Chapter 2 Appendix

Contents

Chapter 5

CURRENT PRACTICES AND PROCEDURES

Shifting from Day to Night

Reporters in the press room anxiously cross the line to retrieve copies of a report once the official Crop Reporting Board clock strikes 3 p.m.

In 1986 the CRB was renamed the Agricultural Statistics Board (ASB). This renaming coincided with the renaming of the agency as the National Agricultural Statistics Service. Years later, in May 1994, one of the most significant changes in ASB delivery of statistical reports occurred when the release of major crop-related reports shifted from 3 p.m. to 8:30 a.m. Lockup periods for some of those reports now started before midnight in order to enable the Board to complete all analysis and publication operations.

Considerable review, planning, and debate went into the final decision to shift to morning releases. A small group of data users contacted the Secretary of Agriculture asking for the change. They cited the fact that major Principal Economic Indicator reports of other Cabinet departments were already morning releases. They also pointed out that USDA data released at 3 p.m. were used for trading in futures markets around the world before U.S. markets opened the next morning.

Many major farm and commodity organizations initially opposed the proposal due to concern that security might be compromised. This was a valid concern since the individuals requesting the change suggested that NASS use its normal estimating procedures and timing to prepare the reports but then secure the reports overnight for morning release (an approach similar to that used by other Federal Government statistical organizations). However, NASS and the World Agricultural Outlook Board would not agree to such a shift in security levels. They responded that, if release timing was changed, they would continue to finalize major reports under lockup conditions and release the reports from lockup. With that assurance of continued security, major organizations agreed with USDA on a 1-year trial of morning releases.

The first morning release was on May 10, 1994, and all major crop releases the rest of 1994 were at 8:30 a.m., except for cotton-related information. Maintaining the afternoon cotton releases was due to a legislative quirk. Earlier in the 20th century, cotton forecasts were issued about the 8th of each month, separate from the Crop Production report which contained the other major crops due to a specific cotton report law. When legislation was passed to allow cotton to be added to the Crop Production report, the amendment specified that cotton information be released at 3 p.m. That time of day was listed since it was the traditional Crop Production release time, although the general Crop Report law did not specify a time.

Cotton industry representatives were not a party to the original request to shift the timing. They were not necessarily opposed to the shift but didn't want to be driven by grain industry considerations. Therefore, NASS followed the cotton-specific law. Since the 1994 Crop Production release calendar had already been announced, NASS released reports at 8:30 a.m., which contained all tables and narratives except for cotton. If cotton were to be included for a particular month, a lockup was reinstated about 10 a.m. and the cotton portion of the report was finished under secured conditions. An accommodation was made to allow the WAOB cotton interagency estimates committee to work in NASS space so the WAOB workspace did not need to be secured during the day. At 3 p.m. the full Crop Production report was released. This Adouble duty@ approach required a number of changes in logistics and careful attention to which individuals were needed at particular times of day to complete all analysis, composition, and release procedures. Most individuals who worked on the overnight portion were able to go home before the 10 a.m. lockup was initiated, but the Chairperson and Secretary of the ASB ended up working both of the back-to-back lockups each month.

For the year 1995, NASS shifted the order of the reports. A shorter lockup was used to issue the cotton data at 3 p.m. one day and then an overnight lockup was implemented with the full report coming out at 8:30 a.m. the next day. This minimized the numbers of pages that had to be printed and avoided someone picking up a Crop Production release that looked complete but was missing the cotton data. By the third year, the law specifying 3 p.m. had been changed and no special accommodations were needed.

The Present Board Concept and Types of Boards

Much of this story has focused on the full lockups with all outside communications cut off and an armed guard on duty. Those procedures for the most market-sensitive reports are critically important. However, NASS practices strong security procedures for all operations and all reports that are issued. The procedures and the levels of security are adapted depending on the time that is required to complete each report and the types of individuals involved.

One purpose of the ASB process, in addition to preserving security, is to ensure accuracy in compiling and interpreting survey results and indications. The Board approach of having a second level of review for all indications and recommendations is just as important today as it was 100 years ago. In fact, a case might be made that the second review is now even more important. In 1905 all calculations were made by a relatively small group of skilled statistical assistants. With today's spreadsheets and the abundance of different surveys with relatively small sample sizes, statisticians often enter their own data. It is necessary to have an independent review to uncover entry errors not initially recognized.

Since NASS field offices evaluate survey data and formulate initial recommendations, it is clear that the State offices are performing a critical Board function. Many offices even parallel the Board process by having State mini-Boards in which multiple staff members meet to review the indications for the most important commodity recommendations to be sent in for ASB action. This is an excellent training opportunity for newer staff members to see first hand how the process will work later in Washington. Readers need to realize that each State office has access only to their data and indications so they are not previewing the actual National Board results.

There are at least five different types of "Boards" that NASS currently uses for specific reports. The most common is often not thought of as a Board by the participants. It is the Commodity Section Review Board that is implemented nearly every working day of the year. For ongoing reports, such as the Weekly Broiler Report, the commodity statistician, his or her statistical assistants, and their Section Head serve as the de facto Board for reviewing all indications and recommendations from the Field, following up on any unusual data relationships, and compiling the report.

One important approach for very detailed, less market-sensitive reports is referred to as a "Review after Summary Board." This is an important quality control procedure for reports such as the monthly Prices and the quarterly Agricultural Labor reports. Staff members work through all the calculation and review procedures on those reports and compile the full report for a Board meeting about 24 hours before release. All narratives have been drafted by that time and Board members review the major data items in the report to be sure that State-to-State and commodity-to-commodity relationships seem reasonable and are explained by the report narratives.

The annual Farm Production Expenditures report, which creates national and regional estimates for major expenditure categories based on relatively small sample sizes, necessitated a new type of Board review. An "Outlier Review Board" is held after basic editing and analysis steps are completed. Based on the underlying statistical distributions of the expanded data for the current year's reports, all records are identified that had overwhelming impacts on the estimates of any category at the regional or national level. If a particular operation appears to belong to higher strata (due to expansion of the operation after control data were determined), the Board might choose to re-summarize that operation in new strata. In some cases, the reported data are correct for a large operation in the highest strata and the Board will recommend actions to smooth the regional estimates since the operation has valid national impact.

One of the most common Board procedures is the "Speculative 'Need to Know' Board" used for reports such as Acreage, Cattle, Grain Stocks, and Hogs and Pigs. Those are very market-sensitive reports with so many State and category interrelationships that national-level figures are needed to guide all of the detailed review and estimate-setting activities. If the full speculative Board approach were to be used, the output of the several hours review after lockup would likely be one page of U.S.-level numbers. Instead, NASS conducts the formal Board meeting 4-5 days before release. Board members receive detailed information on the survey data and any unusual data situations. The members then review all indications and create their recommendations for Board targets for key elements such as total cattle, calf crop, and numbers of beef cows. After the targets are set, the commodity statistician, along with the help of field office representatives, does the intense review of the interrelationships. The Head of the Commodity Section serves as the key reviewer. All members of the Board operate on a strict need-to-know basis. Details are not discussed with any other staff members and all materials are secured when not in use. The full report is finished in time for final composition and printing of immediate release copies. At the time printing is underway, copies do not exist outside of the lockup area.

The ultimate security setting is the "Full Lockup Speculative Boards" used for monthly Crop Production reports. The first few days of work on Crop Production reports are under the need-to-know approach. However, for the speculative crops of corn, cotton, soybeans, wheat, and citrus, the focus is to complete work on all but the speculative States. Thus, the statement is often made that "no one could have had the August 1 U.S. corn yield forecast ahead of the release morning" because that figure was not created until after lockup was in place and no one can leave the lockup area until 8:30 a.m. when the report is released to everyone.

Both the World Agricultural Supply and Demand Estimates and the Crop Production reports, along with five other NASS data series, are Principal Economic Indicators (PEI) of the United States. One of the operating procedures for reports in the PEI series is to provide information to the Council of Economic Advisors an hour and a half ahead of release. NASS and WAOB have always maintained that no information can be provided ahead of release time but, if the Council did want the information ahead of time, Council members would be allowed to enter the lockup facility but could not leave or communicate with anyone outside lockup until release time.

The lockup facility and the reporter release room are assets for the Department of Agriculture. USDA's Agricultural Marketing Service uses the reporter release room for one of its ongoing reports. On rare occasions, analysts of the Department have used the lockup facility to make decisions on final program details and then announce those details out of lockup.

Creating and Adhering to a Calendar

The NASS record for issuing a report on time seems like the old Postal Service motto: "Neither snow nor rain nor heat nor gloom of night stay these couriers from the swift completion of their appointed rounds." NASS has built such detailed contingency plans into the operational procedures that it takes a massive disaster situation to delay or postpone release of a speculative statistical report. Backup and contingency procedures for handling security for NASS reports have covered nearly every possibility, including not being able to get to the South Building work location.

During the first Gulf War, when there were concerns about possible retaliation against U.S. Government buildings, the Chairperson, the Secretary of the Board, and one other person made arrangements that would have allowed the Agricultural Statistics Board to complete work and issue a skeleton report from a non-Government location. However, that procedure dealt only with a 1-day emergency and would not have enabled orderly functioning for an extended period of time. After September 11, 2001, more detailed plans and the creation of necessary electronic file backups and alternative locations were implemented to ensure the agricultural statistics infrastructure would not be totally cut off by the loss of a key building or a number of key participants.

The work on alternatives to standard procedures has already paid off on multiple occasions. The backup system of laptop computers was able to keep operations on schedule when USDA Internet connectivity was totally cut off for a period of time. NASS has also been able to remotely release (non-lockup) reports on days when Washington, D.C., offices were closed for situations such as the World Trade Organization protests and when severe storms were expected in the aftermath of a hurricane. However, there have been three instances in the past 10 years when situations did arise that caused the delay of a scheduled report release. A description of the handling of those situations might round out the explanation of the NASS commitment to security and confidentiality.

The first situation was the East Coast blizzard of 1996. The storm deposited 20-plus inches of snow on the Washington D.C., area the second weekend of January. The January Crop Production report was scheduled for release Wednesday, January 10, and the Crop Production Annual and WASDE reports were scheduled for Thursday, January 11. The storm was severe enough that only limited road transportation was possible through Wednesday. Washington area airports did not resume service until Wednesday, which was the day that the ASB Chair, who had been out of town, was able to return to Washington. By Tuesday, the Administrator, the Statistics Division Director, and one field representative were able to make it to the office and spent much of the day answering telephone calls and communicating with USDA officials. The ASB and WAOB notified USDA and the news services that 2 working day's notice of the new dates and times for the releases would be given to everyone. (Internally, ASB members agreed that they could put out the reports the second day after the cotton specialist could get out of his neighborhood and make it to work.) NASS worked closely with WAOB in evaluating the status of personnel and data sources and issued a Thursday, January 11, notification that all reports would be issued on Tuesday, January 16, following the Monday holiday for Martin Luther King, Jr.'s birthday.

The second instance was caused by the terrorist attacks of September 11, 2001. The Crop Production and World Agricultural Supply and Demands Estimates reports were scheduled for release at 8:30 a.m. on Wednesday, September 12. Work was well along on the morning of September 11, when the first reports were received of the planes hitting the World Trade Center and the Pentagon. Speculative State recommendations had not yet been transmitted to Headquarters. When the word came to close down government operations and evacuate, Fred Vogel, the ASB Chairperson, and Jerry Bange, the WAOB Chairperson, made some critical, appropriate decisions. They held a meeting with their joint staffs and instructed everyone to stop work, save files, shut down all computer operations, and not resume any release deliberations until order and security were restored. NASS and WAOB responded in a manner that assured that data security was not compromised by the disruption of normal procedures. Vogel and Bange prepared a simple announcement that the following day's reports would be delayed (see Appendix C). By that time, no one was in the USDA Office of Communications. However, Roger Runningen of Bloomberg News was in the adjoining hallway and he made sure that the notice went out to all wire services—an excellent example of the press and statistical agencies working together. Once again, NASS and WAOB gave 2 days' notice that the reports would be issued on Friday, September 14.

The third departure from the established Crop Production and World Agricultural Supply and Demands Estimates calendar occurred in 2004. In this case, NASS and WAOB decided on short notice to issue reports a day early. The change was prompted by the death of former President Ronald Reagan. The reports were scheduled to be released on Friday, June 11. President Reagan passed away the weekend before and by Monday, June 7, plans were shaping up for a National Day of Mourning on the 11th. June Crop Production is one of the smaller reports of the year and Statistics Division staff members felt that they could finish work in time for a Thursday morning release. WAOB staff members agreed but the WAOB Chairperson needed to communicate with the other agencies contributing members to the Interagency Crop Estimation Committees. The decision to release a day early was widely applauded within the agriculture community since commodity and futures markets preferred to be closed on the Day of Mourning (see Appendix C).

The ASB calendar for each year is prepared well ahead of time and is widely publicized so all interested in agriculture are aware of the upcoming releases. The calendar has been described as "stable but not static." Improvements such as additional data breakouts are constantly being added to improve the customer service value. One of the first steps in creating the calendar each year is to establish the release dates for the Crop Production reports. The releases take place between the 8th and 12th of the month. The specific dates depend on the timing needed to collect the survey data, centered around the first of the month, and to complete processing in the States and in Headquarters. Release timing is definitely affected by how the weekends fall each month. The relative timing of most other reports is similar from year to year but specific principles are built into the planning, such as the livestock industry preferring to receive most livestock reports on Friday afternoons rather than during the marketing week. NASS planners also bring in a number of special considerations such as not issuing reports on Good Friday.

REFERENCES

Brooks, E. M. (1977). As we recall: The growth of agricultural estimates, 1933-1961. Washington, DC: U.S. Department of Agriculture, Statistical Reporting Service.

Brooks, E. M. (1962). The founding of the crop reporting service, a review of the struggle to establish an agricultural estimating service in the U.S. department of agriculture, 1863-1903. Washington, DC: U.S. Department of Agriculture, Statistical Reporting Service.

Landis, J. (Director). (1983). Trading Places [Motion Picture]. United States: Paramount Pictures.

Mississippi State University, Office of Agricultural Communications (Producer). (1999). Coverage of September 10, 1999 USDA crop report lockup [Television series episode]. Farmweek. Mississippi State.

Schuff, S. (1994, July). Where are these people? And, why are they locking them up? Colorado Rancher and Farmer, 10-17.

Taylor, Henry and Anne D. (1952). The Story of Agricultural Economics. Ames, IA: The Iowa State College Press.

Thomas, R. (1975). The Money Harvest. New York: Warner Books, Inc.

U.S. Department of Agriculture, Bureau of Agricultural Economics. (1938). Seventy-fifth anniversary of the United States Crop Reporting Service, 1863-1938. Washington, DC.

U.S. Department of Agriculture, Bureau of Statistics. (1905, January). Crop Reporter (Vol. 6, No. 9). Washington, DC.

U.S. Department of Agriculture, Motion Picture Service (Producer). (1962). Alice in numberland [Motion Picture]. Washington, DC.

U.S. Department of Agriculture, Motion Picture Service (Producer). (1967). The new numbers [Motion Picture]. Washington, DC.

