depopulated using only CO_2 had the shortest median time (range: 15–16.5 hours) to start depopulation, followed by premises that used only VSD+ (median: 28.33, range: 13.17–72.5 hours), and then premises using a combination of VSD+ and CO_2 (median: 91, range: 52.5–127.5 hours). The other commercial production species had relatively small numbers of observations contributing to method categories; however, the use of only VSD+ resulted in a more rapid start to depopulation than foam for both commercial broiler and commercial duck premises. Individual depopulation of commercial gamebird premises had the most rapid start.

Table 4 presents summary distributions for the time, in hours, from presumptive diagnosis to the start of house-level depopulation by method; this is only for the premises that used a combination of primary depopulation methods. These distributions may provide further insight into the rationale for method choice. For commercial turkey premises, houses depopulated using CO_2, VSD+, or individual methods had a shorter median time to start depopulation than foam. When considered with the results presented in Table 3, it could be inferred that non-foam methods were used to rapidly depopulate known-infected or clinical houses before depopulation of other houses with foam or other AVMA-preferred methods; NICs anecdotally confirmed this input. Across the other commercial production species, the median time to start house-level

[5] https://www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/authorization-response.pdf

depopulation on premises using a combination of methods was shorter when VSD+ was the primary depopulation method.

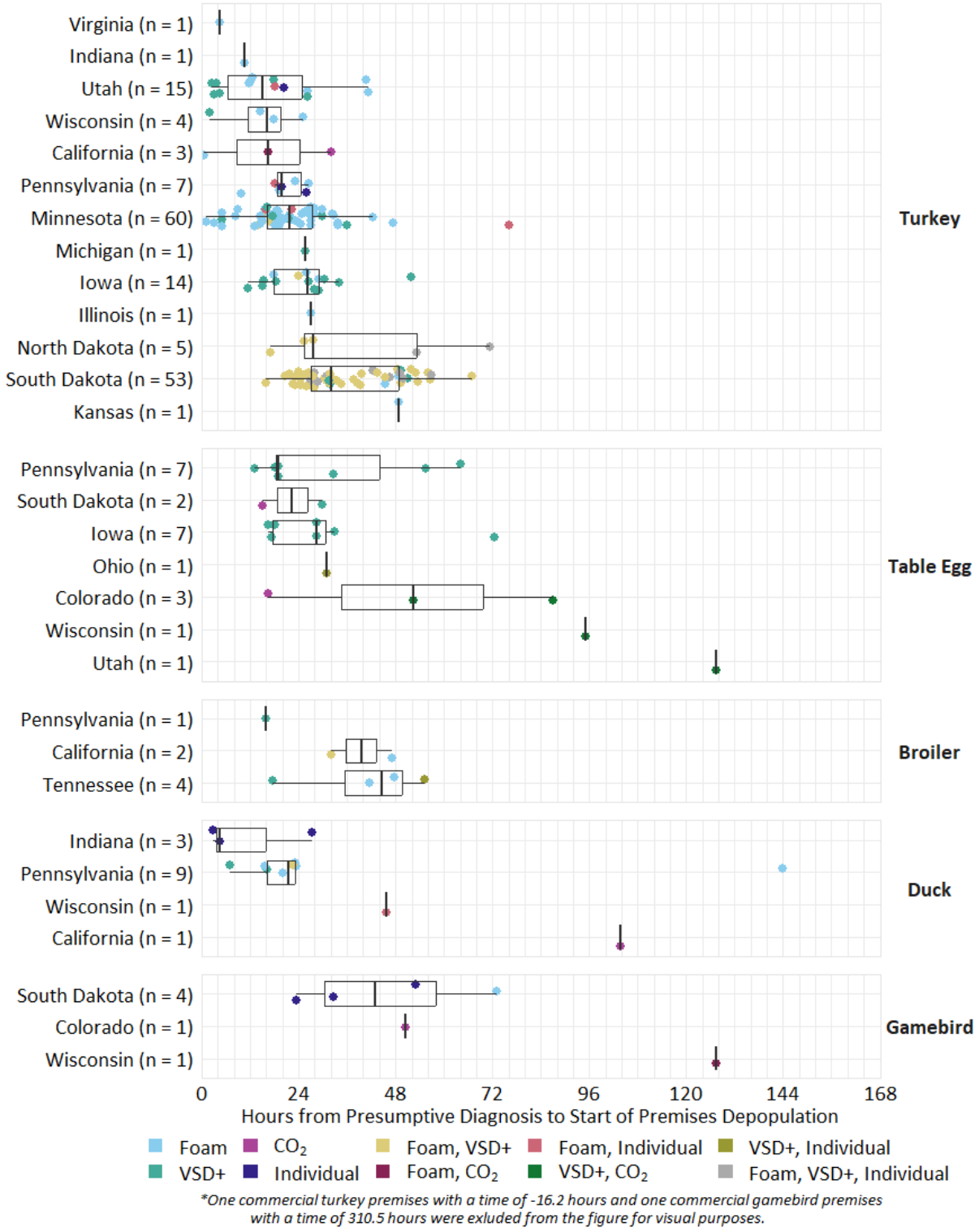

Figure 6. Time from presumptive diagnosis to the start of depopulation of a premises by commercial production species and State, with a color indicator used for the premises-level depopulation method(s) (*n* = number of premises contributing to the summary boxplot distribution as individual points). Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

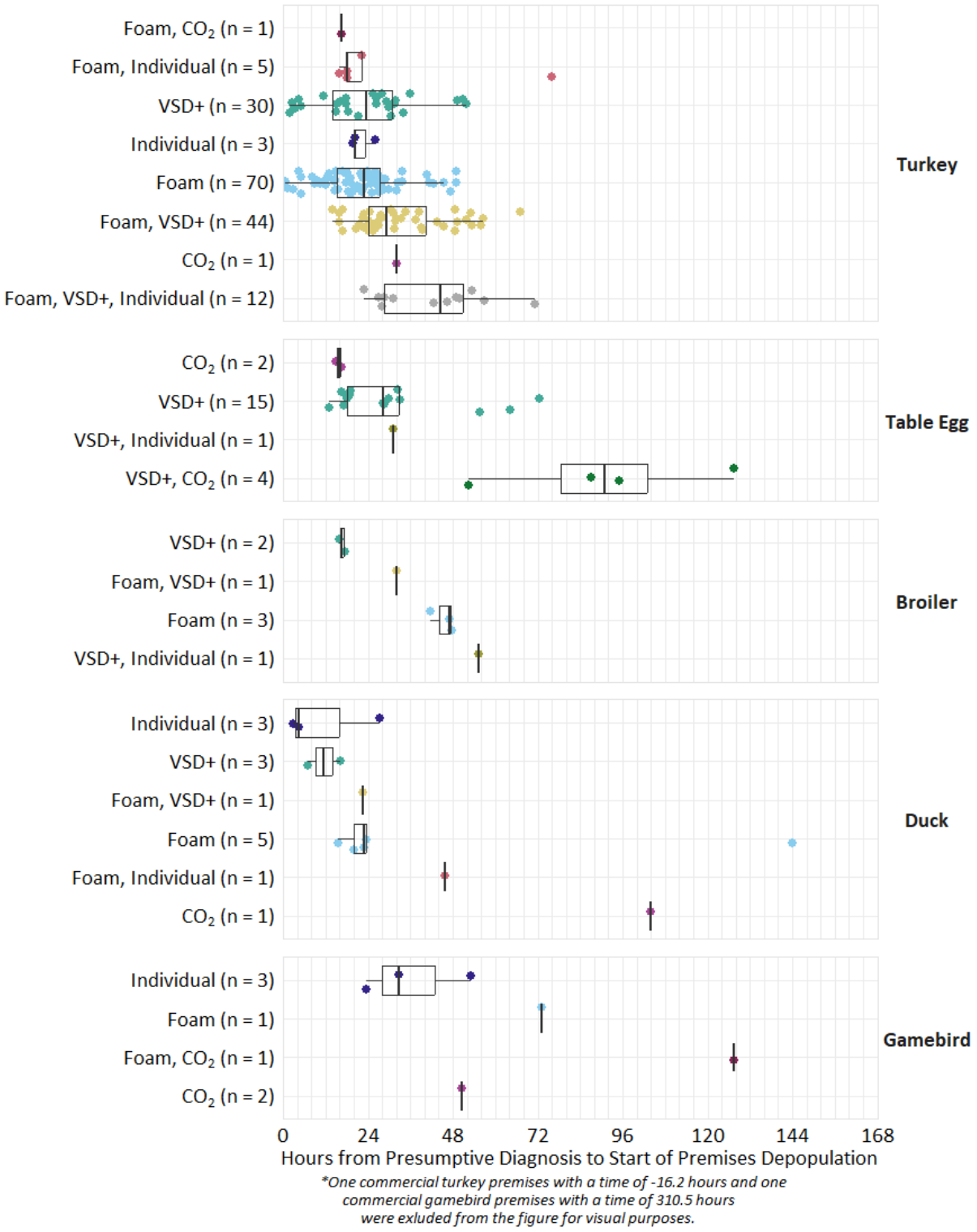

Figure 7. Time from presumptive diagnosis to the start of depopulation of a premises by commercial production type and premises-level depopulation method(s) (*n* = number of premises contributing to the summary boxplot distribution as individual points). Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

Table 4. Hours from presumptive diagnosis to the start of house-level primary depopulation for premises using a combination of depopulation methods by commercial production species and house-level depopulation method.