U.S. Department of Agriculture, Motion Picture Service (Producer). (1980). Facts for farming: Crop and livestock reports [Motion Picture]. Washington, DC.

U.S. Department of Agriculture, National Agricultural Statistics Service. (1988). Monthly report of the condition of the crops, July 10, 1863. [Brochure]. Washington, DC.

U.S. Department of Agriculture, National Agricultural Statistics Service. (1987). The nation's first crop reporter was the father of our country. [Brochure]. Washington, DC.

Office of Communications (Producer). (1988). The need to know [Motion Picture]. Washington, DC.

U.S. Department of Agriculture, Statistical Reporting Service. (1966, July). Agricultural Situation: One hundred years of crop reporting, 1866-1966 (Vol. 50, No. 7). Washington, DC.

U.S. Department of Agriculture, Statistical Reporting Service. (1966, October 14). Centennial dinner, celebrating 100 years of continuous crop and livestock reporting for the entire United States. [Program]. Washington, DC.

U.S. Department of Agriculture, Statistical Reporting Service. (1969). The story of U.S. agricultural estimates, Miscellaneous Publication No. 1088. Washington, DC.

Van Biema, D. (1988, November 13). Talking jobs, eight Washington workers tell why they do what they do. The Washington Post Magazine, 30-31.

Wolfert, I. (1955, August). Drama behind the crop forecasts. Readers Digest, 67, 107-111.

Balance Sheet Uses for Estimation

Seth Riggins

Balance sheets are used in the Hogs and Pigs estimation procedures. There are three time series contained in each quarterly balance sheet: three months, six months and 12 months. The balance sheet provides an analysis tool for quickly examining beginning inventory, supply, disposition and ending inventory for each time series.

Beginning inventory is the total inventory as of the reference period for the time series being examined. For example, on the three month balance sheet, the beginning inventory is the total hogs and pigs inventory as of the reference date for the previous quarter. Supply consists of the pig crop and the number of pigs imported from other countries during the previous quarter, six months and 12 months respectively. Disposition is composed of commercial slaughter, farm slaughter, death loss and export of live pigs during the same time periods as above. Ending Inventory is the total hogs and pigs inventory for the quarter in question.

DEC 1 - MAR 1	March Quarter		
ITEM	2014	2015	2016
Dec 1 (PY) Inventory		67,626	
Dec-Feb Pig Crop			
Imports			
TOTAL SUPPLY		98,553	
Comm. Slaughter			
Farm Slaughter			
Deaths			
Exports			
TOTAL DISPOSITION		31,216	
Indicated Mar 1		67,337	
Estimated Mar 1		67,299	
DIFFERENCE		(38)	

SEP 1 - MAR 1	
ITEM	2015
Sep 1 (PY) Inventory	65,854
Sep-Feb Pig Crop	
Imports	
TOTAL SUPPLY	128,574
Comm. Slaughter	
Farm Slaughter	
Deaths	
Exports	
TOTAL DISPOSITION	61,238
Indicated Mar 1	67,336
Estimated Mar 1	67,299
DIFFERENCE	(37)

MAR 1 - MAR 1	
ITEM	2015
Mar 1 (PY) Inventory	61,344
Mar-Feb Pig Crop	
Imports	
TOTAL SUPPLY	184,433
Comm. Slaughter	
Farm Slaughter	
Deaths	
Exports	
TOTAL DISPOSITION	117,152
Indicated Mar 1	67,281
Estimated Mar 1	67,299
DIFFERENCE	18

As can be seen in the example above (which has 1,000 head units), the balance sheet allows the ASB members to quickly see how the new estimates for total inventory, pig crop and death loss interact with the previous three month, six month and 12 month estimates (which are also open for revision).

Quarterly Hogs and Pigs

ISSN: 1949-1921

Released March 28, 2019, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

United States Hog Inventory Up 2 Percent

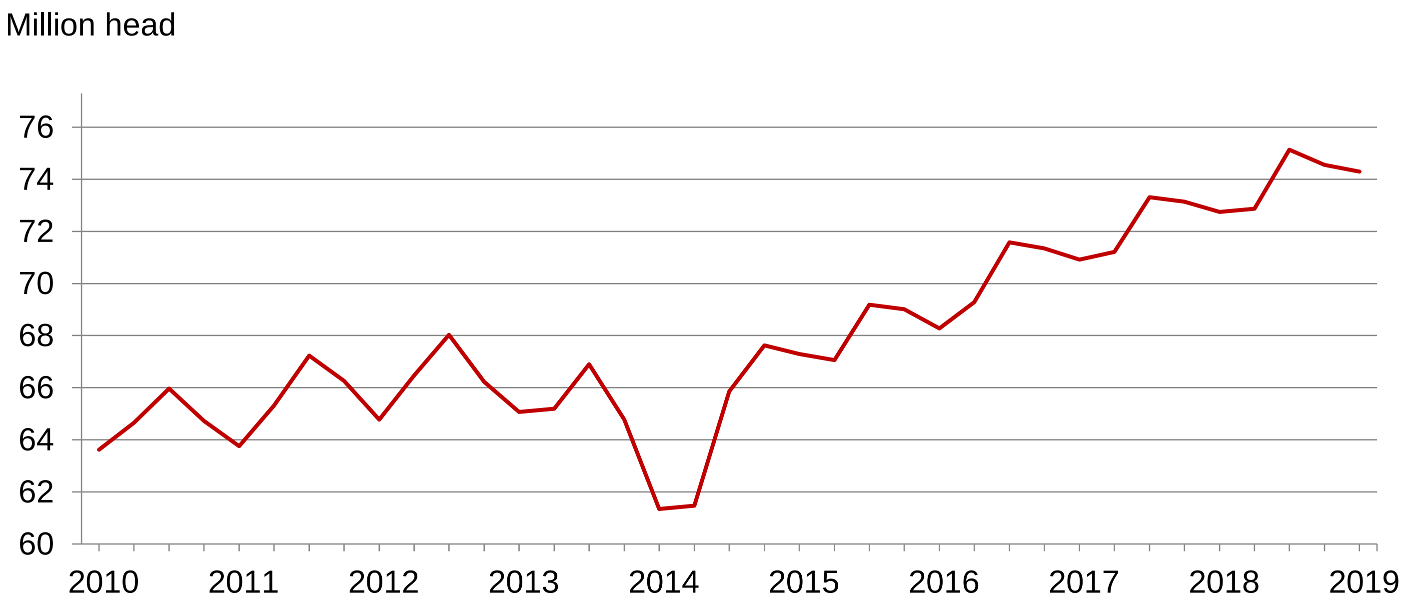
United States inventory of all hogs and pigs on March 1, 2019 was 74.3 million head. This was up 2 percent from March 1, 2018, but down slightly from December 1, 2018.

Breeding inventory, at 6.35 million head, was up 2 percent from last year, and up slightly from the previous quarter.

Market hog inventory, at 67.9 million head, was up 2 percent from last year, but down slightly from last quarter.

The December-February 2019 pig crop, at 33.0 million head, was up 3 percent from 2018. Sows farrowing during this period totaled 3.08 million head, up 2 percent from 2018. The sows farrowed during this quarter represented 49 percent of the breeding herd. The average pigs saved per litter was a record high of 10.70 for the December-February period, compared to 10.58 last year.

Quarterly Hogs and Pigs Inventory – United States: March 1



United States hog producers intend to have 3.12 million sows farrow during the March-May 2019 quarter, up 1 percent from the actual farrowings during the same period in 2018, and up 3 percent from 2017. Intended farrowings for June-August 2019, at 3.19 million sows, are down slightly from 2018, but up 3 percent from 2017.

The total number of hogs under contract owned by operations with over 5,000 head, but raised by contractees, accounted for 47 percent of the total United States hog inventory, unchanged from the previous year.

Revisions

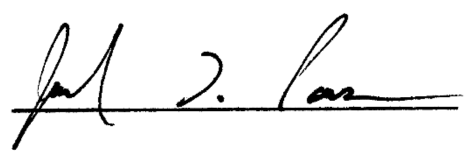
All inventory and pig crop estimates for March 2018 through December 2018 were reviewed using final pig crop, official slaughter, death loss, and updated import and export data. The net revision made to the September 2018 all hogs and pigs inventory was 0.5 percent. A revision of 0.5 percent was made to the June-August 2018 pig crop.

Records

Record highs for all hogs and pigs, market hogs, pig crop and pigs per litter, by quarter, can be found on page 13.

This report was approved on March 28, 2019.

Secretary of Agriculture
Designate
Robert Johansson



Agricultural Statistics Board
Chairperson
Joseph L. Parsons

Contents

Hogs and Pigs Inventory by Class, Weight Group, and Quarter – United States: 2018 and 2019

[May not add due to rounding. Blank data cells indicate estimation period has not yet begun]

Item	2018	2019	2019 as percent of 2018
	(1,000 head)	(1,000 head)	(percent)
March 1 inventory			
All hogs and pigs	72,748	74,296	102
Kept for breeding	6,210	6,349	102
Market	66,538	67,948	102
Market hogs and pigs by weight groups			
Under 50 pounds	20,942	21,456	102
50-119 pounds	18,212	18,639	102
120-179 pounds	14,996	15,268	102
180 pounds and over	12,387	12,585	102
June 1 inventory			
All hogs and pigs	72,866		
Kept for breeding	6,320		
Market	66,546		
Market hogs and pigs by weight groups			
Under 50 pounds	21,327		
50-119 pounds	19,083		
120-179 pounds	13,988		
180 pounds and over	12,147		
September 1 inventory			
All hogs and pigs	75,136		
Kept for breeding	6,330		
Market	68,806		
Market hogs and pigs by weight groups			
Under 50 pounds	22,192		
50-119 pounds	20,357		
120-179 pounds	14,066		
180 pounds and over	12,190		
December 1 inventory			
All hogs and pigs	74,550		
Kept for breeding	6,326		
Market	68,225		
Market hogs and pigs by weight groups			
Under 50 pounds	21,599		
50-119 pounds	18,932		
120-179 pounds	14,412		
180 pounds and over	13,282		

Sows Farrowing, Pig Crop, and Pigs per Litter – United States: 2017-2019

[December preceding year. Blank data cells indicate estimation period has not yet begun]

Item	2017	2018	2019	2019 as percent of 2017	2019 as percent of 2018
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(percent)
Sows farrowing					
December-February	2,990	3,034	3,084	103	102
March-May [1]	3,018	3,100	3,119	103	101
December-May [2 3]	6,007	6,134	6,203	103	101
June-August [1]	3,106	3,200	3,191	103	100
September-November	3,103	3,158			
June-November [3]	6,209	6,358			
Pig crop					
December-February	31,187	32,101	32,999	106	103
March-May	31,839	32,942			
December-May [3]	63,025	65,042			
June-August	33,075	34,320			
September-November	33,328	33,978			
June-November [3]	66,402	68,298			
	(number)	(number)	(number)	(percent)	(percent)
Pigs per litter					
December-February	10.43	10.58	10.70	103	101
March-May	10.55	10.63			
December-May	10.49	10.60			
June-August	10.65	10.72			
September-November	10.74	10.76			
June-November	10.69	10.74			

[1] Intentions for 2019.
[2] Actual farrowings for December 2018-February 2019 plus intentions for March-May 2019.
[3] May not add due to rounding.

Monthly Sows Farrowing, Pigs per Litter, and Pig Crop – United States: December-November 2018 and 2019

[December preceding year. Blank data cells indicate estimation period has not yet begun]

Month	Sows farrowing [1]		Pigs per litter		Pig crop [1]	
	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(number)	(number)	(1,000 head)	(1,000 head)
December	1,026	1,036	10.62	10.72	10,894	11,098
January	1,016	1,032	10.49	10.68	10,661	11,016
February	992	1,017	10.63	10.71	10,546	10,885
March	1,062		10.59		11,245	
April	1,013		10.52		10,658	
May	1,025		10.77		11,038	
June	1,085		10.62		11,523	
July	1,054		10.65		11,229	
August	1,062		10.90		11,569	
September	1,087		10.65		11,576	
October	1,041		10.84		11,289	
November	1,029		10.80		11,113	
Total	12,492		10.67		133,341	

[1] Monthly values may not add to quarterly or annual totals due to rounding.

Breeding, Market, and Total Inventory – States and United States: March 1, 2018 and 2019

[May not add due to rounding]

State	Breeding			Market			Total		
	2018	2019	2019 as percent of 2018	2018	2019	2019 as percent of 2018	2018	2019	2019 as percent of 2018
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	155	155	100	625	635	102	780	790	101
Illinois	550	560	102	4,750	4,640	98	5,300	5,200	98
Indiana	260	260	100	3,790	3,890	103	4,050	4,150	102
Iowa	1,020	1,030	101	21,580	22,470	104	22,600	23,500	104
Kansas	160	170	106	1,900	1,870	98	2,060	2,040	99
Michigan	120	120	100	1,080	1,090	101	1,200	1,210	101
Minnesota	570	580	102	7,930	8,120	102	8,500	8,700	102
Missouri	455	470	103	2,995	3,030	101	3,450	3,500	101
Nebraska	420	450	107	3,030	3,100	102	3,450	3,550	103
North Carolina	900	900	100	8,000	8,000	100	8,900	8,900	100
Ohio	190	190	100	2,460	2,410	98	2,650	2,600	98
Oklahoma	445	450	101	1,725	1,720	100	2,170	2,170	100
Pennsylvania	110	120	109	1,100	1,120	102	1,210	1,240	102
South Dakota	235	245	104	1,425	1,585	111	1,660	1,830	110
Texas	145	150	103	975	930	95	1,120	1,080	96
Utah	75	80	107	430	670	156	505	750	149
Other States [1]	400	419	105	2,743	2,668	97	3,143	3,086	98
United States	6,210	6,349	102	66,538	67,948	102	72,748	74,296	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: March 1, 2018 and 2019

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2018	2019	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	285	290	120	125	105	105	115	115
Illinois	1,465	1,435	1,465	1,515	980	1,000	840	690
Indiana	965	990	1,140	1,100	860	920	825	880
Iowa	5,490	5,610	6,670	7,210	5,460	5,780	3,960	3,870
Kansas	405	480	540	430	410	395	545	565
Michigan	320	330	265	280	245	220	250	260
Minnesota	2,630	2,590	2,360	2,300	1,790	1,950	1,150	1,280
Missouri	1,455	1,525	560	540	530	505	450	460
Nebraska	1,040	1,060	775	850	670	670	545	520
North Carolina	3,240	3,190	1,720	1,650	1,710	1,590	1,330	1,570
Ohio	680	700	610	610	600	520	570	580
Oklahoma	735	800	335	360	260	210	395	350
Pennsylvania	290	305	305	305	270	245	235	265
South Dakota	510	590	370	380	280	310	265	305
Texas	270	265	270	260	185	180	250	225
Utah	155	295	90	120	95	130	90	125
Other States [1]	1,007	1,001	617	604	546	538	572	525
United States	20,942	21,456	18,212	18,639	14,996	15,268	12,387	12,585

[1] Individual State estimates not available for the 34 Other States.