Commercial Turkey Houses							
Premises Depopulation Methods	**House Method**	**# Houses**	**Min.**	**p25**	**Median**	**p75**	**Max.**
Foam, VSD+	Foam	95	17	29.21	47.25	56.125	95
Foam, VSD+	VSD+	78	14	26.02	33	48.125	77.25
Foam, CO_2	Foam	6	37.75	38.875	40.71	42.23	44
Foam, CO_2	CO_2	1			16.5		
Foam, Individual	Foam	25	8.75	18.25	25.25	45.25	76
Foam, Individual	Individual	11	8.5	18	18.08	20.04	80
Foam, VSD+, Individual	Foam	28	23	48.8775	52.21	71	130.58
Foam, VSD+, Individual	VSD+	21	23.5	42.5	50.5	53.75	80
Foam, VSD+, Individual	Individual	13	23	49	50.5	70	96
Commercial Table Egg Houses							
Premises Depopulation Methods	**House Method**	**# Houses**	**Min.**	**p25**	**Median**	**p75**	**Max.**
VSD+, CO_2	VSD+	28	52.5	160.38	238.88	298.5	480.5
VSD+, CO_2	CO_2	23	87	171.5	312	351	432
VSD+, Individual	VSD+	16	31.00	153.06	196.17	219.59	249.23
VSD+, Individual	Individual	1			240		
Commercial Broiler Houses							
Premises Depopulation Methods	**House Method**	**# Houses**	**Min.**	**p25**	**Median**	**p75**	**Max.**
Foam, VSD+	Foam	3	147		150		152
Foam, VSD+	VSD+	1			32		
VSD+, Individual	VSD+	1			57.17		
VSD+, Individual	Individual	1			55.17		
Commercial Duck Houses							
Premises Depopulation Methods	**House Method**	**# Houses**	**Min.**	**p25**	**Median**	**p75**	**Max.**
Foam, VSD+	Foam	2	43.78				44.5
Foam, VSD+	VSD+	4	22.67		31.8		45.17
Foam, Individual	Foam	5	45.67	47.00	65.33	68.75	70.03
Foam, Individual	Individual	1			47.5		
Commercial Gamebird Houses							
Premises Depopulation Methods	**House Method**	**# Houses**	**Min.**	**p25**	**Median**	**p75**	**Max.**
Foam, CO_2	Foam	4	151.00		182.50		218.50
Foam, CO_2	CO_2	4	127.50		197.00		266.50

Min. = minimum; p25 = 25th percentile; p75= 75th percentile; Max. = maximum

D. Time to Complete Primary Depopulation of an Infected Premises

The time to complete primary depopulation of premises was calculated as the difference (in hours) from when the first house on a premises started primary depopulation and the last house on the premises completed primary depopulation. Overall, the median time to complete depopulation was 6.5 hours (range: 0.42–103.75 hours) for commercial turkey, 51.3 hours (range: 3.67–407.5 hours) for commercial table egg, 4.5 hours (range: 1.25–121 hours) for commercial broiler, 4.3 hours (range: 0.58–28.67 hours) for commercial duck, and 31.25 hours (range: 1.4–143.5 hours) for commercial gamebird premises. The percentage of premises that completed depopulation of the entire premises in 24 hours or less was 83 percent (134/161) of commercial turkey, 86 percent (6/7) of commercial broiler, 79 percent (11/14) of commercial duck, and 38 percent (3/8) of commercial gamebird premises. Commercial table egg premises were frequently larger in scale and took substantially longer to complete depopulation. Only 25 percent (5/20) of analyzed commercial table egg premises completed depopulation within 24 hours; 65 percent (13/20) completed depopulation within 72 hours and 15 percent (3/20) took more than one week to complete depopulation. Within commercial production species, some variation by State- and premises-level depopulation method(s) was observed. Figure 8 and Figure 9 present the hours to complete primary depopulation of a premises by State- and premises-level depopulation method(s), respectively, for each commercial production species. Given the large differences in the timescale to complete depopulation, distributions for table egg premises are provided separately in Figure 8B and Figure 9B.

Evaluating commercial turkey premises, the median time to complete primary depopulation of the entire premises was eight hours or less for most States (Figure 8). California, South Dakota, North Dakota, and Virginia had slightly higher medians than the other States. By method type, the commercial turkey premises that used CO_2 or VSD+ in combination with foam or CO_2 took longer to complete premises depopulation. Input from NICs indicated this delay to complete depopulation may reflect the need to source materials for AVMA-preferred depopulation methods. Nationwide impacts to supply chains and employment due to the COVID-19 pandemic impacted the coordination of depopulation activities. Two significant challenges that impacted depopulation were the sourcing of carbon dioxide and foam and the hiring of truck drivers to deliver resources. When faced with these challenges, it was not uncommon for VSD+ to be used on clinical barns to allow for additional time to coordinate supplies and for AVMA-preferred depopulation equipment to arrive onsite.

This may also explain that premises depopulated using a combination of foam and VSD+ had a higher median time to complete depopulation (median: 17.5, range: 3–50.5 hours) when compared to the other premises-level depopulation method(s) seen in Figure 9. Among the other premises-level methods, the time to complete depopulation using foam (median: 3.5, range: 0.42–53.6 hours) was slightly shorter than using VSD+ (median: 6.28, range: 2.56–73.67 hours).

Included in the analysis, the two commercial table egg premises depopulated using CO_2 had the shortest time (range: 32–33 hours) to complete depopulation. However, these premises may be outliers in comparison to the other data available. One premises was a table egg pullet farm and only had one barn stocked. The other was a table egg layer

premises that had 4 barns, and in the dataset used, the median number of barns per table egg premises was 10 (range: 1–41 barns). According to data reported in EMRS at the premises level, two additional table egg layer premises were depopulated using only CO_2. These premises recorded total depopulation times of 11 and 16 days, which fall within the range for depopulation times reported for premises depopulated using a combination of VSD+ and CO_2 (median: 319.88, range: 120.5–407.5 hours). Unfortunately, these premises did not have individual house-level reports available for inclusion in this analysis. The extended time needed to complete depopulation using CO_2 may reflect limitations in CO_2 sourcing, as anecdotally reported by the NICs, and the time needed to utilize CO_2 delivery carts. The median time for premises depopulation by only VSD+ was 48.5 hours (range: 3.67–145.75 hours).

The remaining commercial production species had fewer observations contributing to their summary distributions. For broiler premises, the hours to complete depopulation across depopulation method(s) was highly similar (range: 1.25–6.74 hours), apart from one premises that used a combination of foam and VSD+ and took 121 hours to complete depopulation. This premises depopulated the confirmed-infected barn using VSD+, and then five days later depopulated the remaining houses using foam. This may reflect a delay in resource acquisition. For commercial duck premises, median depopulation time was shorter for Indiana (median: 4, range: 3.42–4.75 hours) and Pennsylvania (median: 4.17, range: 0.58–25.5 hours), when compared to Wisconsin (25.08 hours) and California (28.67 hours). There was some variation in time to depopulate commercial gamebird premise by State and depopulation method(s). Further investigation suggests this may be influenced by the flock size. The three premises in South Dakota that depopulated their flocks in less than 12 hours using individual methods ranged from 200 to almost 1400 birds. Two gamebird premises appear to be outliers: the first premises took 77.5 hours using foam and completed depopulation on two separate days that were two days apart, while the other outlier premises took 145.4 hours to depopulate using foam and CO_2. The second premises was substantially larger, with approximately 188,000 birds. The next largest gamebird premises contained 32,000 birds.

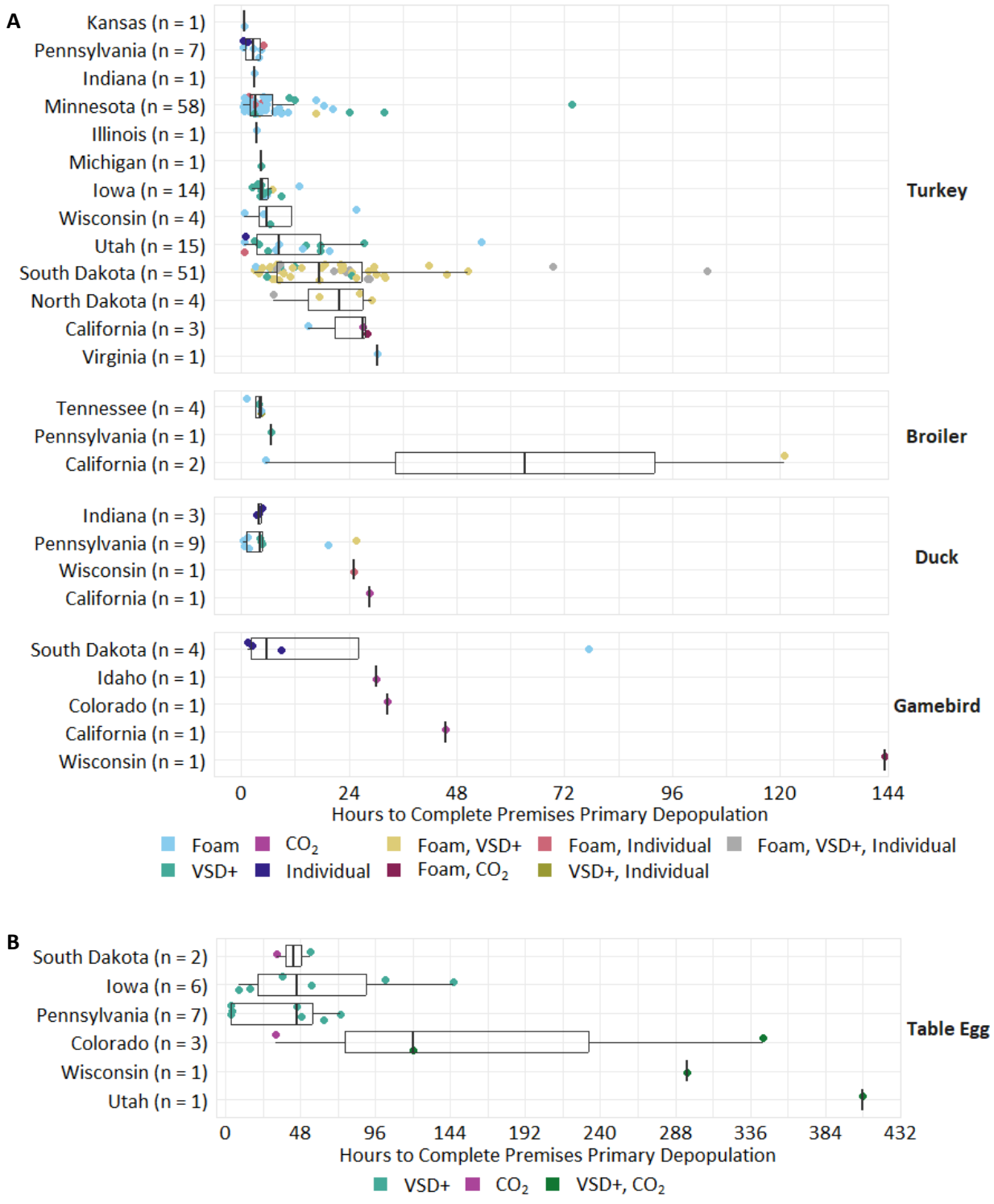

Figure 8. Time to complete primary depopulation of all houses on a premises by commercial production species and State (*n* = number of premises contributing to the summary boxplot distribution as individual points). Panel A presents commercial turkey, broiler, duck, and gamebird premises. Panel B presents commercial table egg premises. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

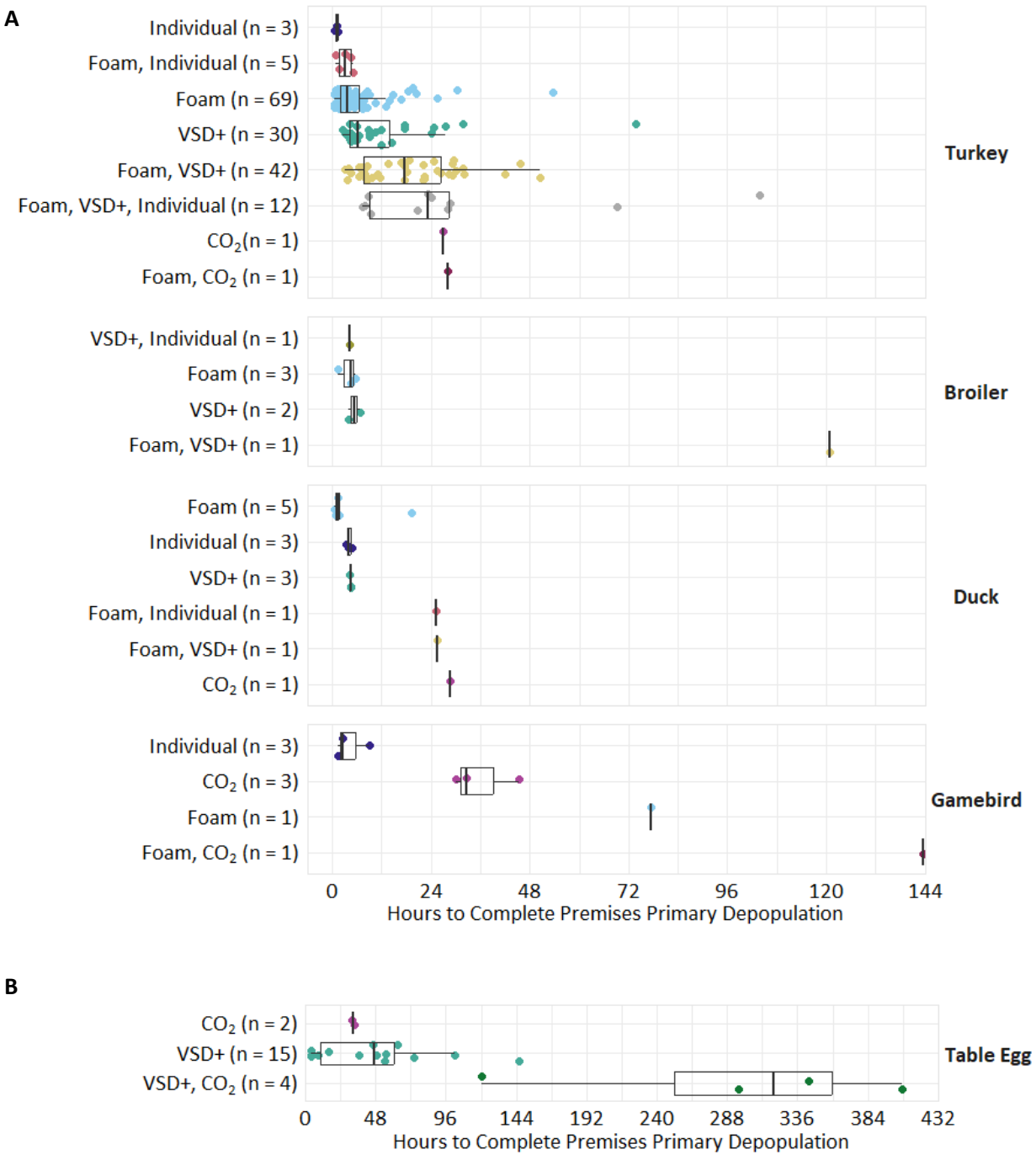

Figure 9. Time to complete primary depopulation of all houses on a premises by commercial production species and premises-level depopulation method(s) (*n* = number of premises contributing to the summary boxplot distribution as individual points). Panel A presents commercial turkey, broiler, duck, and gamebird premises. Panel B presents commercial table egg premises. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