Breeding, Market, and Total Inventory – States and United States: June 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	155	155	100	565	605	107	720	760	106
Illinois	530	570	108	4,720	4,780	101	5,250	5,350	102
Indiana	260	250	96	3,740	3,700	99	4,000	3,950	99
Iowa	1,030	1,040	101	20,970	21,560	103	22,000	22,600	103
Kansas	160	165	103	1,800	1,875	104	1,960	2,040	104
Michigan	110	120	109	1,000	1,080	108	1,110	1,200	108
Minnesota	570	580	102	8,030	7,920	99	8,600	8,500	99
Missouri	440	460	105	2,810	3,040	108	3,250	3,500	108
Nebraska	420	430	102	2,980	3,070	103	3,400	3,500	103
North Carolina	880	910	103	8,120	7,990	98	9,000	8,900	99
Ohio	190	190	100	2,360	2,460	104	2,550	2,650	104
Oklahoma	450	460	102	1,560	1,690	108	2,010	2,150	107
Pennsylvania	105	120	114	1,085	1,170	108	1,190	1,290	108
South Dakota	200	240	120	1,290	1,440	112	1,490	1,680	113
Texas	125	145	116	785	995	127	910	1,140	125
Utah	75	80	107	605	450	74	680	530	78
Other States [1]	409	405	99	2,681	2,721	101	3,090	3,126	101
United States	6,109	6,320	103	65,101	66,546	102	71,210	72,866	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: June 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	255	290	120	120	100	95	90	100
Illinois	1,430	1,550	1,530	1,460	930	930	830	840
Indiana	920	940	1,170	1,150	790	780	860	830
Iowa	5,450	5,560	6,950	7,080	4,950	5,200	3,620	3,720
Kansas	480	420	490	515	355	375	475	565
Michigan	290	310	240	290	245	220	225	260
Minnesota	2,610	2,610	2,440	2,430	1,660	1,760	1,320	1,120
Missouri	1,360	1,505	580	590	435	475	435	470
Nebraska	1,005	1,050	785	840	615	600	575	580
North Carolina	3,290	3,370	1,880	1,840	1,490	1,450	1,460	1,330
Ohio	720	670	650	630	550	580	440	580
Oklahoma	685	785	340	400	230	215	305	290
Pennsylvania	285	310	345	355	280	250	175	255
South Dakota	455	510	345	380	240	270	250	280
Texas	165	300	235	275	175	165	210	255
Utah	245	175	120	90	130	90	110	95
Other States [1]	1,002	972	621	638	521	533	537	577
United States	20,647	21,327	18,841	19,083	13,696	13,988	11,917	12,147

[1] Individual State estimates not available for the 34 Other States.

Breeding, Market, and Total Inventory – States and United States: September 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	160	155	97	600	625	104	760	780	103
Illinois	540	570	106	4,860	4,880	100	5,400	5,450	101
Indiana	260	250	96	3,840	3,950	103	4,100	4,200	102
Iowa	980	1,040	106	21,720	22,560	104	22,700	23,600	104
Kansas	165	170	103	1,845	1,860	101	2,010	2,030	101
Michigan	120	120	100	1,070	1,100	103	1,190	1,220	103
Minnesota	550	580	105	7,850	8,020	102	8,400	8,600	102
Missouri	440	465	106	3,060	3,285	107	3,500	3,750	107
Nebraska	410	430	105	3,090	3,020	98	3,500	3,450	99
North Carolina	900	910	101	8,400	8,390	100	9,300	9,300	100
Ohio	180	190	106	2,420	2,360	98	2,600	2,550	98
Oklahoma	455	460	101	1,735	1,820	105	2,190	2,280	104
Pennsylvania	110	120	109	1,100	1,190	108	1,210	1,310	108
South Dakota	215	245	114	1,325	1,475	111	1,540	1,720	112
Texas	135	145	107	895	985	110	1,030	1,130	110
Utah	80	80	100	600	525	88	680	605	89
Other States [1]	417	400	96	2,782	2,761	99	3,199	3,161	99
United States	6,117	6,330	103	67,192	68,806	102	73,309	75,136	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: September 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	275	305	125	150	105	95	95	75
Illinois	1,505	1,570	1,620	1,580	930	890	805	840
Indiana	1,050	990	1,180	1,240	780	870	830	850
Iowa	5,670	5,900	7,250	7,750	5,100	5,210	3,700	3,700
Kansas	475	445	510	530	360	385	500	500
Michigan	310	330	260	290	250	220	250	260
Minnesota	2,630	2,720	2,550	2,530	1,550	1,700	1,120	1,070
Missouri	1,485	1,605	640	640	460	530	475	510
Nebraska	1,015	1,010	835	865	600	570	640	575
North Carolina	3,400	3,450	1,950	2,000	1,550	1,520	1,500	1,420
Ohio	700	650	685	640	540	500	495	570
Oklahoma	770	845	440	385	265	230	260	360
Pennsylvania	305	325	340	340	275	270	180	255
South Dakota	450	520	365	405	260	275	250	275
Texas	235	310	255	275	160	150	245	250
Utah	235	220	125	105	130	105	110	95
Other States [1]	1,023	997	627	632	559	546	573	585
United States	21,533	22,192	19,757	20,357	13,874	14,066	12,028	12,190

[1] Individual State estimates not available for the 34 Other States.

Breeding, Market, and Total Inventory – States and United States: December 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	150	155	103	600	595	99	750	750	100
Illinois	530	560	106	4,870	4,740	97	5,400	5,300	98
Indiana	260	260	100	3,740	3,940	105	4,000	4,200	105
Iowa	1,000	1,020	102	21,800	22,280	102	22,800	23,300	102
Kansas	165	170	103	1,945	1,880	97	2,110	2,050	97
Michigan	120	120	100	1,070	1,060	99	1,190	1,180	99
Minnesota	570	570	100	7,930	8,330	105	8,500	8,900	105
Missouri	450	470	104	2,950	3,080	104	3,400	3,550	104
Nebraska	430	440	102	3,170	3,060	97	3,600	3,500	97
North Carolina	900	900	100	8,100	8,200	101	9,000	9,100	101
Ohio	190	200	105	2,510	2,350	94	2,700	2,550	94
Oklahoma	460	445	97	1,740	1,755	101	2,200	2,200	100
Pennsylvania	110	120	109	1,130	1,190	105	1,240	1,310	106
South Dakota	215	255	119	1,345	1,485	110	1,560	1,740	112
Texas	140	150	107	910	960	105	1,050	1,110	106
Utah	80	80	100	470	630	134	550	710	129
Other States [1]	409	411	100	2,686	2,690	100	3,095	3,100	100
United States	6,179	6,326	102	66,966	68,225	102	73,145	74,550	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: December 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	255	270	130	125	115	85	100	115
Illinois	1,550	1,480	1,480	1,500	920	910	920	850
Indiana	980	1,010	1,040	1,200	775	820	945	910
Iowa	5,800	5,700	6,870	7,100	5,080	5,260	4,050	4,220
Kansas	475	455	520	515	425	380	525	530
Michigan	330	320	240	280	245	210	255	250
Minnesota	2,720	2,790	2,350	2,400	1,600	1,830	1,260	1,310
Missouri	1,450	1,550	560	550	445	510	495	470
Nebraska	1,030	1,030	840	790	640	610	660	630
North Carolina	3,190	3,190	1,790	1,780	1,570	1,600	1,550	1,630
Ohio	740	670	660	610	560	520	550	550
Oklahoma	735	760	430	385	230	280	345	330
Pennsylvania	305	335	335	335	250	265	240	255
South Dakota	460	565	365	365	270	285	250	270
Texas	240	270	240	260	180	170	250	260
Utah	185	240	85	125	100	135	100	130
Other States [1]	962	964	609	612	520	542	594	572
United States	21,407	21,599	18,544	18,932	13,925	14,412	13,089	13,282

[1] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: December-February 2018 and 2019

[December preceding year. May not add due to rounding]

State	Sows farrowing			Pigs per litter		Pig crop [1]		
	2018	2019	2019 as percent of 2018	2018	2019	2018	2019	2019 as percent of 2018
	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	72	78	108	9.70	9.20	698	718	103
Illinois	260	265	102	10.60	10.65	2,756	2,822	102
Indiana	130	125	96	10.45	10.20	1,359	1,275	94
Iowa	550	530	96	11.00	11.20	6,050	5,936	98
Kansas	79	86	109	10.20	10.60	806	912	113
Michigan	53	56	106	10.70	10.90	567	610	108
Minnesota	295	290	98	11.20	11.60	3,304	3,364	102
Missouri	225	240	107	10.15	10.55	2,284	2,532	111
Nebraska	180	185	103	11.70	11.55	2,106	2,137	101
North Carolina	445	450	101	9.90	9.90	4,406	4,455	101
Ohio	91	91	100	10.80	10.70	983	974	99
Oklahoma	200	205	103	10.60	10.65	2,120	2,183	103
Pennsylvania	48	54	113	10.60	10.80	509	583	115
South Dakota	113	118	104	11.45	11.85	1,294	1,398	108
Texas	60	66	110	9.90	10.20	594	673	113
Utah	36	40	111	7.70	9.20	277	368	133
Other States [2]	197	205	104	10.08	10.05	1,988	2,059	104
United States	3,034	3,084	102	10.58	10.70	32,101	32,999	103

[1] Number of pigs born December-February that were still on hand March 1, or had been sold.
[2] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: March-May 2017-2019

[May not add due to rounding]

State	Sows farrowing				Pigs per litter		Pig crop [1]		
	2017	2018	2019 [2]	2019 as percent of 2018	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	77	75	73	97	10.40	9.60	801	720	90
Illinois	255	275	270	98	10.55	10.70	2,690	2,943	109
Indiana	135	115	130	113	10.50	10.30	1,418	1,185	84
Iowa	510	560	530	95	10.95	11.10	5,585	6,216	111
Kansas	81	76	85	112	10.00	10.10	810	768	95
Michigan	51	53	55	104	10.50	10.90	536	578	108
Minnesota	300	310	295	95	11.40	11.20	3,420	3,472	102
Missouri	220	240	250	104	10.25	10.20	2,255	2,448	109
Nebraska	185	190	195	103	11.45	11.30	2,118	2,147	101
North Carolina	470	455	465	102	10.00	10.10	4,700	4,596	98
Ohio	97	88	92	105	10.60	11.00	1,028	968	94
Oklahoma	195	205	205	100	10.60	10.70	2,067	2,194	106
Pennsylvania	51	50	53	106	10.50	10.50	536	525	98
South Dakota	102	110	118	107	11.40	11.70	1,163	1,287	111
Texas	50	64	66	103	7.30	9.80	365	627	172
Utah	39	34	40	118	9.00	7.60	351	258	74
Other States [3]	200	200	197	98	10.00	10.06	1,996	2,010	101
United States	3,018	3,100	3,119	101	10.55	10.63	31,839	32,942	103

[1] Number of pigs born March-May that were still on hand June 1, or had been sold.
[2] Intentions.
[3] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: June-August 2017-2019

[May not add due to rounding]

State	Sows farrowing				Pigs per litter		Pig crop [1]		
	2017	2018	2019 [2]	2019 as percent of 2018	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	78	80	77	96	10.90	9.50	850	760	89
Illinois	265	265	275	104	10.75	10.65	2,849	2,822	99
Indiana	135	125	130	104	10.35	10.50	1,397	1,313	94
Iowa	520	580	560	97	11.20	11.20	5,824	6,496	112
Kansas	85	87	87	100	10.60	10.90	901	948	105
Michigan	54	57	54	95	10.80	10.80	583	616	106
Minnesota	300	305	300	98	11.40	11.15	3,420	3,401	99
Missouri	235	255	255	100	10.15	10.45	2,385	2,665	112
Nebraska	190	185	200	108	11.65	11.30	2,214	2,091	94
North Carolina	490	485	465	96	10.05	10.30	4,925	4,996	101
Ohio	97	89	95	107	10.70	10.90	1,038	970	93
Oklahoma	205	210	210	100	10.60	10.65	2,173	2,237	103
Pennsylvania	51	51	53	104	10.60	10.70	541	546	101
South Dakota	105	117	115	98	11.30	11.10	1,187	1,299	109
Texas	52	69	70	101	7.80	10.10	406	697	172
Utah	36	39	39	100	9.00	11.00	324	429	132
Other States [3]	208	201	206	102	9.88	10.10	2,058	2,034	99
United States	3,106	3,200	3,191	100	10.65	10.72	33,075	34,320	104

[1] Number of pigs born June-August that were still on hand September 1, or had been sold.
[2] Intentions.
[3] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: September-November 2017 and 2018

[May not add due to rounding]

State	Sows Farrowing			Pigs per litter		Pig crop [1]		
	2017	2018	2018 as percent of 2017	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	72	75	104	10.20	9.60	734	720	98
Illinois	265	270	102	10.70	10.65	2,836	2,876	101
Indiana	135	120	89	10.35	10.60	1,397	1,272	91
Iowa	550	560	102	11.15	11.20	6,133	6,272	102
Kansas	83	85	102	10.80	10.90	896	927	103
Michigan	53	54	102	10.90	10.50	578	567	98
Minnesota	315	300	95	11.45	11.40	3,607	3,420	95
Missouri	235	250	106	10.40	10.60	2,444	2,650	108
Nebraska	195	190	97	11.70	11.45	2,282	2,176	95
North Carolina	460	465	101	10.20	10.15	4,692	4,720	101
Ohio	94	98	104	10.80	10.50	1,015	1,029	101
Oklahoma	195	205	105	10.70	10.60	2,087	2,173	104
Pennsylvania	49	52	106	10.40	11.00	510	572	112
South Dakota	105	127	121	11.45	11.65	1,202	1,480	123
Texas	60	67	112	9.20	10.40	552	697	126
Utah	35	37	106	9.00	10.00	315	370	117
Other States [2]	202	203	100	10.15	10.15	2,048	2,057	100
United States	3,103	3,158	102	10.74	10.76	33,328	33,978	102

[1] Number of pigs born September-November that were still on hand December 1, or had been sold.
[2] Individual State estimates not available for the 34 Other States.

Statistical Methodology

Survey Procedures: A random sample of roughly 5,100 United States producers was surveyed to provide data for these estimates. Survey procedures ensured that all hog and pig producers, regardless of size, had a chance to be included in the survey. Large operations were sampled more heavily than small operations. During the first half of March 2019, data were collected from about 3,500 operations, 69.2 percent of the total sample. The data collected were received by electronic data reporting, mail, telephone, and face-to-face personal interviews. Regardless of when operations responded, they were asked to report inventories as of March 1, 2019.

Estimating Procedures: Hogs and pigs estimates were prepared by the Agricultural Statistics Board after reviewing recommendations and analysis submitted by each regional field office. National and State survey data were reviewed for reasonableness with each other and with estimates from past years using a balance sheet. The balance sheet begins with the previous inventory estimate, adds the estimates of births and imports, and subtracts the estimates of slaughter, exports, and deaths. This indicated ending inventory level is compared to the Agricultural Statistics Board estimate for reasonableness.