E. Time to Complete House-level Depopulation

In addition to depopulation at the premises level, the time to depopulate individual houses was analyzed. At the house level, the median time to depopulate was 1.42 hours (range: 0.08–67.47 hours) for commercial turkeys, 4.05 hours (range: 0.75–226 hours) for commercial table egg, 2.33 hours (range: 0.5–5.5 hours) for commercial broiler, 0.94 hours (range: 0–4.75 hours) for commercial ducks, and 4.5 hours (range: 1.4–10 hours) for commercial gamebird. Across commercial production species, slight variations were observed by State (Figure 10) and primary depopulation methods (Figure 11). For commercial turkey, broiler, and duck houses, the median time for depopulation by VSD+ was longer than foam. This may reflect the recommendation of heat application for a minimum of three hours at 104°F to 110°F when using VSD+. For commercial table egg houses, house-level depopulation by CO_2 (median: 33, range: 11–226 hours) was substantially longer than depopulation by VSD+ (median: 3.75, range: 0.75–9.0 hours). This may reflect the size of commercial table egg houses and the need to manually move birds from within-house structures to CO_2 containers.

For commercial turkey houses, the median time to depopulate was 0.67 hours (range: 0.08–13.75 hours) for foam, 0.75 hours (range: 0.15–4 hours) for individual, 1.5 hours (range: 1–1.5 hours) for CO_2, and 4 hours (range: 1.25–67.47 hours) for VSD+ primary depopulation methods. Outliers were observed for houses depopulated using VSD+ within the commercial turkey house data distributions. These observations could be partially explained by how the time to complete VSD+ was reported. Some reports appear to have recorded the end of VSD+ as the time the heat application ceased, while other reports record the end of VSD+ as the time the barn could be entered safely by responders.

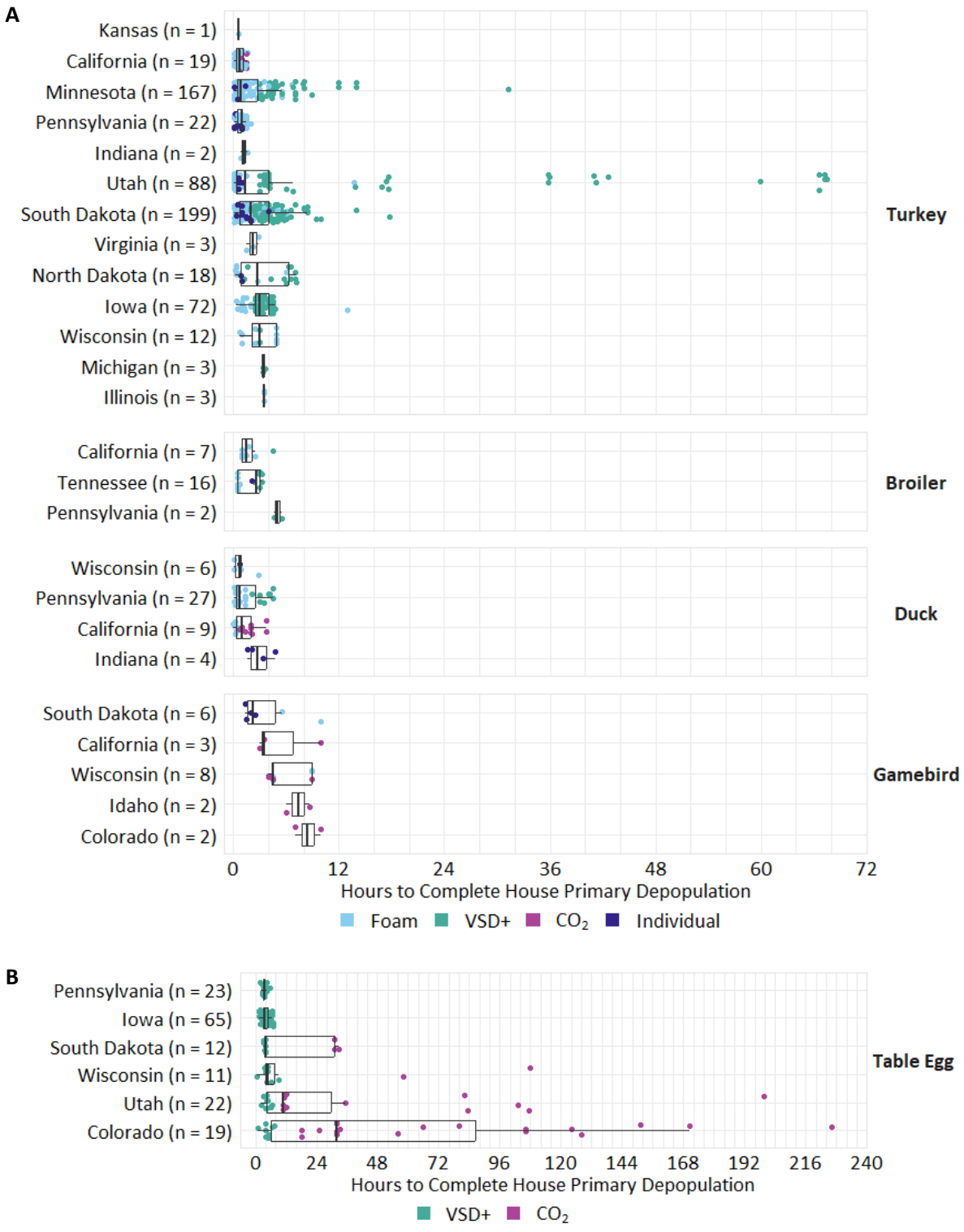

Figure 10. Time to complete house-level primary depopulation by commercial production species and State (*n* = number of houses contributing to the summary boxplot distribution as individual points). Panel A presents commercial turkey, broiler, duck, and gamebird premises. Panel B presents commercial table egg premises. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

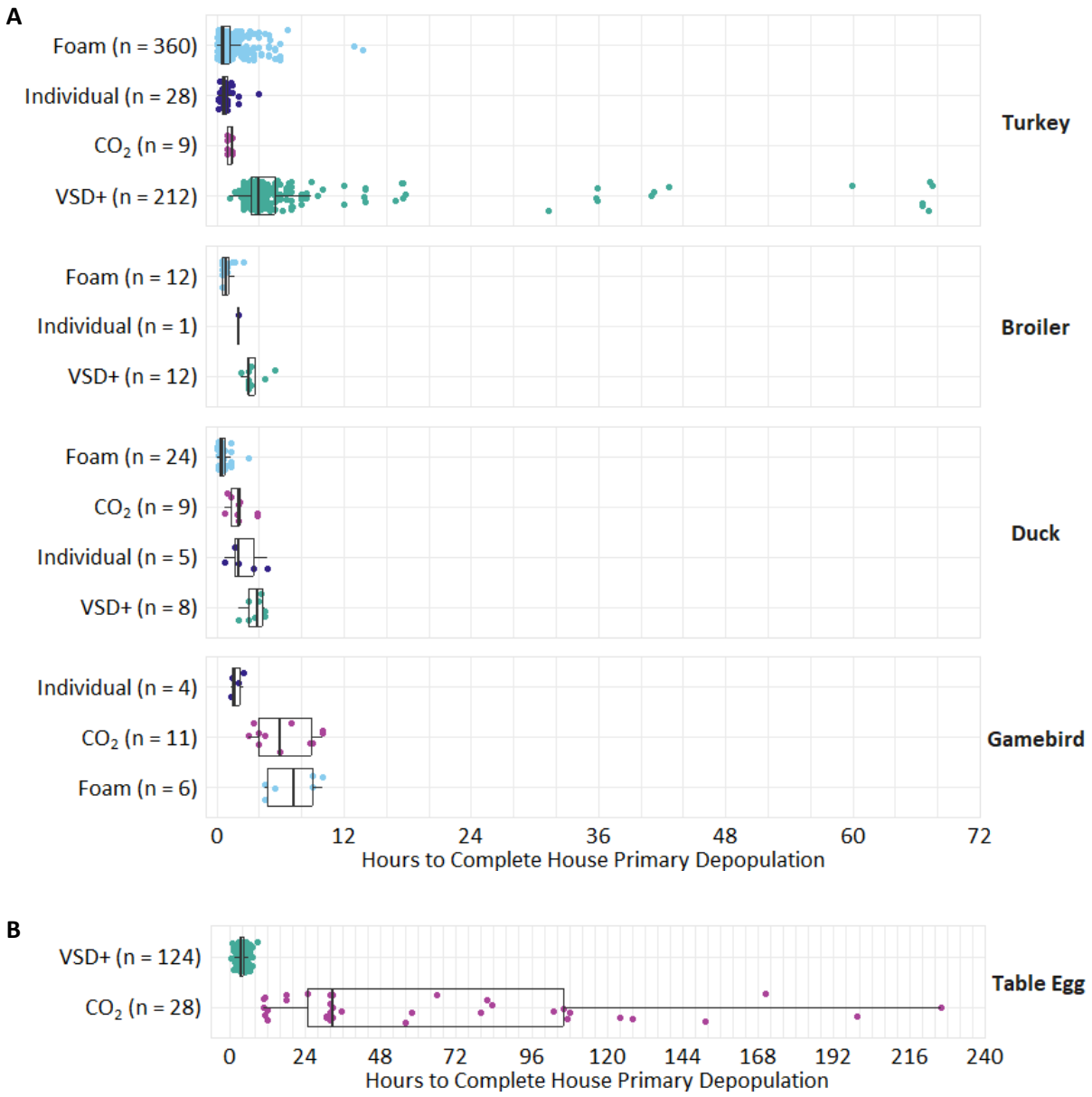

Figure 11. Time to complete house-level primary depopulation by commercial production species and house-level depopulation method (*n* = number of houses contributing to the summary boxplot distribution as individual points). Panel A presents commercial turkey, broiler, duck, and gamebird premises. Panel B presents commercial table egg premises. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

F. Animal Welfare

Every effort is taken in the planning and response phases of an emergency to ensure depopulation occurs rapidly and that animals designated for depopulation are handled in a humane manner before and during their depopulation. Given the extenuating circumstances during an emergency response, the welfare of animals is prioritized as much as possible, and birds continued to receive standard care (e.g., feed, water, and monitoring) while awaiting primary depopulation.

Two quantitative measurements available from the house-level depopulation reports for assessing animal welfare impacts of primary depopulation methods were as follows: 1) whether a secondary depopulation method was required (Table 5); and 2) the time interval between completion of primary depopulation and completion of secondary depopulation (Figure 12). The need for a secondary depopulation method indicates 100 percent of the birds did not succumb to the primary method. The time from the completion of primary depopulation to completion of secondary depopulation may reflect a period of increased stress for the birds that did not succumb to the primary depopulation method. Birds in caged-house systems that did not succumb to primary depopulation had access to residual feed and water while awaiting secondary depopulation methods. While house-level reports had a data field for reporting the need for a secondary depopulation method, this field was frequently left blank. If needed, analysts manually entered or corrected this field based on other data available in the report, such as notes in the comment sections. If no response was provided on the form, and no comments inferred a secondary depopulation method was used, it was assumed a secondary depopulation method was not required; this may bias the analysis. Within the data available, secondary depopulation methods were needed for 38 percent (273/724) of commercial turkey, 59 percent (168/281) of commercial table egg, 35 percent (12/34) of commercial broiler, 29 percent (19/66) of commercial duck, and 14 percent (3/21) of commercial gamebird houses included in the analysis. The need for a secondary depopulation method varied by primary depopulation method within commercial production species (Table 5). None of the primary methods, AVMA-preferred or those preferred under constrained circumstances, consistently achieved 100 percent mortality. Across production species, a secondary depopulation method was required more frequently when VSD+ was the primary depopulation method; however, it is possible that the need for a secondary method of depopulation was under reported when CO_2 was the primary method because secondary depopulation (i.e., cervical dislocation) was conducted immediately when birds were removed from the cart.

The time to complete secondary depopulation was calculated as the difference between the reported end of primary depopulation and the reported end of secondary depopulation. This value could not be calculated if the house-level report did not record the completion time for secondary depopulation; 100 house-level reports indicated a secondary method was required but did not indicate a time of completion. Within the data available, secondary depopulation was completed the same day for 70 percent (144/205) of commercial turkey, 44 percent (59/135) of commercial table egg, 83 percent (10/12) of commercial broiler, 80 percent (20/25) of commercial duck, and 100 percent (1/1) of commercial gamebird houses (Figure 12). Secondary depopulation was completed within one day of primary depopulation for all commercial broiler houses and

all but one duck house. One commercial turkey house, depopulated using VSD+, took two days to complete secondary depopulation. The distribution for table egg premises was right-skewed, ranging from zero to five days following primary depopulation (Figure 12), and 17 percent (23/135) of commercial table egg houses took two or more days to complete secondary depopulation.

Because of concerns raised over delayed secondary depopulation of table egg premises, analysts initiated further inquiry into observations where secondary depopulation was reported two or more days after primary depopulation. This inquiry indicated the time to complete secondary depopulation may have been impacted by several factors, including the disease status of other houses on a premises, the time of day at which primary depopulation occurred, the need for barns to return to safe heat and CO_2 levels for responders to enter, the need to source and conduct secondary depopulation methods, and how the timelines were reported.

On premises where multiple clinical houses were identified, follow-up conversations with responders indicated the priority was to conduct primary depopulation for all houses before following up with secondary depopulation methods within individual houses. This may explain some of the delays to complete secondary depopulation. Furthermore, review of house-level depopulation reports suggests that in some instances, primary depopulation using VSD+ was performed in the evening and responders entered the barns the subsequent morning when heat and CO_2 levels returned to safe conditions to complete secondary depopulation. Based on how this time interval was calculated, these situations reflect that secondary depopulation occurred one day later. Additionally, conversations with responders indicated depopulation was frequently documented to end when responders could walk the barn and verify all birds were deceased. This could be one to two days after the actual depopulation of the birds. This could explain the delay observed in Figure 12 and could also explain why the data field was frequently reported as a date with no associated time, requiring this outcome to be reported as a difference of days instead of hours, as seen in other sections of this report.

For table egg premises, time to complete secondary depopulation may be influenced by the secondary depopulation method choice, which was typically either CO_2 carts or individual depopulation methods. As previously indicated, CO_2 proved difficult to source during the outbreak and house-level depopulation using CO_2 carts was time intensive (see Figure 11). Field responders were limited to 12-hour operational periods, and the process of capturing birds or removing them from cages, placing them in CO_2 carts, conducting depopulation, and removing the deceased birds was laborious. Additionally, field responders indicated that there were several instances where CO_2 carts would have to be emptied prior to being moved between floors of a single house or between houses. This occasionally required CO_2 company personnel to come back to the site, further delaying depopulation.

The house structure on commercial table egg premises may also impact the success of depopulation and the date reported. Field responders indicated that on some commercial table egg premises, house structure (cage-free houses, manure pits, etc.) provided areas for birds to hide. These birds may be identified on a final walk-through and subsequently depopulated, which may also impact the date reported for the end of secondary depopulation. Unfortunately, the total number of birds depopulated per day

was not recorded, and therefore, the proportion of delay attributed to reporting practices versus a true delay in achieving 100 percent depopulation cannot be objectively assessed.

Table 5. Percentage of houses requiring a secondary depopulation method by commercial production species and house-level primary depopulation method.