Revision Policy: Revisions to previous estimates are made to improve quarter to quarter relationships. Estimates for the previous four quarters are subject to revision when current estimates are made. In December, estimates for all quarters of the current and previous year are reviewed. The reviews are primarily based on hog check-off receipts and slaughter. Estimates will also be reviewed after data from the Department of Agriculture five-year Census of Agriculture are available. No revisions will be made after that date.

Reliability: Since all operations raising hogs are not included in the sample, survey estimates are subject to sampling variability. Survey results are also subject to non-sampling errors such as omissions, duplication, and mistakes in reporting, recording, and processing the data. The effects of these errors cannot be measured directly. They are minimized through rigid quality controls in the data collection process and through a careful review of all reported data for consistency and reasonableness.

To assist users in evaluating the reliability of the estimates in this report, the **"Root Mean Square Error"** is shown for selected items in the following table. The "Root Mean Square Error" is a statistical measure based on past performance and is computed using the difference between first and final estimates. The "Root Mean Square Error" for hog inventory estimates over the past 20 quarters is 1.1 percent. This means that chances are 2 out of 3 that the final estimate will not be above or below the current estimate of 74.3 million head by more than 1.1 percent. Chances are 9 out of 10 that the difference will not exceed 1.9 percent.

Reliability of March 1 Hog Estimates

[Based on data for the previous twenty quarters]

Item	Root mean square error	90 percent confidence level	Difference between first and latest estimate				
			Average	Smallest	Largest	Years	
						Below latest	Above latest
	(percent)	(percent)	(1,000)	(1,000)	(1,000)	(number)	(number)
All hogs and pigs	1.1	1.9	583	0	1,576	9	10
Pig crop	1.9	3.2	423	0	1,158	12	7
Expected farrowings							
Next quarter	2.5	4.4	67	19	129	13	7
Following quarter	3.0	5.2	75	11	197	12	8

Records by Quarter – United States: 1866 to Present

[This table provides data users with record high estimates of all hogs and pigs, market hogs, pig crop, and pigs per litter since each data series began]

Item	Estimate	Record high	Series began
	(1,000 head)	(year)	(year)
All hogs and pigs			
March 1	74,296	2019	1988
June 1	72,866	2018	1964
September 1	75,136	2018	1988
December 1	83,741	1943	1866
Market			
March 1	67,948	2019	1988
June 1	66,546	2018	1964
September 1	68,806	2018	1988
December 1	68,225	2018	1963
Pig crop			
December-February[1]	32,999	2019	1970
March-May	32,942	2018	1970
June-August	34,320	2018	1970
September-November	33,978	2018	1970
	(number)	(year)	(year)
Pigs per litter			
December-February[1]	10.70	2019	1970
March-May	10.63	2018	1970
June-August	10.72	2018	1970
September-November	10.76	2018	1970

[1] December preceding year.

Information Contacts

Listed below are the commodity specialists in the Livestock Branch of the National Agricultural Statistics Service to contact for additional information. E-mail inquiries may be sent to nass@nass.usda.gov.

Travis Averill, Chief, Livestock Branch .... (202) 720-3570

Scott Hollis, Head, Livestock Section .... (202) 690-2424
- Sherry Bertramsen – Livestock Slaughter .... (202) 690-8632
- Holly Brenize – Sheep and Goats .... (202) 720-0585
- Donnie Fike – Dairy Products .... (202) 720-4448
- Heidi Gleich – Cattle, Cattle on Feed .... (202) 720-3040
- Mike Miller – Milk Production and Milk Cows .... (202) 720-3278
- Seth Riggins – Hogs and Pigs .... (202) 720-3106

Access to NASS Reports

For your convenience, you may access NASS reports and products the following ways:

- All reports are available electronically, at no cost, on the NASS web site: www.nass.usda.gov

- Both national and state specific reports are available via a free e-mail subscription. To set-up this free subscription, visit www.nass.usda.gov and click on "National" or "State" in upper right corner above "search" box to create an account and select the reports you would like to receive.

- Cornell's Mann Library has launched a new website housing NASS's and other agency's archived reports. The new website, https://usda.library.cornell.edu. All email subscriptions containing reports will be sent from the new website, https://usda.library.cornell.edu. To continue receiving the reports via e-mail, you will have to go to the new website, create a new account and re-subscribe to the reports. If you need instructions to set up an account or subscribe, they are located at: https://usda.library.cornell.edu/help. You should whitelist notifications@usda-esmis.library.cornell.edu in your email client to avoid the emails going into spam/junk folders.

For more information on NASS surveys and reports, call the NASS Agricultural Statistics Hotline at (800) 727-9540, 7:30 a.m. to 4:00 p.m. ET, or e-mail: nass@nass.usda.gov.

USDA NASS Data Users' Meeting

Tuesday, April 23, 2019

University of Chicago – Gleacher Center
450 North Cityfront Plaza Drive
Chicago, IL 60611
312-464-8787

USDA's National Agricultural Statistics Service will hold an open forum for users of U.S. domestic and international agriculture data. NASS is organizing the 2019 Data Users' Meeting in cooperation with five other USDA agencies – Agricultural Marketing Service, Economic Research Service, Farm Service Agency, Foreign Agricultural Service, and World Agricultural Outlook Board – and the Census Bureau's Foreign Trade Division. Agency representatives will provide updates on recent and pending changes in statistical and information programs important to agriculture, answer questions, and welcome comments and input from data users.

For registration details or additional information about the Data Users' Meeting, see the meeting page on the NASS website (https://www.nass.usda.gov/Education_and_Outreach/Meeting/index.php). Contact Vernita Murray (NASS) at 202-690-8141 or vernita.murray@nass.usda.gov or Patricia Snipe (NASS) at 202-720-2248 or patricia.snipe@nass.usda.gov for information.

The Data Users' Meeting precedes the Industry Outlook Conference at the same location on Wednesday, April 24, 2019. The outlook meeting brings together analysts from various commodity sectors to discuss developments and trends. For registration details or additional information about the Industry Outlook Conference, see the conference page on the LMIC website (http://lmic.info/page/meetings). Or contact Laura Lahr at 303-716-9935 or laura.lahr@lmic.info.

Quarterly Hogs and Pigs

ISSN: 1949-1921

Released December 20, 2018, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

United States Hog Inventory Up 2 Percent

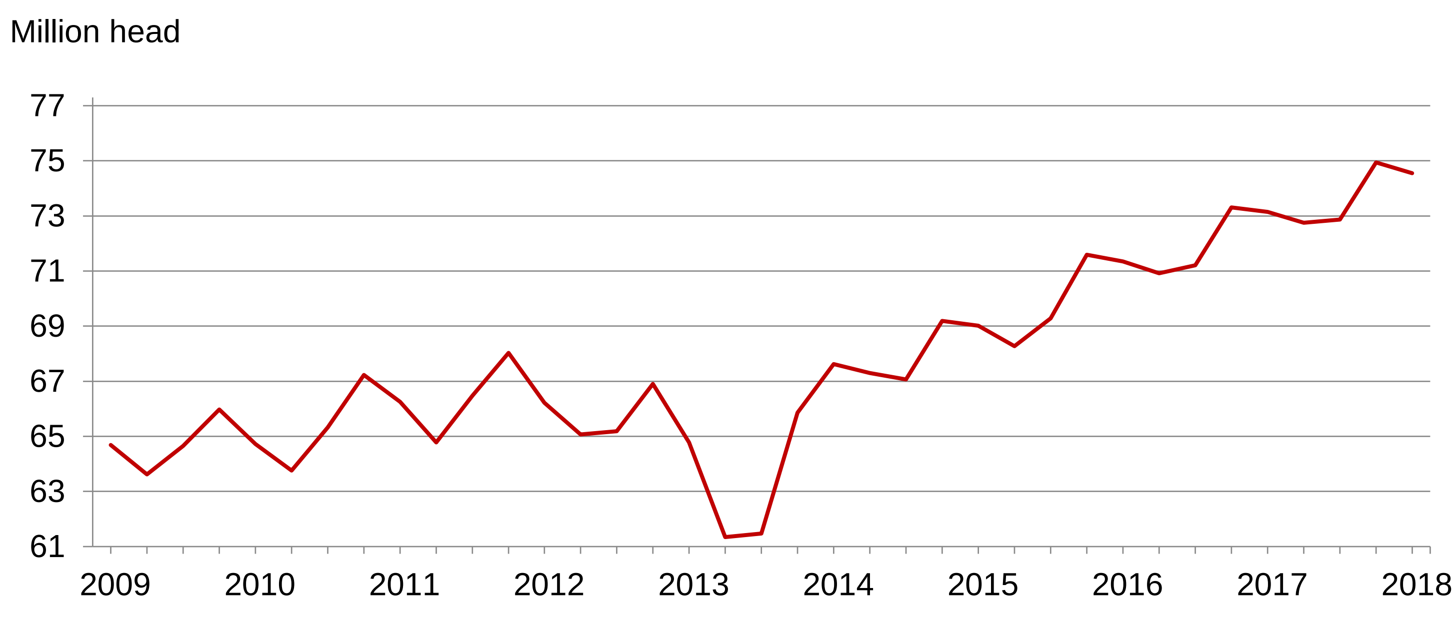
United States inventory of all hogs and pigs on December 1, 2018 was 74.6 million head. This was up 2 percent from December 1, 2017, but down 1 percent from September 1, 2018.

Breeding inventory, at 6.33 million head, was up 2 percent from last year, but down slightly from the previous quarter.

Market hog inventory, at 68.2 million head, was up 2 percent from last year, but down 1 percent from last quarter.

The September-November 2018 pig crop, at 34.0 million head, was up 2 percent from 2017. Sows farrowing during this period totaled 3.16 million head, up 2 percent from 2017. The sows farrowed during this quarter represented 50 percent of the breeding herd. The average pigs saved per litter was a record high of 10.76 for the September-November period, compared to 10.74 last year.

Quarterly Hogs and Pigs Inventory – United States: December 1



United States hog producers intend to have 3.11 million sows farrow during the December-February 2019 quarter, up 2 percent from the actual farrowings during the same period in 2018, and up 4 percent from 2017. Intended farrowings for March-May 2019, at 3.15 million sows, are up 2 percent from 2018, and up 4 percent from 2017.

The total number of hogs under contract owned by operations with over 5,000 head, but raised by contractees, accounted for 47 percent of the total United States hog inventory, unchanged from the previous year.

Revisions

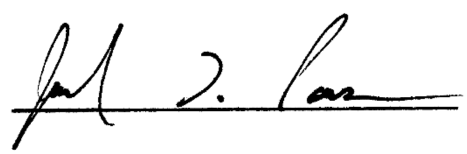
All inventory and pig crop estimates for March 2017 through September 2018 were reviewed using final pig crop, official slaughter, death loss, and updated import and export data. The revision made to the September 2018 all hogs and pigs inventory was 0.7 percent. The net revision made to the June 2018 all hogs and pigs inventory was 0.8 percent. A revision of 0.7 percent was made to the March-May 2018 pig crop. The net revision made to the March 2018 all hogs and pigs inventory was 0.2 percent. A net revision of 0.7 percent was made to the December 2017-February 2018 pig crop. The net revision made to December 2017 all hogs and pigs inventory was 0.3 percent. A net revision of less than 0.1 percent was made to the September-November 2017 pig crop.

Records

Record highs for all hogs and pigs, market hogs, pig crop and pigs per litter, by quarter, can be found on page 15.

This report was approved on December 20, 2018.

Secretary of Agriculture
Designate
Robert Johansson



Agricultural Statistics Board
Chairperson
Joseph L. Parsons

Contents

Hogs and Pigs Inventory by Class, Weight Group, and Quarter – United States: 2017 and 2018

[May not add due to rounding]

Item	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)
March 1 inventory			
All hogs and pigs	70,916	72,748	103
Kept for breeding	6,098	6,210	102
Market	64,818	66,538	103
Market hogs and pigs by weight groups			
Under 50 pounds	20,422	20,942	103
50-119 pounds	17,942	18,212	102
120-179 pounds	14,485	14,996	104
180 pounds and over	11,969	12,387	103
June 1 inventory			
All hogs and pigs	71,210	72,866	102
Kept for breeding	6,109	6,320	103
Market	65,101	66,546	102
Market hogs and pigs by weight groups			
Under 50 pounds	20,647	21,327	103
50-119 pounds	18,841	19,083	101
120-179 pounds	13,696	13,988	102
180 pounds and over	11,917	12,147	102
September 1 inventory			
All hogs and pigs	73,309	74,941	102
Kept for breeding	6,117	6,330	103
Market	67,192	68,611	102
Market hogs and pigs by weight groups			
Under 50 pounds	21,533	22,092	103
50-119 pounds	19,757	20,262	103
120-179 pounds	13,874	14,066	101
180 pounds and over	12,028	12,190	101
December 1 inventory			
All hogs and pigs	73,145	74,550	102
Kept for breeding	6,179	6,326	102
Market	66,966	68,225	102
Market hogs and pigs by weight groups			
Under 50 pounds	21,407	21,599	101
50-119 pounds	18,544	18,932	102
120-179 pounds	13,925	14,412	103
180 pounds and over	13,089	13,282	101

Sows Farrowing, Pig Crop, and Pigs per Litter – United States: 2017-2019

[May not add due to rounding. Blank data cells indicate estimation period has not yet begun]

Item	2017	2018	2019	2018 as percent of 2017	2019 as percent of 2018
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(percent)
Sows farrowing					
December-February [1] [2]	2,990	3,034	3,110	101	102
March-May [2]	3,018	3,100	3,147	103	102
December-May [1]	6,007	6,134	6,257	102	102
June-August	3,106	3,185		103	
September-November	3,103	3,158		102	
June-November	6,209	6,343		102	
Pig crop					
December-February [1]	31,187	32,101		103	
March-May	31,839	32,942		103	
December-May [1]	63,025	65,042		103	
June-August	33,075	34,155		103	
September-November	33,328	33,978		102	
June-November	66,402	68,133		103	
	(number)	(number)	(number)	(percent)	(percent)
Pigs per litter					
December-February [1]	10.43	10.58		101	
March-May	10.55	10.63		101	
December-May [1]	10.49	10.60		101	
June-August	10.65	10.72		101	
September-November	10.74	10.76		100	
June-November	10.69	10.74		100	

[1] December preceding year.
[2] Intentions for 2019.

Monthly Sows Farrowing, Pigs per Litter, and Pig Crop – United States: December-November 2017 and 2018

[December preceding year]

Month	Sows farrowing [1]		Pigs per litter		Pig crop [1]	
	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(number)	(number)	(1,000 head)	(1,000 head)
December	1,007	1,026	10.44	10.62	10,514	10,894
January	993	1,016	10.39	10.49	10,323	10,661
February	989	992	10.46	10.63	10,350	10,546
March	1,037	1,062	10.54	10.59	10,932	11,245
April	977	1,013	10.56	10.52	10,315	10,658
May	1,004	1,025	10.55	10.77	10,592	11,038
June	1,060	1,078	10.56	10.66	11,187	11,487
July	1,020	1,048	10.65	10.70	10,859	11,215
August	1,027	1,060	10.74	10.81	11,028	11,453
September	1,065	1,087	10.65	10.65	11,343	11,576
October	1,026	1,041	10.77	10.84	11,050	11,289
November	1,013	1,029	10.80	10.80	10,935	11,113
Total	12,216	12,477	10.59	10.67	129,428	133,176

[1] Monthly values may not add to quarterly or annual totals due to rounding.