	House-level Primary Depopulation Method			
Production Species	**Foam**	**VSD+**	**CO_2**	**Individual**
Commercial Turkey Houses	32% (141/435)	51% (127/247)	0% (0/9)	15% (5/33)
Commercial Table Egg Houses		74% (147/200)	21% (17/80)	100% (1/1)
Commercial Broiler Houses	0% (0/21)	100% (12/12)		0% (0/1)
Commercial Duck Houses	13% (4/30)	73% (8/11)	37% (7/19)	0% (0/6)
Commercial Gamebird Houses	0% (0/6)		27% (3/11)	0% (0/4)

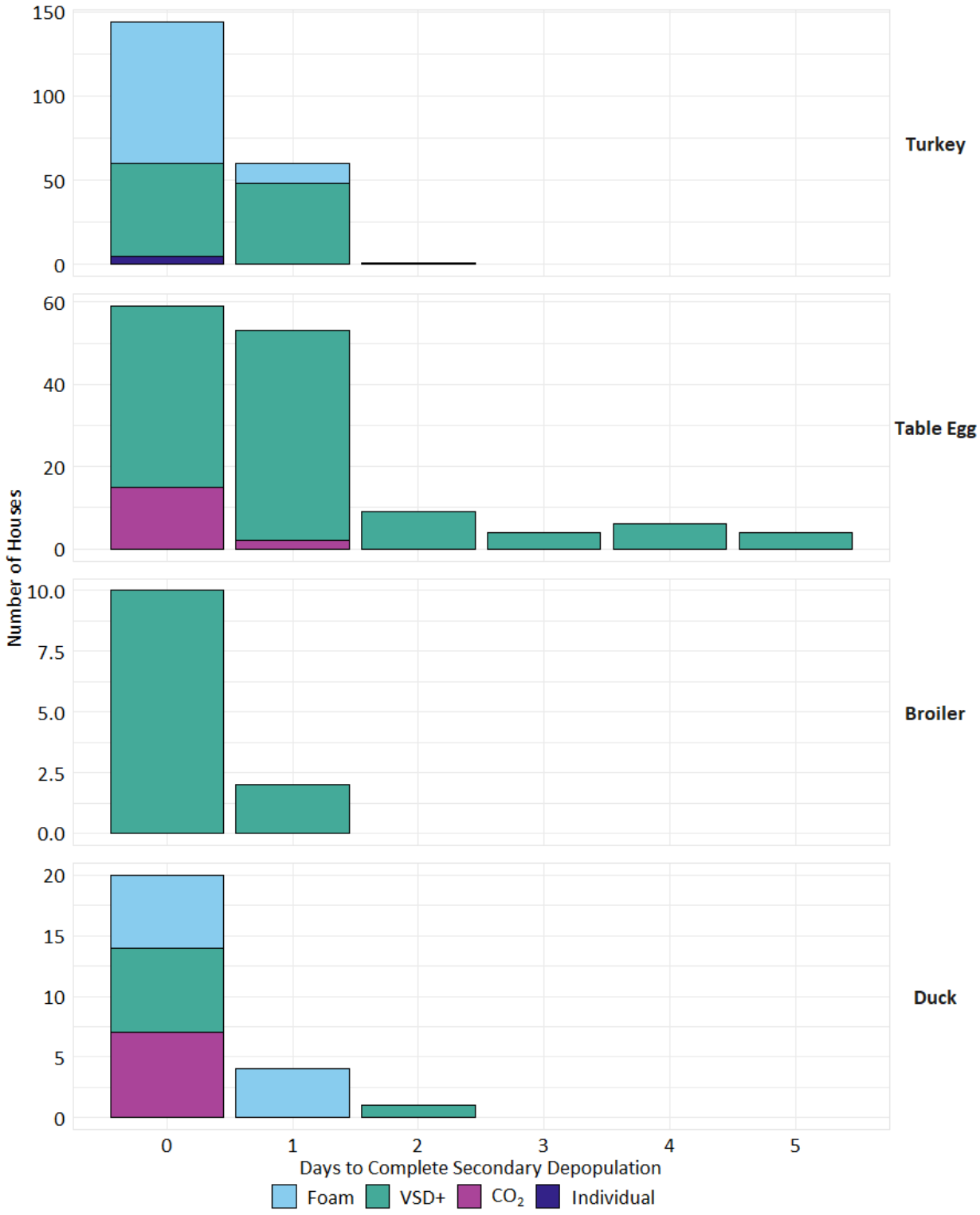

Figure 12. Days to complete secondary depopulation following the end of primary depopulation by commercial production species and primary depopulation method. Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

G. Lateral Spread

Substantial lateral spread observed during the 2014–2015 HPAI outbreak led to the establishment of the 24–48 hour depopulation goal for HPAI infected premises[6]. This goal is intended to prevent the suffering of infected birds, prevent further disease spread between birds on an infected premises, and prevent lateral spread from an infected premises. An infected premises awaiting depopulation raises concern for lateral spread due to viral amplification and spread among the birds leading to greater environmental contamination and increased likelihood of transmission off the premises via vectors and fomites.

Throughout the course of the outbreak, the NVSL has conducted whole genome sequencing and performed phylogenetic analysis in support of epidemiological outbreak investigations and to monitor viral evolution. It is important to note that the outcomes of phylogenetic analysis were interpreted in context of the available virus and epidemiologic information. Using the available data, virus from infected premises were categorized by introduction type (independent point source introduction (IND) or common source or lateral transmission (CSLT)). As of 31 August 2023, approximately 17 percent (142/822) of all infected premises were the result of CSLT; however, when assessing only commercial premises, 31 percent (100/323) could be categorized as CSLT. Of the 48 distinct phylogenetic clusters identified among the CSLT category across all infected premises, the majority of the clusters were limited to 2 premises (63 percent; 30/48), whereas only 15 percent of clusters (7/48) had 5 or more linked premises. This data supports that lateral spread has been limited in most instances for the 2022-2023 event. The two largest clusters were associated with transmission among the live bird marketing system in the Northeast region of the United States, and involved a total of 16 and 27 premises, respectively. These cases are briefly described in the June 2023 interim report for Epidemiologic and Other Analyses of HPAI Affected Poultry Flocks.[7]

While one intent of the 24–48 hour depopulation goal is to prevent lateral spread, it is difficult to objectively define and measure the extent to which depopulation methods or timing prevent or contribute to lateral spread. Phylogenetic data helps identify premises where lateral spread likely occurred, and may provide insight into directionality; however, the epidemiological and production data is needed to better understand the timing and mechanisms of virus movement. Conclusive evidence indicating the exact day of transmission is rare, and this makes it challenging to confidently separate cases of lateral spread that occurred before detection from cases of lateral spread that occurred after detection due to the timing of depopulation.

Specifically regarding the subset of commercial premises in this report, 32 percent (75/238) were categorized as CSLT (breakdown by commercial production species: turkey 27 percent (49/179), table egg 39 percent (10/26), broiler 56 percent (5/9), duck 63 percent (10/16), and gamebird 13 percent (1/8)). The proportion of premises in the CSLT category by production species and State is presented in Table 6. Differences in

[6] https://www.aphis.usda.gov/animal_health/emergency_management/downloads/hpai/depopulationpolicy.pdf
[7] https://www.aphis.usda.gov/animal_health/downloads/animal_diseases/ai/epi-analyses-avian-flu-poultry-2nd-interim-rpt.pdf

the proportion of premises categorized as CSLT were observed and were not unexpected as both climate and production systems vary within and between states; additionally, it is important to consider the number of observations per State and production species. The proportion of premises categorized as CSLT by premises-level depopulation method(s) is presented in Table 7.

As indicated above, definitive associations between depopulation method and lateral spread cannot be drawn because the timing of lateral transmission relative to detection and depopulation is unknown. Furthermore, associations are also confounded by the State-level response since the occurrence of lateral spread (Table 6) and depopulation method choice (Figure 1) varied by State. For instance, this report suggests that a premises categorized as CSLT was less likely to have been depopulated by a combination of foam and VSD+, when compared to using only one or the other independently. Other factors not available in our working dataset, such as integrated company structures, may have also influenced the occurrence of lateral spread and depopulation method choice.

Table 6. Proportion of premises categorized as common source or lateral transmission (CSLT) by production species and State.