Breeding, Market, and Total Inventory – States and United States: December 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Alabama	10.00	10.00	100	47.00	43.00	91	57.00	53.00	93
Alaska	0.30	0.30	100	1.20	1.60	133	1.50	1.90	127
Arizona	17.00	17.00	100	143.00	153.00	107	160.00	170.00	106
Arkansas	48.00	46.00	96	83.00	84.00	101	131.00	130.00	99
California	4.00	8.00	200	91.00	93.00	102	95.00	101.00	106
Colorado	150.00	155.00	103	600.00	595.00	99	750.00	750.00	100
Connecticut	0.60	0.50	83	2.60	3.20	123	3.20	3.70	116
Delaware	2.00	2.00	100	4.00	4.50	113	6.00	6.50	108
Florida	3.00	3.00	100	12.00	10.00	83	15.00	13.00	87
Georgia	22.00	17.00	77	58.00	50.00	86	80.00	67.00	84
Hawaii	2.00	3.00	150	6.00	6.00	100	8.00	9.00	113
Idaho	5.00	6.00	120	32.00	26.00	81	37.00	32.00	86
Illinois	530.00	560.00	106	4,870.00	4,740.00	97	5,400.00	5,300.00	98
Indiana	260.00	260.00	100	3,740.00	3,940.00	105	4,000.00	4,200.00	105
Iowa	1,000.00	1,020.00	102	21,800.00	22,280.00	102	22,800.00	23,300.00	102
Kansas	165.00	170.00	103	1,945.00	1,880.00	97	2,110.00	2,050.00	97
Kentucky	45.00	37.00	82	365.00	248.00	68	410.00	285.00	70
Louisiana	2.00	2.00	100	4.00	4.00	100	6.00	6.00	100
Maine	1.00	1.00	100	3.50	3.40	97	4.50	4.40	98
Maryland	4.00	3.50	88	17.00	15.50	91	21.00	19.00	90
Massachusetts	1.50	2.00	133	6.00	6.00	100	7.50	8.00	107
Michigan	120.00	120.00	100	1,070.00	1,060.00	99	1,190.00	1,180.00	99
Minnesota	570.00	570.00	100	7,930.00	8,330.00	105	8,500.00	8,900.00	105
Mississippi	51.00	51.00	100	519.00	524.00	101	570.00	575.00	101
Missouri	450.00	470.00	104	2,950.00	3,080.00	104	3,400.00	3,550.00	104
Montana	25.00	33.00	132	154.00	159.00	103	179.00	192.00	107
Nebraska	430.00	440.00	102	3,170.00	3,060.00	97	3,600.00	3,500.00	97
Nevada	0.10	0.30	300	2.90	5.70	197	3.00	6.00	200
New Hampshire	0.70	0.60	86	2.70	2.90	107	3.40	3.50	103
New Jersey	1.50	1.00	67	7.00	7.50	107	8.50	8.50	100
New Mexico	0.50	0.60	120	1.10	0.70	64	1.60	1.30	81
New York	6.00	6.00	100	42.00	40.00	95	48.00	46.00	96
North Carolina	900.00	900.00	100	8,100.00	8,200.00	101	9,000.00	9,100.00	101
North Dakota	35.00	35.00	100	112.00	110.00	98	147.00	145.00	99
Ohio	190.00	200.00	105	2,510.00	2,350.00	94	2,700.00	2,550.00	94
Oklahoma	460.00	445.00	97	1,740.00	1,755.00	101	2,200.00	2,200.00	100
Oregon	1.50	1.50	100	7.50	7.50	100	9.00	9.00	100
Pennsylvania	110.00	120.00	109	1,130.00	1,190.00	105	1,240.00	1,310.00	106
Rhode Island	0.30	0.30	100	1.70	1.40	82	2.00	1.70	85
South Carolina	10.00	12.00	120	175.00	188.00	107	185.00	200.00	108
South Dakota	215.00	255.00	119	1,345.00	1,485.00	110	1,560.00	1,740.00	112
Tennessee	23.00	23.00	100	212.00	197.00	93	235.00	220.00	94
Texas	140.00	150.00	107	910.00	960.00	105	1,050.00	1,110.00	106
Utah	80.00	80.00	100	470.00	630.00	134	550.00	710.00	129
Vermont	1.00	1.00	100	2.70	2.70	100	3.70	3.70	100
Virginia	5.00	6.00	120	235.00	339.00	144	240.00	345.00	144
Washington	3.00	3.00	100	14.00	14.00	100	17.00	17.00	100
West Virginia	1.00	1.00	100	4.00	3.00	75	5.00	4.00	80
Wisconsin	45.00	44.00	98	260.00	281.00	108	305.00	325.00	107
Wyoming	32.00	33.00	103	58.00	55.00	95	90.00	88.00	98
United States	6,179.00	6,325.60	102	66,965.90	68,224.60	102	73,144.90	74,550.20	102

Market Inventory by Weight Group – States and United States: December 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Alabama	15.00	18.00	11.00	7.00	10.00	8.00	11.00	10.00
Alaska	0.30	0.40	0.50	0.60	0.20	0.20	0.20	0.40
Arizona	50.00	55.00	31.00	30.00	31.00	33.00	31.00	35.00
Arkansas	69.00	63.00	6.00	13.00	5.00	5.00	3.00	3.00
California	24.00	25.00	22.00	22.00	23.00	22.00	22.00	24.00
Colorado	255.00	270.00	130.00	125.00	115.00	85.00	100.00	115.00
Connecticut	1.30	1.60	0.60	0.50	0.40	0.60	0.30	0.50
Delaware	2.80	3.00	0.40	0.50	0.30	0.50	0.50	0.50
Florida	4.00	3.00	4.00	3.00	2.00	2.00	2.00	2.00
Georgia	32.00	28.00	9.00	8.00	8.00	7.00	9.00	7.00
Hawaii	2.00	2.70	1.50	1.30	1.50	1.30	1.00	0.70
Idaho	17.00	14.00	4.50	4.00	3.50	3.00	7.00	5.00
Illinois	1,550.00	1,480.00	1,480.00	1,500.00	920.00	910.00	920.00	850.00
Indiana	980.00	1,010.00	1,040.00	1,200.00	775.00	820.00	945.00	910.00
Iowa	5,800.00	5,700.00	6,870.00	7,100.00	5,080.00	5,260.00	4,050.00	4,220.00
Kansas	475.00	455.00	520.00	515.00	425.00	380.00	525.00	530.00
Kentucky	107.00	73.00	95.00	72.00	55.00	42.00	108.00	61.00
Louisiana	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maine	1.10	1.10	1.00	0.80	0.70	0.80	0.70	0.70
Maryland	4.00	4.00	5.00	4.00	5.00	3.50	3.00	4.00
Massachusetts	2.00	2.50	2.00	2.00	1.00	0.80	1.00	0.70
Michigan	330.00	320.00	240.00	280.00	245.00	210.00	255.00	250.00
Minnesota	2,720.00	2,790.00	2,350.00	2,400.00	1,600.00	1,830.00	1,260.00	1,310.00
Mississippi	203.00	208.00	126.00	126.00	90.00	95.00	100.00	95.00
Missouri	1,450.00	1,550.00	560.00	550.00	445.00	510.00	495.00	470.00
Montana	60.00	68.00	35.00	34.00	29.00	28.00	30.00	29.00
Nebraska	1,030.00	1,030.00	840.00	790.00	640.00	610.00	660.00	630.00
Nevada	0.90	1.20	0.80	1.10	0.60	1.10	0.60	2.30
New Hampshire	0.70	0.60	0.60	0.70	0.70	0.80	0.70	0.80
New Jersey	1.80	2.00	2.10	2.10	1.30	1.60	1.80	1.80
New Mexico	0.30	0.20	0.30	0.20	0.30	0.20	0.20	0.10
New York	8.00	7.50	12.00	8.50	11.00	12.50	11.00	11.50
North Carolina	3,190.00	3,190.00	1,790.00	1,780.00	1,570.00	1,600.00	1,550.00	1,630.00
North Dakota	59.00	57.00	22.00	22.00	16.00	14.00	15.00	17.00
Ohio	740.00	670.00	660.00	610.00	560.00	520.00	550.00	550.00
Oklahoma	735.00	760.00	430.00	385.00	230.00	280.00	345.00	330.00
Oregon	2.50	2.00	1.50	2.00	1.00	1.50	2.50	2.00
Pennsylvania	305.00	335.00	335.00	335.00	250.00	265.00	240.00	255.00
Rhode Island	0.40	0.40	0.80	0.50	0.20	0.20	0.30	0.30
South Carolina	31.00	26.00	47.00	54.00	47.00	54.00	50.00	54.00
South Dakota	460.00	565.00	365.00	365.00	270.00	285.00	250.00	270.00
Tennessee	65.00	67.00	44.00	41.00	51.00	43.00	52.00	46.00
Texas	240.00	270.00	240.00	260.00	180.00	170.00	250.00	260.00
Utah	185.00	240.00	85.00	125.00	100.00	135.00	100.00	130.00
Vermont	0.80	0.80	0.70	0.70	0.60	0.50	0.60	0.70
Virginia	52.00	86.00	62.00	84.00	59.00	84.00	62.00	85.00
Washington	5.00	5.00	3.50	3.00	2.50	3.00	3.00	3.00
West Virginia	1.00	1.00	0.50	0.50	0.50	0.50	2.00	1.00
Wisconsin	89.00	88.00	53.00	59.00	59.00	69.00	59.00	65.00
Wyoming	49.00	48.00	3.00	3.00	3.00	2.00	3.00	2.00
United States	21,406.90	21,599.00	18,544.30	18,932.00	13,925.30	14,411.60	13,089.40	13,282.00

Breeding, Market, and Total Inventory – States and United States: March 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	155	155	100	545	625	115	700	780	111
Illinois	540	550	102	4,710	4,750	101	5,250	5,300	101
Indiana	280	260	93	3,770	3,790	101	4,050	4,050	100
Iowa	1,000	1,020	102	20,800	21,580	104	21,800	22,600	104
Kansas	165	160	97	1,815	1,900	105	1,980	2,060	104
Michigan	110	120	109	1,000	1,080	108	1,110	1,200	108
Minnesota	560	570	102	7,940	7,930	100	8,500	8,500	100
Missouri	445	455	102	2,655	2,995	113	3,100	3,450	111
Nebraska	415	420	101	2,935	3,030	103	3,350	3,450	103
North Carolina	880	900	102	8,320	8,000	96	9,200	8,900	97
Ohio	185	190	103	2,315	2,460	106	2,500	2,650	106
Oklahoma	445	445	100	1,645	1,725	105	2,090	2,170	104
Pennsylvania	100	110	110	1,040	1,100	106	1,140	1,210	106
South Dakota	200	235	118	1,250	1,425	114	1,450	1,660	114
Texas	120	145	121	800	975	122	920	1,120	122
Utah	80	75	94	620	430	69	700	505	72
Other States [1]	418	400	96	2,658	2,743	103	3,076	3,143	102
United States	6,098	6,210	102	64,818	66,538	103	70,916	72,748	103

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: March 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	250	285	110	120	95	105	90	115
Illinois	1,530	1,465	1,460	1,465	920	980	800	840
Indiana	1,030	965	1,050	1,140	810	860	880	825
Iowa	5,300	5,490	6,540	6,670	5,370	5,460	3,590	3,960
Kansas	455	405	475	540	345	410	540	545
Michigan	285	320	245	265	240	245	230	250
Minnesota	2,590	2,630	2,420	2,360	1,680	1,790	1,250	1,150
Missouri	1,350	1,455	515	560	400	530	390	450
Nebraska	920	1,040	745	775	650	670	620	545
North Carolina	3,140	3,240	1,860	1,720	1,800	1,710	1,520	1,330
Ohio	690	680	660	610	545	600	420	570
Oklahoma	740	735	300	335	270	260	335	395
Pennsylvania	265	290	305	305	280	270	190	235
South Dakota	455	510	325	370	240	280	230	265
Texas	180	270	220	270	175	185	225	250
Utah	265	155	115	90	130	95	110	90
Other States [1]	977	1,007	597	617	535	546	549	572
United States	20,422	20,942	17,942	18,212	14,485	14,996	11,969	12,387

[1] Individual State estimates not available for the 34 Other States.

Breeding, Market, and Total Inventory – States and United States: June 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	155	155	100	565	605	107	720	760	106
Illinois	530	570	108	4,720	4,780	101	5,250	5,350	102
Indiana	260	250	96	3,740	3,700	99	4,000	3,950	99
Iowa	1,030	1,040	101	20,970	21,560	103	22,000	22,600	103
Kansas	160	165	103	1,800	1,875	104	1,960	2,040	104
Michigan	110	120	109	1,000	1,080	108	1,110	1,200	108
Minnesota	570	580	102	8,030	7,920	99	8,600	8,500	99
Missouri	440	460	105	2,810	3,040	108	3,250	3,500	108
Nebraska	420	430	102	2,980	3,070	103	3,400	3,500	103
North Carolina	880	910	103	8,120	7,990	98	9,000	8,900	99
Ohio	190	190	100	2,360	2,460	104	2,550	2,650	104
Oklahoma	450	460	102	1,560	1,690	108	2,010	2,150	107
Pennsylvania	105	120	114	1,085	1,170	108	1,190	1,290	108
South Dakota	200	240	120	1,290	1,440	112	1,490	1,680	113
Texas	125	145	116	785	995	127	910	1,140	125
Utah	75	80	107	605	450	74	680	530	78
Other States [1]	409	405	99	2,681	2,721	101	3,090	3,126	101
United States	6,109	6,320	103	65,101	66,546	102	71,210	72,866	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: June 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	255	290	120	120	100	95	90	100
Illinois	1,430	1,550	1,530	1,460	930	930	830	840
Indiana	920	940	1,170	1,150	790	780	860	830
Iowa	5,450	5,560	6,950	7,080	4,950	5,200	3,620	3,720
Kansas	480	420	490	515	355	375	475	565
Michigan	290	310	240	290	245	220	225	260
Minnesota	2,610	2,610	2,440	2,430	1,660	1,760	1,320	1,120
Missouri	1,360	1,505	580	590	435	475	435	470
Nebraska	1,005	1,050	785	840	615	600	575	580
North Carolina	3,290	3,370	1,880	1,840	1,490	1,450	1,460	1,330
Ohio	720	670	650	630	550	580	440	580
Oklahoma	685	785	340	400	230	215	305	290
Pennsylvania	285	310	345	355	280	250	175	255
South Dakota	455	510	345	380	240	270	250	280
Texas	165	300	235	275	175	165	210	255
Utah	245	175	120	90	130	90	110	95
Other States [1]	1,002	972	621	638	521	533	537	577
United States	20,647	21,327	18,841	19,083	13,696	13,988	11,917	12,147

[1] Individual State estimates not available for the 34 Other States.

Breeding, Market, and Total Inventory – States and United States: September 1, 2017 and 2018

[May not add due to rounding]

State	Breeding			Market			Total		
	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)	(1,000 head)	(1,000 head)	(percent)
Colorado	160	155	97	600	625	104	760	780	103
Illinois	540	570	106	4,860	4,830	99	5,400	5,400	100
Indiana	260	250	96	3,840	3,950	103	4,100	4,200	102
Iowa	980	1,040	106	21,720	22,460	103	22,700	23,500	104
Kansas	165	170	103	1,845	1,860	101	2,010	2,030	101
Michigan	120	120	100	1,070	1,080	101	1,190	1,200	101
Minnesota	550	580	105	7,850	8,020	102	8,400	8,600	102
Missouri	440	465	106	3,060	3,285	107	3,500	3,750	107
Nebraska	410	430	105	3,090	3,020	98	3,500	3,450	99
North Carolina	900	910	101	8,400	8,390	100	9,300	9,300	100
Ohio	180	190	106	2,420	2,360	98	2,600	2,550	98
Oklahoma	455	460	101	1,735	1,800	104	2,190	2,260	103
Pennsylvania	110	120	109	1,100	1,190	108	1,210	1,310	108
South Dakota	215	245	114	1,325	1,475	111	1,540	1,720	112
Texas	135	145	107	895	985	110	1,030	1,130	110
Utah	80	80	100	600	525	88	680	605	89
Other States [1]	417	400	96	2,782	2,756	99	3,199	3,156	99
United States	6,117	6,330	103	67,192	68,611	102	73,309	74,941	102

[1] Individual State estimates not available for the 34 Other States.

Market Inventory by Weight Group – States and United States: September 1, 2017 and 2018

[Weight groups may not add to market inventory due to rounding]

State	Under 50 pounds		50-119 pounds		120-179 pounds		180 pounds and over	
	2017	2018	2017	2018	2017	2018	2017	2018
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
Colorado	275	305	125	150	105	95	95	75
Illinois	1,505	1,540	1,620	1,560	930	890	805	840
Indiana	1,050	990	1,180	1,240	780	870	830	850
Iowa	5,670	5,850	7,250	7,700	5,100	5,210	3,700	3,700
Kansas	475	445	510	530	360	385	500	500
Michigan	310	320	260	280	250	220	250	260
Minnesota	2,630	2,720	2,550	2,530	1,550	1,700	1,120	1,070
Missouri	1,485	1,605	640	640	460	530	475	510
Nebraska	1,015	1,010	835	865	600	570	640	575
North Carolina	3,400	3,450	1,950	2,000	1,550	1,520	1,500	1,420
Ohio	700	650	685	640	540	500	495	570
Oklahoma	770	835	440	375	265	230	260	360
Pennsylvania	305	325	340	340	275	270	180	255
South Dakota	450	520	365	405	260	275	250	275
Texas	235	310	255	275	160	150	245	250
Utah	235	220	125	105	130	105	110	95
Other States [1]	1,023	997	627	627	559	546	573	585
United States	21,533	22,092	19,757	20,262	13,874	14,066	12,028	12,190

[1] Individual State estimates not available for the 34 Other States.

Annual Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: December-November 2017 and 2018

[December preceding year. May not add due to rounding]

State	Sows farrowing			Pigs per litter		Pig crop		
	2017	2018	2018 as percent of 2017	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Alabama	16.50	17.50	106	9.45	10.11	156.00	177.00	113
Alaska	0.30	0.28	93	8.33	7.86	2.50	2.20	88
Arizona	31.00	30.00	97	9.42	10.07	292.00	302.00	103
Arkansas	110.00	102.00	93	10.37	10.60	1,141.00	1,081.00	95
California	11.00	10.00	91	6.45	6.40	71.00	64.00	90
Colorado	304.00	302.00	99	10.35	9.60	3,147.00	2,898.00	92
Connecticut	0.40	0.40	100	8.75	8.25	3.50	3.30	94
Delaware	2.40	2.90	121	10.00	11.38	24.00	33.00	138
Florida	4.00	4.00	100	6.00	6.00	24.00	24.00	100
Georgia	44.00	39.50	90	9.98	9.85	439.00	389.00	89
Hawaii	0.40	1.20	300	5.00	3.17	2.00	3.80	190
Idaho	6.10	9.00	148	8.36	8.89	51.00	80.00	157
Illinois	1,050.00	1,065.00	101	10.55	10.65	11,078.00	11,344.00	102
Indiana	550.00	490.00	89	10.36	10.47	5,698.00	5,129.00	90
Iowa	2,090.00	2,240.00	107	11.02	11.13	23,025.00	24,922.00	108
Kansas	329.00	327.00	99	10.36	10.55	3,407.00	3,449.00	101
Kentucky	95.00	89.00	94	9.82	9.88	933.00	879.00	94
Louisiana	0.80	0.80	100	7.00	7.00	5.60	5.60	100
Maine	0.70	0.90	129	7.71	7.33	5.40	6.60	122
Maryland	4.30	4.00	93	9.77	10.00	42.00	40.00	95
Massachusetts	1.70	2.00	118	8.06	7.55	13.70	15.10	110
Michigan	208.00	217.00	104	10.66	10.73	2,217.00	2,328.00	105
Minnesota	1,190.00	1,210.00	102	11.40	11.24	13,568.00	13,597.00	100
Mississippi	117.00	116.00	99	10.40	10.45	1,217.00	1,212.00	100
Missouri	910.00	970.00	107	10.21	10.36	9,295.00	10,047.00	108
Montana	47.50	53.00	112	10.99	10.96	522.00	581.00	111
Nebraska	745.00	745.00	100	11.59	11.44	8,635.00	8,520.00	99
Nevada	0.40	0.40	100	5.25	5.75	2.10	2.30	110
New Hampshire	0.40	0.50	125	8.00	8.00	3.20	4.00	125
New Jersey	1.00	0.80	80	7.80	6.25	7.80	5.00	64
New Mexico	0.40	0.40	100	7.75	7.75	3.10	3.10	100
New York	5.70	6.00	105	9.30	9.33	53.00	56.00	106
North Carolina	1,880.00	1,850.00	98	10.04	10.12	18,871.00	18,718.00	99
North Dakota	73.50	73.50	100	11.13	11.14	818.00	819.00	100
Ohio	380.00	366.00	96	10.72	10.79	4,075.00	3,950.00	97
Oklahoma	795.00	820.00	103	10.55	10.64	8,387.00	8,724.00	104
Oregon	0.90	1.70	189	8.33	8.00	7.50	13.60	181
Pennsylvania	198.00	201.00	102	10.46	10.71	2,071.00	2,152.00	104
Rhode Island	0.50	0.40	80	6.80	5.75	3.40	2.30	68
South Carolina	21.00	18.50	88	7.38	8.27	155.00	153.00	99
South Dakota	414.00	467.00	113	11.36	11.48	4,705.00	5,360.00	114
Tennessee	51.00	48.00	94	10.08	9.98	514.00	479.00	93
Texas	212.00	260.00	123	8.58	10.06	1,818.00	2,615.00	144
Utah	149.00	146.00	98	8.92	9.14	1,329.00	1,334.00	100
Vermont	0.70	1.00	143	7.00	6.80	4.90	6.80	139
Virginia	7.30	7.60	104	9.59	9.61	70.00	73.00	104
Washington	2.80	3.50	125	7.61	8.00	21.30	28.00	131
West Virginia	0.70	0.80	114	8.14	7.63	5.70	6.10	107
Wisconsin	81.00	83.00	102	9.53	10.45	772.00	867.00	112
Wyoming	72.00	72.50	101	9.94	9.27	716.00	672.00	94
United States	12,216.40	12,477.08	102	10.59	10.67	129,427.70	133,175.80	103

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: December-February 2017-2019

[December preceding year. May not add due to rounding]

State	Sows farrowing				Pigs per litter		Pig crop [1]		
	2017	2018	2019 [2]	2019 as percent of 2018	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	77	72	75	104	9.90	9.70	762	698	92
Illinois	265	260	280	108	10.20	10.60	2,703	2,756	102
Indiana	145	130	135	104	10.25	10.45	1,486	1,359	91
Iowa	510	550	520	95	10.75	11.00	5,483	6,050	110
Kansas	80	79	86	109	10.00	10.20	800	806	101
Michigan	50	53	55	104	10.40	10.70	520	567	109
Minnesota	275	295	285	97	11.35	11.20	3,121	3,304	106
Missouri	220	225	250	111	10.05	10.15	2,211	2,284	103
Nebraska	175	180	190	106	11.55	11.70	2,021	2,106	104
North Carolina	460	445	455	102	9.90	9.90	4,554	4,406	97
Ohio	92	91	95	104	10.80	10.80	994	983	99
Oklahoma	200	200	200	100	10.30	10.60	2,060	2,120	103
Pennsylvania	47	48	52	108	10.30	10.60	484	509	105
South Dakota	102	113	125	111	11.30	11.45	1,153	1,294	112
Texas	50	60	69	115	9.90	9.90	495	594	120
Utah	39	36	38	106	8.70	7.70	339	277	82
Other States [3]	203	197	200	101	9.86	10.08	2,001	1,988	99
United States	2,990	3,034	3,110	102	10.43	10.58	31,187	32,101	103

[1] Number of pigs born December-February that were still on hand March 1, or had been sold.
[2] Intentions.
[3] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: March-May 2017-2019

[May not add due to rounding]

State	Sows farrowing				Pigs per litter		Pig crop [1]		
	2017	2018	2019 [2]	2019 as percent of 2018	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	77	75	75	100	10.40	9.60	801	720	90
Illinois	255	275	280	102	10.55	10.70	2,690	2,943	109
Indiana	135	115	130	113	10.50	10.30	1,418	1,185	84
Iowa	510	560	520	93	10.95	11.10	5,585	6,216	111
Kansas	81	76	86	113	10.00	10.10	810	768	95
Michigan	51	53	52	98	10.50	10.90	536	578	108
Minnesota	300	310	295	95	11.40	11.20	3,420	3,472	102
Missouri	220	240	255	106	10.25	10.20	2,255	2,448	109
Nebraska	185	190	195	103	11.45	11.30	2,118	2,147	101
North Carolina	470	455	465	102	10.00	10.10	4,700	4,596	98
Ohio	97	88	96	109	10.60	11.00	1,028	968	94
Oklahoma	195	205	210	102	10.60	10.70	2,067	2,194	106
Pennsylvania	51	50	52	104	10.50	10.50	536	525	98
South Dakota	102	110	126	115	11.40	11.70	1,163	1,287	111
Texas	50	64	70	109	7.30	9.80	365	627	172
Utah	39	34	39	115	9.00	7.60	351	258	74
Other States [3]	200	200	201	101	10.00	10.06	1,996	2,010	101
United States	3,018	3,100	3,147	102	10.55	10.63	31,839	32,942	103

[1] Number of pigs born March-May that were still on hand June 1, or had been sold.
[2] Intentions.
[3] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: June-August 2017 and 2018

[May not add due to rounding]

State	Sows farrowing			Pigs per litter		Pig crop [1]		
	2017	2018	2018 as percent of 2017	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	78	80	103	10.90	9.50	850	760	89
Illinois	265	260	98	10.75	10.65	2,849	2,769	97
Indiana	135	125	93	10.35	10.50	1,397	1,313	94
Iowa	520	570	110	11.20	11.20	5,824	6,384	110
Kansas	85	87	102	10.60	10.90	901	948	105
Michigan	54	57	106	10.80	10.80	583	616	106
Minnesota	300	305	102	11.40	11.15	3,420	3,401	99
Missouri	235	255	109	10.15	10.45	2,385	2,665	112
Nebraska	190	185	97	11.65	11.30	2,214	2,091	94
North Carolina	490	485	99	10.05	10.30	4,925	4,996	101
Ohio	97	89	92	10.70	10.90	1,038	970	93
Oklahoma	205	210	102	10.60	10.65	2,173	2,237	103
Pennsylvania	51	51	100	10.60	10.70	541	546	101
South Dakota	105	117	111	11.30	11.10	1,187	1,299	109
Texas	52	69	133	7.80	10.10	406	697	172
Utah	36	39	108	9.00	11.00	324	429	132
Other States [2]	208	201	97	9.88	10.10	2,058	2,034	99
United States	3,106	3,185	103	10.65	10.72	33,075	34,155	103

[1] Number of pigs born June-August that were still on hand September 1, or had been sold.
[2] Individual State estimates not available for the 34 Other States.

Sows Farrowing, Pigs per Litter, and Pig Crop – States and United States: September-November 2017 and 2018

[May not add due to rounding]

State	Sows Farrowing			Pigs per litter		Pig crop [1]		
	2017	2018	2018 as percent of 2017	2017	2018	2017	2018	2018 as percent of 2017
	(1,000 head)	(1,000 head)	(percent)	(number)	(number)	(1,000 head)	(1,000 head)	(percent)
Colorado	72	75	104	10.20	9.60	734	720	98
Illinois	265	270	102	10.70	10.65	2,836	2,876	101
Indiana	135	120	89	10.35	10.60	1,397	1,272	91
Iowa	550	560	102	11.15	11.20	6,133	6,272	102
Kansas	83	85	102	10.80	10.90	896	927	103
Michigan	53	54	102	10.90	10.50	578	567	98
Minnesota	315	300	95	11.45	11.40	3,607	3,420	95
Missouri	235	250	106	10.40	10.60	2,444	2,650	108
Nebraska	195	190	97	11.70	11.45	2,282	2,176	95
North Carolina	460	465	101	10.20	10.15	4,692	4,720	101
Ohio	94	98	104	10.80	10.50	1,015	1,029	101
Oklahoma	195	205	105	10.70	10.60	2,087	2,173	104
Pennsylvania	49	52	106	10.40	11.00	510	572	112
South Dakota	105	127	121	11.45	11.65	1,202	1,480	123
Texas	60	67	112	9.20	10.40	552	697	126
Utah	35	37	106	9.00	10.00	315	370	117
Other States [2]	202	203	100	10.15	10.15	2,048	2,057	100
United States	3,103	3,158	102	10.74	10.76	33,328	33,978	102

[1] Number of pigs born September-November that were still on hand December 1, or had been sold.
[2] Individual State estimates not available for the 34 Other States.

Statistical Methodology

Survey Procedures: A random sample of roughly 8,500 United States producers was surveyed to provide data for these estimates. Survey procedures ensured that all hog and pig producers, regardless of size, had a chance to be included in the survey. Large operations were sampled more heavily than small operations. During the first half of December 2018, data were collected from about 6,100 operations, 71 percent of the total sample. The data collected were received by electronic data reporting, mail, telephone, and face-to-face personal interviews. Regardless of when operations responded, they were asked to report inventories as of December 1, 2018.