Location	Turkey	Table Egg	Broiler	Duck	Gamebird	Overall
Arkansas			0% (0/1)			0% (0/1)
California	50% (3/6)		100% (2/2)	0% (0/2)	0% (0/1)	45% (5/11)
Colorado		40% (2/5)			0% (0/1)	33% (2/6)
Illinois	0% (0/1)					0% (0/1)
Idaho					0% (0/1)	0% (0/1)
Indiana	0% (0/1)			67% (2/3)		50% (2/4)
Iowa	36% (5/14)	29% (2/7)				33% (7/21)
Kansas	0% (0/1)					0% (0/1)
Maryland		0% (0/1)				0% (0/1)
Michigan	0% (0/1)					0% (0/1)
Minnesota	27% (17/62)					27% (17/62)
Missouri	50% (1/2)					50% (1/2)
Nebraska		0% (0/1)				0% (0/1)
North Dakota	0% (0/6)					0% (0/6)
Ohio		0% (0/1)				0% (0/1)
Pennsylvania	78% (7/9)	86% (6/7)	50% (1/2)	80% (8/10)		79% (22/28)
South Dakota	6% (3/53)	0% (0/2)			25% (1/4)	7% (4/59)
Tennessee			50% (2/4)			50% (2/4)
Utah	65% (11/17)	0% (0/1)				61% (11/18)
Virginia	0% (0/2)					0% (0/2)
Wisconsin	50% (2/4)	0% (0/1)		0% (0/1)	0 (0/1)	29% (2/7)
Total	27% (49/179)	39% (10/26)	56% (5/9)	63% (10/16)	13% (1/8)	32% (75/238)

Table 7. Proportion of premises categorized as common source or lateral transmission (CSLT) by production species and premises-level depopulation method(s).

Depopulation Method(s)	Turkey	Table Egg	Broiler	Duck	Gamebird	Overall
Foam	36% (28/78)		60% (3/5)	100% (5/5)	0% (0/1)	40% (36/89)
VSD+	34% (11/32)	47% (8/17)	50% (1/2)	100% (3/3)		43% (23/54)
CO_2	0% (0/1)	25% (1/4)		0% (0/2)	0% (0/3)	10% (1/10)
Individual	100% (4/4)			67% (2/3)	33% (1/3)	70% (7/10)
Foam, VSD+	4% (2/45)		100% (1/1)	0% (0/1)		6% (3/47)
Foam, CO_2	100% (1/1)				0% (0/1)	50% (1/2)
Foam, Individual	33% (2/6)			0% (0/1)		29% (2/7)
VSD+, CO_2		25% (1/4)				25% (1/4)
VSD+, Individual		0% (0/1)	0% (0/1)	0% (0/1)		33% (1/3)
Foam, VSD+, Individual	8% (1/12)					8% (1/12)

As seen in Figure 13, CEAH analysts assessed if a delayed start to depopulation was associated with potential lateral spread and examined the time from presumptive diagnosis to house-level depopulation by production species and whether a premises was categorized as CSLT. For commercial turkey and duck premises, this report suggests that premises involved in a CSLT cluster started depopulation sooner than premises categorized as IND. However, similar median times were observed for commercial table egg and commercial broiler premises. This association is counterintuitive to what CEAH analysts expected and is likely due to State-level influence, given that the time to start depopulation for premises categorized as CSLT varied by State. More rapid depopulation of premises categorized as CSLT may also reflect a higher level of disease awareness; it is possible that knowledge of contact with infected premises, which resulted in lateral spread, led to testing and ultimately the rapid depopulation of linked premises.

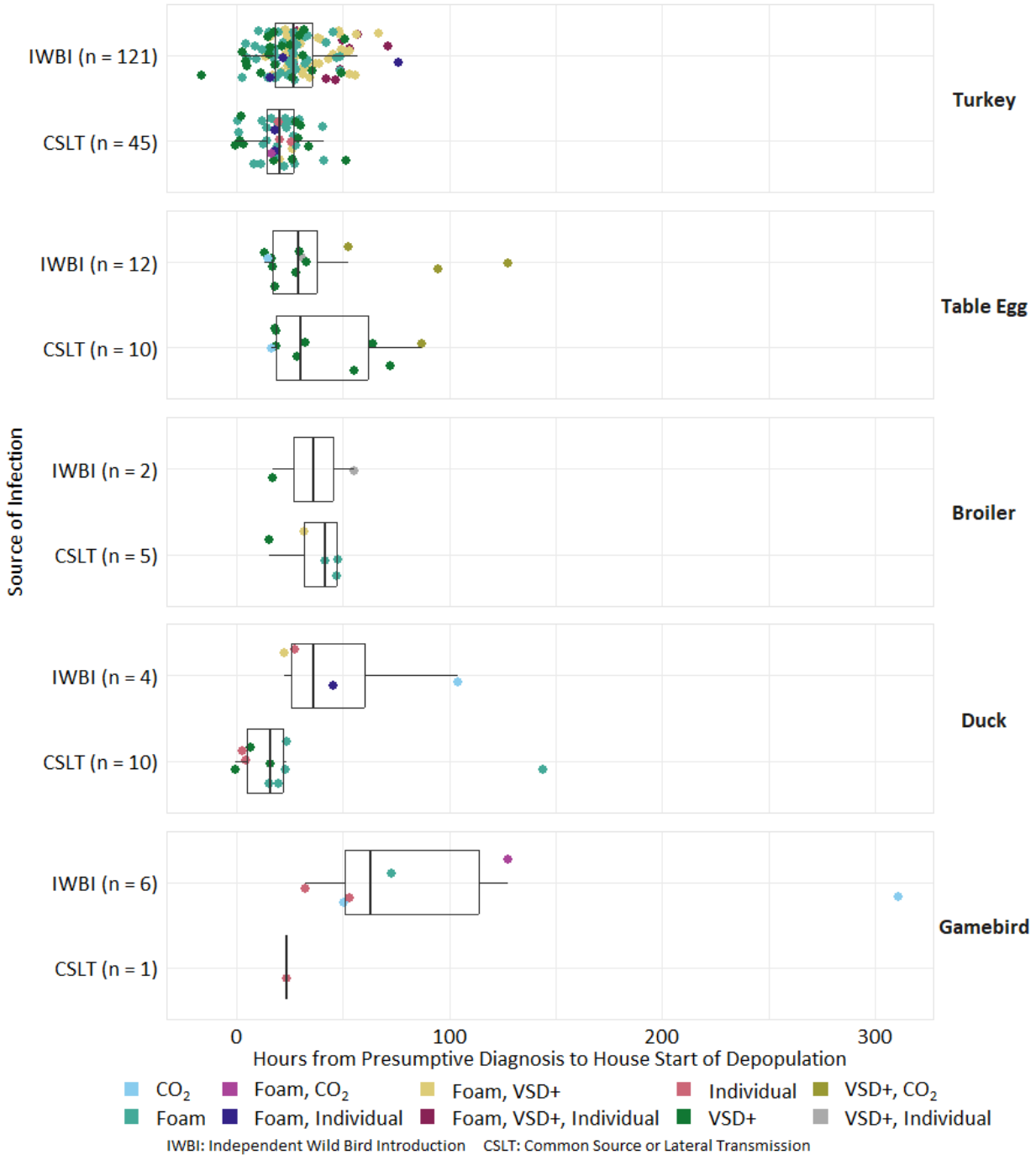

Figure 13. Time from presumptive diagnosis to the start of depopulation of a premises by commercial production species and source of infection (*n* = number of premises contributing to the summary boxplot distribution as individual points). Commercial production species reflect production types grouped by commodity. For example, table egg premises include table egg layer, table egg breeder, and table egg pullet premises.

H. Comparison to 2014–2015 HPAI Outbreak

There was a significant improvement in the data recorded in EMRS during the 2022–2023 outbreak as compared to the 2014–2015 outbreak. Using the 2014–2015 data available in EMRS, it is possible to calculate the days from when a premises received a confirmed diagnosis until it completed depopulation. Data reported in EMRS at the premises level for the 2022–2023 outbreak and the 2014–2015 outbreak were used to compare the depopulation timelines for the two outbreaks. Depopulated premises in 2014–2015 included 148 commercial turkey, 44 commercial table egg, and 3 commercial broiler premises. Premises-level depopulation methods by commercial production species in 2014–2015 are reported in Table 8. Methods were reported as foam, CO_2, individual, or other. Details defining "other" methods and house-level depopulation reports were not available.

Table 8. Reported depopulation methods by commercial production species at the premises for the 2014–2015 outbreak.