Estimating Procedures: Hogs and pigs estimates were prepared by the Agricultural Statistics Board after reviewing recommendations and analysis submitted by each regional field office. National and State survey data were reviewed for reasonableness with each other and with estimates from past years using a balance sheet. The balance sheet begins with the previous inventory estimate, adds the estimates of births and imports, and subtracts the estimates of slaughter, exports, and deaths. This indicated ending inventory level is compared to the Agricultural Statistics Board estimate for reasonableness.

Revision Policy: Revisions to previous estimates are made to improve quarter to quarter relationships. Estimates for the previous four quarters are subject to revision when current estimates are made. In December, estimates for all quarters of the current and previous year are reviewed. The reviews are primarily based on hog check-off receipts and slaughter. Estimates will also be reviewed after data from the Department of Agriculture five-year Census of Agriculture are available. No revisions will be made after that date.

Reliability: Since all operations raising hogs are not included in the sample, survey estimates are subject to sampling variability. Survey results are also subject to non-sampling errors such as omissions, duplication, and mistakes in reporting, recording, and processing the data. The effects of these errors cannot be measured directly. They are minimized through rigid quality controls in the data collection process and through a careful review of all reported data for consistency and reasonableness.

To assist users in evaluating the reliability of the estimates in this report, the **"Root Mean Square Error"** is shown for selected items in the following table. The "Root Mean Square Error" is a statistical measure based on past performance and is computed using the difference between first and final estimates. The "Root Mean Square Error" for hog inventory estimates over the past 20 quarters is 1.2 percent. This means that chances are 2 out of 3 that the final estimate will not be above or below the current estimate of 74.6 million head by more than 1.2 percent. Chances are 9 out of 10 that the difference will not exceed 2.1 percent.

Reliability of December 1 Hog Estimates

[Based on data for the previous twenty quarters]

Item	Root mean square error	90 percent confidence level	Difference between first and latest estimate				
			Average	Smallest	Largest	Years	
						Below latest	Above latest
	(percent)	(percent)	(1,000)	(1,000)	(1,000)	(number)	(number)
All hogs and pigs	1.2	2.1	651	59.6	1,576	9	11
Pig crop	2.0	3.5	467	13	1,158	12	8
Expected farrowings							
Next quarter	2.5	4.4	66	19	129	12	8
Following quarter	3.1	5.3	78	11	197	11	9

Records by Quarter – United States: 1866 to Present

[This table provides data users with record high estimates of all hogs and pigs, market hogs, pig crop, and pigs per litter since each data series began]

Item	Estimate	Record high	Series began
	(1,000 head)	(year)	(year)
All hogs and pigs			
March 1	72,748	2018	1988
June 1	72,866	2018	1964
September 1	74,941	2018	1988
December 1	83,741	1943	1866
Market			
March 1	66,538	2018	1988
June 1	66,546	2018	1964
September 1	68,611	2018	1988
December 1	68,225	2018	1963
Pig crop			
December-February[1]	32,101	2018	1970
March-May	32,942	2018	1970
June-August	34,155	2018	1970
September-November	33,978	2018	1970
	(number)	(year)	(year)
Pigs per litter			
December-February[1]	10.58	2018	1970
March-May	10.63	2018	1970
June-August	10.72	2018	1970
September-November	10.76	2018	1970

[1] December preceding year.

Information Contacts

Listed below are the commodity specialists in the Livestock Branch of the National Agricultural Statistics Service to contact for additional information. E-mail inquiries may be sent to nass@nass.usda.gov.

Travis Averill, Chief, Livestock Branch .... (202) 720-3570

Scott Hollis, Head, Livestock Section .... (202) 690-2424
- Sherry Bertramsen – Livestock Slaughter .... (202) 690-8632
- Holly Brenize – Sheep and Goats .... (202) 720-0585
- Donnie Fike – Dairy Products .... (202) 720-4448
- Heidi Gleich – Cattle, Cattle on Feed .... (202) 720-3040
- Mike Miller – Milk Production and Milk Cows .... (202) 720-3278
- Seth Riggins – Hogs and Pigs .... (202) 720-3106

Access to NASS Reports

For your convenience, you may access NASS reports and products the following ways:

- All reports are available electronically, at no cost, on the NASS web site: www.nass.usda.gov

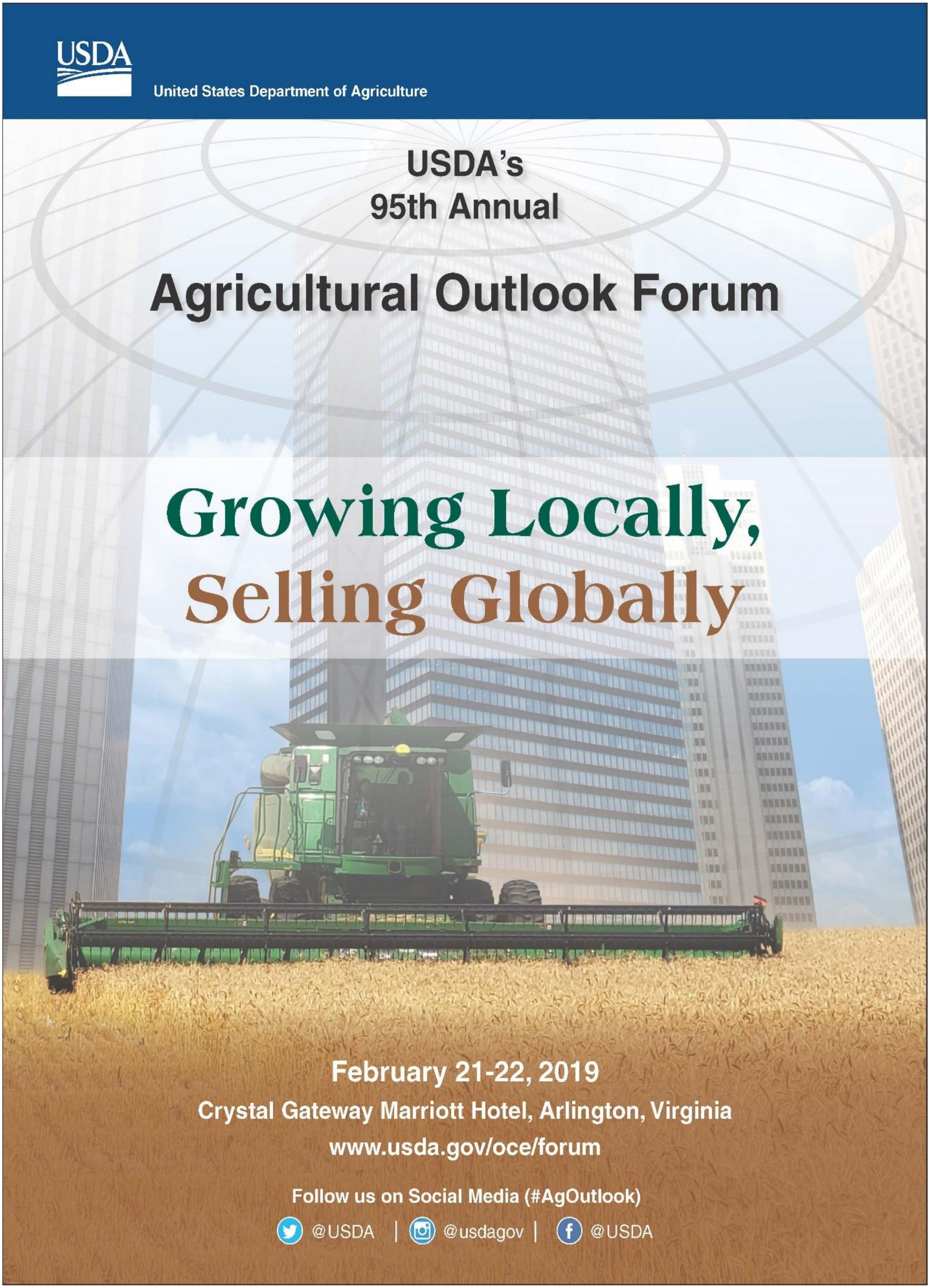
- Both national and state specific reports are available via a free e-mail subscription. To set-up this free subscription, visit www.nass.usda.gov and click on "National" or "State" in upper right corner above "search" box to create an account and select the reports you would like to receive.

- Cornell's Mann Library has launched a new website housing NASS's and other agency's archived reports. The new website, https://usda.library.cornell.edu. All email subscriptions containing reports will be sent from the new website, https://usda.library.cornell.edu. To continue receiving the reports via e-mail, you will have to go to the new website, create a new account and re-subscribe to the reports. If you need instructions to set up an account or subscribe, they are located at: https://usda.library.cornell.edu/help. You should whitelist notifications@usda-esmis.library.cornell.edu in your email client to avoid the emails going into spam/junk folders.

For more information on NASS surveys and reports, call the NASS Agricultural Statistics Hotline at (800) 727-9540, 7:30 a.m. to 4:00 p.m. ET, or e-mail: nass@nass.usda.gov.

The U.S. Department of Agriculture (USDA) prohibits discrimination against its customers, employees, and applicants for employment on the basis of race, color, national origin, age, disability, sex, gender identity, religion, reprisal, and where applicable, political beliefs, marital status, familial or parental status, sexual orientation, or all or part of an individual's income is derived from any public assistance program, or protected genetic information in employment or in any program or activity conducted or funded by the Department. (Not all prohibited bases will apply to all programs and/or employment activities.)

If you wish to file a Civil Rights program complaint of discrimination, complete the USDA Program Discrimination Complaint Form (PDF), found online at www.ascr.usda.gov/filing-program-discrimination-complaint-usda-customer, or at any USDA office, or call (866) 632-9992 to request the form. You may also write a letter containing all of the information requested in the form. Send your completed complaint form or letter to us by mail at U.S. Department of Agriculture, Director, Office of Adjudication, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, by fax (202) 690-7442 or email at program.intake@usda.gov.


USDA
United States Department of Agriculture
USDA's
95th Annual
Agricultural Outlook Forum
Growing Locally,
Selling Globally
February 21-22, 2019
Crystal Gateway Marriott Hotel, Arlington, Virginia
www.usda.gov/oce/forum
Follow us on Social Media (#AgOutlook)
@USDA | @usdagov | @USDA

Chapter 3 Appendix

Contents

HOG REPORT – DECEMBER 1, 2018

OMB No. 0535-0213
Approval Expires: 6/30/2020
Project Code: 164
SurveyId: 1531
Version: D – AK, CT, DE, FL, HI, ID, LA, ME, MD, MA, NV, NH, NJ, NM, NY, OR, RI, VT, WA, WV

United States Department of Agriculture

NATIONAL AGRICULTURAL STATISTICS SERVICE

USDA/NASS
National Operations Division
9700 Page Avenue, Suite 400
St. Louis, MO 63132-1547
Phone: 1-888-424-7828
Fax: 1-855-415-3687
E-mail: nass@nass.usda.gov

Please make corrections to name, address and ZIP Code, if necessary.

State	POID	Tract	Subtr.
__ __	__ __ __ __ __ __ __ __ __	__ __	__ __

1. [Verify name and mailing address of this operation. Make any corrections necessary (including the correct operation name) on the label and continue.] ☐ [Check if name label verified]

2. Has this operation owned or raised hogs or pigs at any time since December 1, 2017? (INCLUDE hogs and pigs raised under contract.)

   ☐ Yes - [Go to item 3 on page 2.]

   ☐ No - Were any hogs or pigs owned by someone else on this operation on December 1, 2018?

      ☐ Yes - [Go to item 11 on page 6.]

      ☐ No - [Go to Section 2 on page 7.]

For Office Use Only
R. Unit
9921
Subst
9941

3. Are the day-to-day decisions for this operation made by one individual, a hired manager, or partners? (Check one)

- ☐ One individual - (Go to Section 1 on Page 3.)
- ☐ A hired manager - (Go to Section 1 on Page 3.)
- ☐ Partners - (Continue)

How many individuals are involved in the day-to-day decisions of this operation? (Enter the number of partners.) .... **Number** ______

Include the partner named on the label. Partners jointly operate land and share in decision making. Do not include landlords and tenants as partners.

4. Please identify the other person(s) in this partnership, then go to Section 1, Page 3. (Verify partners' names and make necessary corrections if names have already been entered.)

Name: ______________________

Address: ______________________

City: ______________ State: ______ Zip: ______

Phone: (   ) -______________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________

Address: ______________________

City: ______________ State: ______ Zip: ______

Phone: (   ) -______________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________

Address: ______________________

City:______________ State: ______ Zip: ______

Phone: (   ) -______________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________

Address:______________________

City: ______________ State: ______ Zip: ______

Phone: (   ) -______________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

For Office Use Only	For Office Use Only	For Office Use Only	For Office Use Only
Stratum	**Stratum**	**Stratum**	**Stratum**
9922	9923	9927	9928
Ind. Op.	**Ind. Op.**	**Ind. Op.**	**Ind. Op.**
9924	9924	9924	9924

Section 1 - Hogs and Pigs Owned

1. On December 1, did this operation (named on label) own any hogs or pigs, regardless of location? (INCLUDE hogs or pigs being raised under contract for you by someone else.)

   ☐ Yes - [Go to item 2]

   ☐ No - Did this operation own hogs or pigs at any time from December 1, 2017 through November 30, 2018?

      ☐ Yes - [Go to item 8 on page 5.]

      ☐ No - Were any hogs or pigs owned by someone else on this operation on December 1?

         ☐ Yes - [Go to item 11 on page 6.]

         ☐ No - [Go to Section 2 on page 7.]

			Number Owned December 1
2. How many sows and gilts for breeding were owned by this operation on December 1? (INCLUDE unweaned gilts intended for breeding.)..		+	301
a. How many of the [item 2] sows and gilts are expected to farrow during December 2018, January or February 2019?...	331		
b. How many of the [item 2] sows and gilts are expected to farrow during March, April or May 2019?..	332		
3. How many boars and young males for breeding were owned by this operation on December 1? (INCLUDE unweaned boar pigs intended for breeding.)..		+	302
4. Of the hogs and pigs for market and home use owned by this operation on December 1, how many were in each of the following four weight groups? (EXCLUDE breeding hogs and pigs reported in [item 2] or [item 3].)			
a. Under 50 pounds? (INCLUDE unweaned pigs intended for market or home use.)...............		+	315
b. 50 - 119 pounds?..		+	316
c. 120 - 179 pounds?..		+	313
d. 180 pounds and over? (INCLUDE sows and boars no longer used for breeding.)................		+	314
5. [Add Items 2 + 3 + 4a + 4b + 4c + 4d and verify the total. If necessary, make corrections before continuing.]			
Then the total hogs and pigs owned by this operation on December 1 was:............................		=	300

Section 1 - Hogs and Pigs Owned (continued)

Inventory Values for Hogs and Pigs on Hand on December 1, 2018

6. What is the average value per head of the following [Report to nearest dollar.]

a.	Sows and gilts used and to be used for breeding?	$ per Head	304
b.	Boars used and to be used for breeding?	$ per Head	305
c.	Market hogs and pigs for each of the following four weight groups?		
(i)	Under 50 pounds? (INCLUDE unweaned pigs intended for market or home use.)........	$ per Head	307
(ii)	50 - 119 pounds?........	$ per Head	308
(iii)	120 - 179 pounds?........	$ per Head	309
(iv)	180 pounds and over? (INCLUDE sows and boars no longer used for breeding.)........	$ per Head	310

Out-Of-State Hogs and Pigs

7. Did this operation own any hogs or pigs in another State on December 1?

Code
321

1 ☐ Yes - [Remove any out-of-state hogs or pigs included in items 2 through 5 then continue to item 8.]