Depopulation Method	Turkey	Table Egg	Broiler
Foam	93.9% (138/147)	2.3% (1/43)	33.3% (1/3)
CO_2	1.4% (2/147)	97.7% (42/43)	67.7% (2/3)
Individual	2.0% (3/147)	0% (0/0)	0% (0/0)
Other	2.7% (4/147)	0% (0/0)	0% (0/0)
Total	100% (147/147)	100% (43/43)	100% (3/3)

Comparing this interval to the 2022–2023 outbreak, the median time to complete depopulation is substantially shorter than the 2014–2015 outbreak (Figure 14). The median time from confirmed diagnosis to completion of depopulation for commercial turkeys was 0 days (range: -5–3 days) in 2022–2023, compared to 3 days (range: -3–10 days) in 2014–2015. The median time for commercial table egg premises was 4 days (range: -1–19 days) in 2022–2023, compared to 15.5 days (range: 4–38 days) in 2014–2015. The median time for commercial broiler premises was 0 days (range: -1–4 days) in 2022–2023, compared to 6 days (range: 3–10 days) in 2014–2015. Shorter time intervals observed during the 2022–2023 outbreak can be attributed to some States starting premises depopulation following a presumptive diagnosis and to depopulation method choice. As an example, Minnesota contributed a significant portion of commercial turkey premises to the dataset and frequently started depopulation following a presumptive diagnosis, per USDA policy on authorizing response activities. For table egg premises, the use of VSD+ in 2022–2023 reduced the time to completed depopulation when compared to the use of CO_2 in 2014–2015.

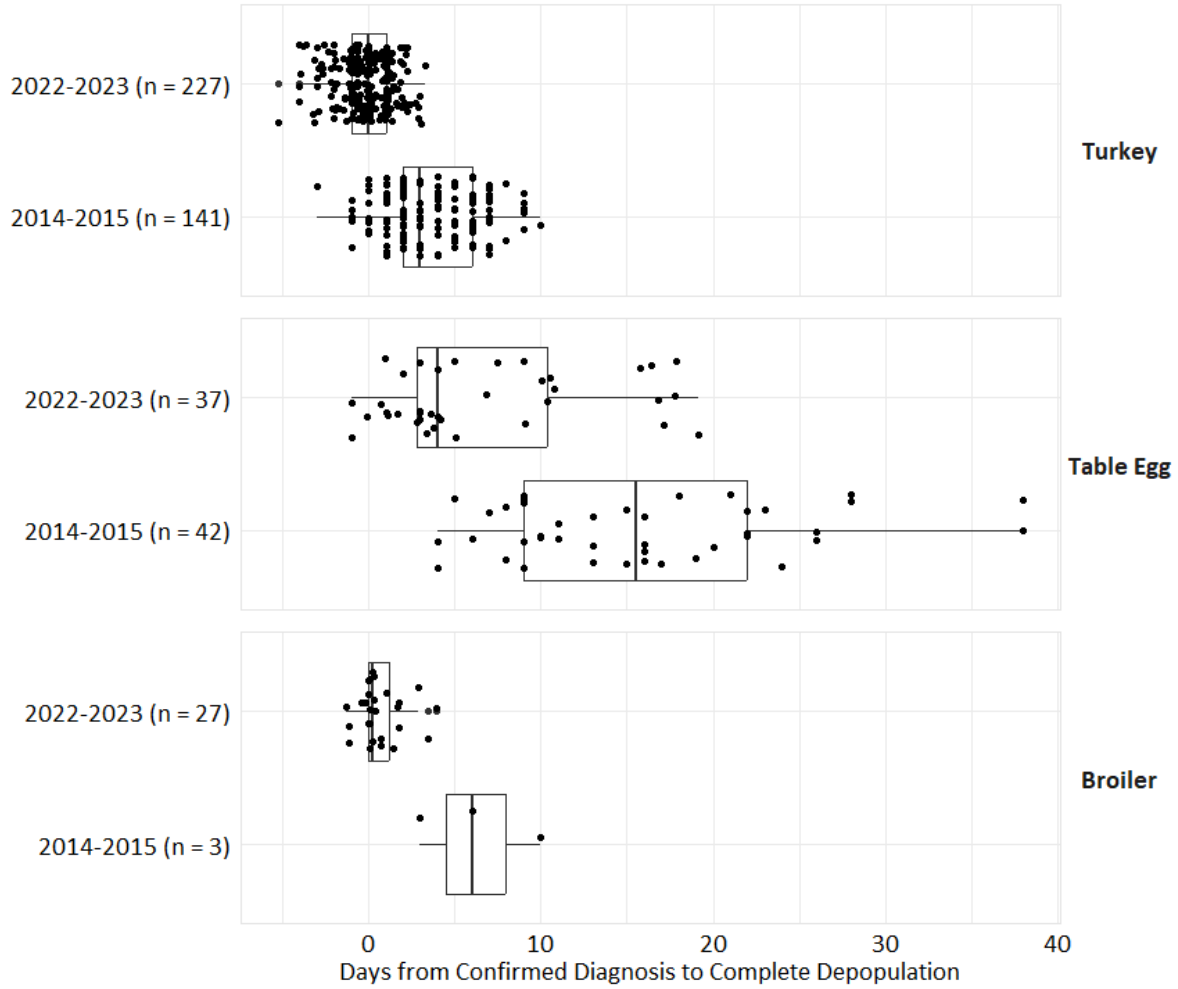

Figure 14. Comparison of the time from confirmed diagnosis to completion of depopulation between the 2014–2015 outbreak and the 2022–2023 outbreak (*n* = number of premises contributing to the summary boxplot distribution as individual points).

CONCLUSION

The 2022–2023 HPAI outbreak is the largest and longest HPAI outbreak in the history of the United States. The number and the geographic distribution of HPAI cases has placed an intense demand on outbreak response resources. Throughout the outbreak, there were multiple competing requests for AVMA-preferred depopulation resources (e.g., people, supplies, and equipment) at the same time from different States and poultry companies. From February 8, 2022, to August 31, 2023, there were 169 distinct days in which there was an HPAI detection in more than one State on the same day. In terms of numbers of new detections, during the spring and fall 2022 outbreak peaks, there were nine (on April 1, 2022) and eight (on September 29, 2022) States reporting new cases on the same day. Consecutive days of new detections in the same and different States also occurred regularly. This required constant prioritization for the use of limited resources from USDA–APHIS–VS, State, and poultry company stockpiles for AVMA-preferred depopulation methods.

Even though resource constraints existed, the USDA maintained a goal of depopulation within 48 hours of presumptive diagnosis to thwart the extensive lateral spread seen during the 2014–2015 outbreak. To help achieve this goal, VSD+ has been used during the 2022–2023 outbreak in constrained circumstances. Although this report could not definitively demonstrate that the use of VSD+ in the 2022–2023 outbreak prevented lateral transmission, this report does show that a) depopulation was completed more rapidly, and b) that lateral transmission was significantly decreased when compared to 2014–2015 (and when occurred was limited); both of which can be partially attributed to the use of VSD+ to meet the 24–48 hour depopulation goal for HPAI.

Compared to the 2014–2015 outbreak, the use of VSD+ in the 2022–2023 outbreak has become the primary method of depopulation for commercial table egg premises (replacing CO_2), and significantly reduced the use of foam for depopulation on commercial turkey premises. The primary depopulation method selected and the timing to start and finish depopulation was substantially influenced by the State where the infected premises was located, resource constraints, and other factors of this outbreak as previously discussed. The impact of the State on response decisions limits the ability to conduct a formal analysis due to predictor variables being highly correlated with each State.

Aside from the need to rapidly depopulate infected premises, descriptive analysis could not fully describe the complete rationale for using VSD+ since use varied by State and production species. When VSD+ was used in combination with other methods for premises in this report, it was frequently used to depopulate infected houses or houses with older birds. In many instances, the use of VSD+ also allowed for a more rapid start to depopulation. This report suggests a secondary depopulation method was required more frequently when VSD+ was the primary depopulation method, which may reflect welfare concerns. However, looking at relative depopulation timelines, it appears some States that used VSD+ in their early depopulation efforts shifted to using other depopulation methods with increasing numbers of detections. This may reflect a change in resource availability, or efforts to move away from the use of VSD+.

Post-analysis insight from the NICs supports several of the observations stated in the descriptive analysis. Incident commander input indicated additional methods of depopulation

were intentionally used on some premises where VSD+ was implemented. While this did not occur on all premises using VSD+ for depopulation, use of a combination of depopulation methods was a relatively common strategy to promote animal welfare, prevent animal suffering, and to effect complete depopulation as expeditiously as possible while facing resource availability constraints.

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