3 ☐ No - [Continue to item 8.]

Section 1 - Hogs and Pigs Owned (continued)

8. Did any sows or gilts owned by this operation farrow during December 2017 - November 2018?

☐ Yes - (Complete the following for each three month period, starting with the most recent)

	Sows Farrowed and Pigs Weaned during:			
	Sept., Oct. and Nov. 2018	Jun., Jul. and Aug. 2018	Mar., Apr. and May 2018	Dec. 2017, Jan. and Feb. 2018
. How many sows and gilts owned by this operation farrowed during (months)?.	869	870	871	872
. How many pigs were (will be) weaned from these (Item 8a) litters?.......................................	873	874	875	876

☐ No - (Continue)

Section 1 - Hogs and Pigs Owned (continued)

Death Loss from December 1, 2017 - November 30, 2018

	Weaned Pigs and older Hogs that died during:			
	Sept., Oct. and Nov. 2018	Jun., Jul. and Aug. 2018	Mar., Apr. and May 2018	Dec. 2017, Jan. and Feb. 2018
9. How many weaned pigs and older hogs owned by this operation died during (months)?....................................	335	334	878	879

Contract Hog and Pig Production

10. Were any hogs or pigs owned by this operation being raised under contract by another person or firm on December 1?

1 ☐ Yes - Continue   3 ☐ No - (Go to item 11) [336]

a. How many producers were raising hogs or pigs for you under contract on December 1?.. [317]

b. How many hogs and pigs (owned by this operation) were these [item 9a] producers raising for you under contract on December 1?... [333]

[Verify that these hogs and pigs ARE included in the total (item 5 on page 3), then continue.]

11. Were any hogs or pigs owned by someone else on this operation on December 1? [323]

1 ☐ Yes - [Continue]   3 ☐ No - [Go to Section 3 on page 8]

a. How many hogs and pigs owned by someone else were on this operation on December 1?.. [322]

b. Who owns the hogs and pigs?...................

(Owner's Name, Address, & Phone Number)

Name ______________________

Address ______________________

City, St., ZIP ______________________

Phone ______________________

c. Is this hog owner a contractor?

☐ Yes   ☐ No

[Verify that these hogs and pigs ARE NOT included in item 5 on page 3]

d. Will the operator on the label own hogs or pigs at any time between now and June 1, 2018? [324]

1 ☐ Yes   3 ☐ No

Slaughter for Consumption by this Operation (regardless of ownership)

	Total
12. During 2018, how many hogs and pigs were custom slaughtered at commercial establishments for consumption by this operation?..	881
13. During 2018, how many hogs and pigs were slaughtered on this operation **for** consumption by this operation? (INCLUDE mobile slaughtering. EXCLUDE custom slaughter at commercial establishments.)...	880

[Complete Section 2 only if the operation shown on the label DOES NOT own hogs or raise hogs under contract, otherwise go to Section 3 on page 8.]

Office Use - Completion Code - Hog Presence		
	1 - Incomplete, Hogs Present 2 - Incomplete, Unknown Presence	499
	3 - Valid Zero	

Section 2 - Intentions to Own or Raise Hogs

[Complete Section 2 only if the operation shown on the label DOES NOT own hogs or raise hogs under contract, otherwise go to Section 3 on page 8.]

1. Will the operator on the label raise hogs or pigs on this operation at any time between now and June 1, 2018? [Check one.]

   492
   - 1 ☐ Yes - [Go to Section 3 on page 8.]
   - 2 ☐ Don't Know - [Continue with item 2.]
   - 3 ☐ No - [Continue with item 2.]

2. Does this operation (named on the label) own and operate any buildings, structures, or facilities for raising hogs or pigs? (such as buildings used for breeding, farrowing, finishing, etc.) [Check one.]

   488
   - 1 ☐ Yes
   - 3 ☐ No

3. Has this operation sold, rented, or turned over any hog facilities to someone else?

   ☐ Yes - Continue ☐ No - [Go to item 5.]

4. Who is using the hog facilities now?................

   [Enter the name and address of the person or firm now using the facilities.]

   Operation Name ____________________

   Operator Name ____________________

   Address ____________________

   City, St., ZIP ____________________

   Phone ____________________

   [Write a note to describe the current status of this operation, then continue with Section 3 on page 8.]

5. Was the operator (name on label) operating a farm or ranch on December 1, 2018? (INCLUDE growing crops or raising livestock.)

   ☐ Yes ☐ Don't Know ☐ No

Section 3 - Conclusion

1. Do you (the operator named on the label) make any day-to-day decisions for another hog operation?

☐ Yes - Continue ☐ No - Go to Comments

a. What is the name of the other hog operation(s)? ....

Operation Name: ______________________________

Address: ______________________________

City: ____________________ State: _____ ZIP: __________

Phone: (______) ______________________

Comments: ______________________________

2. Survey Results: To receive the complete results of this survey on the release date go to www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/

To have a brief summary emailed to you at a later date, please enter your email address. 1095

Would you rather have a brief summary mailed to you at a later date? 1 ☐ Yes 3 ☐ No 9990

Respondent Name:	9911 Phone:	9910 MM DD YY Date:

Thank you for your help

OFFICE USE ONLY

Response		Respondent		Mode		Enum.	Eval.	Change	Office Use for POID			
1-Comp 2-R 3-Inac 4-Office Hold 5-R – Est 6-Inac – Est 7-Off Hold – Est	9901	1-Op/Mgr 2-Sp 3-Acct/Bkpr 4-Partner 9-Oth	9902	1-PASI (Mail) 2-PATI (Tel) 3-PAPI (Face-to-Face) 6-e-mail 7-Fax 19-Other	9903	9998	9900	9985	9989 __ __ __ - __ __ __ - __ __ __			
									Optional Use			
									9907	9908	9906	9916
S/E Name												

HOG REPORT – DECEMBER 1, 2018

OMB No. 0535-0213
Approval Expires: 6/30/2020
Project Code: 164
SurveyId: 1531
Version: A - AL, AZ, AR, CA, CO, GA, IL, IN, IA, KS, KY, MI, MN, MS, MO, MT, NE, NC, ND, OH, OK, PA, SC, SD, TN, TX, UT, VA, WI, WY

United States Department of Agriculture

NATIONAL AGRICULTURAL STATISTICS SERVICE

USDA/NASS
National Operations Division
9700 Page Avenue, Suite 400
St. Louis, MO 63132-1547
Phone: 1-888-424-7828
Fax: 1-855-415-3687
E-mail: nass@nass.usda.gov

Please make corrections to name, address and ZIP Code, if necessary.

State	POID	Tract	Subtr.
__ __	__ __ __ __ __ __ __ __ __	__ __	__ __

1. [Verify name and mailing address of this operation. Make any corrections necessary (including the correct operation name) on the label and continue.] ☐ [Check if name label verified]

2. Has this operation owned or raised hogs or pigs at any time since September 1, 2018? (INCLUDE hogs and pigs raised under contract.)

   ☐ Yes - Go to item 3 on page 2.

   ☐ No - Were any hogs or pigs owned by someone else on this operation on December 1, 2018?

   ☐ Yes - Go to item 11 on page 6.

   ☐ No - Were any hogs or pigs slaughtered for consumption by this operation, regardless of ownership during 2018?

   ☐ Yes - [Go to item 12 on page 6.

   ☐ No - [Go to Section 2 on page 7.]

For Office Use Only
R. Unit
9921
Subst
9941

3. Are the day-to-day decisions for this operation made by one individual, a hired manager, or partners? (Check one)

☐ One individual - (Go to Section 1 on Page 3.)

☐ A hired manager - (Go to Section 1 on Page 3.)

☐ Partners - (Continue)

How many individuals are involved in the day-to-day decisions of this operation? (Enter the number of partners.) .... **Number** ____

Include the partner named on the label. Partners jointly operate land and share in decision making. Do not include landlords and tenants as partners.

4. Please identify the other person(s) in this partnership, then go to Section 1, Page 3. (Verify partners' names and make necessary corrections if names have already been entered.)

Name: ______________________________

Address: ______________________________

City: ________________ State: ______ Zip: ________

Phone: ( ) -________________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________________

Address: ______________________________

City: ________________ State: ______ Zip: ________

Phone: ( ) -________________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________________

Address: ______________________________

City:________________ State: ______ Zip: ________

Phone: ( ) -________________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

Name: ______________________________

Address:______________________________

City: ________________ State: ______ Zip: ________

Phone: ( ) -________________

Did this partner also operate land individually on December 1, 2018?

☐ Yes ☐ No

For Office Use Only	For Office Use Only	For Office Use Only	For Office Use Only
Stratum	**Stratum**	**Stratum**	**Stratum**
9922	9923	9927	9928
Ind. Op.	**Ind. Op.**	**Ind. Op.**	**Ind. Op.**
9924	9924	9924	9924

Section 1 - Hogs and Pigs Owned

1. On December 1, did this operation (named on label) own any hogs or pigs, regardless of location? (INCLUDE hogs or pigs being raised under contract for you by someone else.)

   ☐ Yes - [Go to item 2]

   ☐ No - Did this operation own hogs or pigs at any time from September1 through November 30, 2018?

      ☐ Yes - [Go to item 8 on page 5.]

      ☐ No - Were any hogs or pigs owned by someone else on this operation on December 1?

         ☐ Yes - [Go to item 11 on page 6.]

         ☐ No - Were any hogs or pigs slaughtered for consumption by this operation, regardless of ownership, during 2018?

            ☐ Yes - [Go to item 12 on page 6.]

            ☐ No - [Go to Section 2 on page 7.]

			Number Owned December 1
2. How many sows and gilts for breeding were owned by this operation on December 1? (INCLUDE unweaned gilts intended for breeding.)...		+	301
a. How many of the [item 2] sows and gilts are expected to farrow during December 2018, January or February 2019?..	331		
b. How many of the [item 2] sows and gilts are expected to farrow during March, April or May 2019?..	332		
3. How many boars and young males for breeding were owned by this operation on December 1? (INCLUDE unweaned boar pigs intended for breeding.)..		+	302
4. Of the hogs and pigs for market and home use owned by this operation on December 1, how many were in each of the following four weight groups? (EXCLUDE breeding hogs and pigs reported in [item 2] or [item 3].)			
a. Under 50 pounds? (INCLUDE unweaned pigs intended for market or home use.)...............		+	315
b. 50 - 119 pounds?...		+	316
c. 120 - 179 pounds?...		+	313
d. 180 pounds and over? (INCLUDE sows and boars no longer used for breeding.)................		+	314
5. [Add Items 2 + 3 + 4a + 4b + 4c + 4d and verify the total. If necessary, make corrections before continuing.]			
Then the total hogs and pigs owned by this operation on December 1 was:............................		=	300

Section 1 - Hogs and Pigs Owned (continued)

Inventory Values for Hogs and Pigs on Hand on December 1, 2018

6. What is the average value per head of the following [Report to nearest dollar.]

a. Sows and gilts used and to be used for breeding?.	$ per Head	304
b. Boars used and to be used for breeding?.	$ per Head	305
c. Market hogs and pigs for each of the following four weight groups?		
(i) Under 50 pounds? (INCLUDE unweaned pigs intended for market or home use.)..	$ per Head	307
(ii) 50 - 119 pounds?...	$ per Head	308
(iii) 120 - 179 pounds?...	$ per Head	309
(iv) 180 pounds and over? (INCLUDE sows and boars no longer used for breeding.)..	$ per Head	310

Out-Of-State Hogs and Pigs

7. Did this operation own any hogs or pigs in another State on December 1?

1 ☐ Yes - [Remove any out-of-state hogs or pigs included in items 2 through 5 then continue to item 8.]

3 ☐ No - [Continue to item 8.]

Code
321

Section 1 - Hogs and Pigs Owned (continued)

Farrowings and pig crop from September 1 through November 30, 2018

8. Did any sows or gilts owned by this operation farrow during the last three months? (September - November)

☐ Yes - (Complete the following for each month starting with the most recent month)

a. How many sows and gilts owned by this operation farrowed during (month)..

Farrowings		
November Sows	**October** Sows	**September** Sows
888	891	894

b. How many of the pigs from these (item 8a) litters were:

i. owned by this operation on December 1?..........

ii. sold or slaughtered before December 1?...........

	Pig Crop		
	November Pig Crop	**October** Pig Crop	**September** Pig Crop
i.	889	892	895
ii.	890	893	896

☐ No - (Continue)

Section 1 - Hogs and Pigs Owned (continued)

Death Loss from September 1 through November 30, 2018

9. How many weaned pigs and older hogs owned by this operation died during September, October and November 2018?.................. | 335

Contract Hog and Pig Production

10. Were any hogs or pigs owned by this operation being raised under contract by another person or firm on December 1?

   1 ☐ Yes - Continue   3 ☐ No - (Go to item 11) | 336

   a. How many producers were raising hogs or pigs for you under contract on December 1?.................. | 317

   b. How many hogs and pigs (owned by this operation) were these [item 9a] producers raising for you under contract on December 1?.................. | 333

   [Verify that these hogs and pigs ARE included in the total (item 5 on page 3), then continue.]

11. Were any hogs or pigs owned by someone else on this operation on December 1? | 323

   1 ☐ Yes - [Continue]   3 ☐ No - [Go to Section 3 on page 8]

   a. How many hogs and pigs owned by someone else were on this operation on December 1?.................. | 322

   b. Who owns the hogs and pigs?..................

   (Owner's Name, Address, & Phone Number)

   Name ____________________

   Address ____________________

   City, St., ZIP ____________________

   Phone ____________________

   c. Is this hog owner a contractor?

   ☐ Yes   ☐ No

   [Verify that these hogs and pigs ARE NOT included in item 5 on page 3]

   d. Will the operator on the label own hogs or pigs at any time between now and June 1, 2018? | 324

   1 ☐ Yes   3 ☐ No

Slaughter for Consumption by this Operation (regardless of ownership)

	Total
12. During 2018, how many hogs and pigs were custom slaughtered at commercial establishments for consumption by this operation?..................	881
13. During 2018, how many hogs and pigs were slaughtered on this operation **for** consumption by this operation? (INCLUDE mobile slaughtering. EXCLUDE custom slaughter at commercial establishments.)..................	880

[Complete Section 2 only if the operation shown on the label DOES NOT own hogs or raise hogs under contract, otherwise go to Section 3 on page 8.]

Office Use - Completion Code - Hog Presence	1 - Incomplete, Hogs Present 2 - Incomplete, Unknown Presence	499
	3 - Valid Zero	

Section 2 - Intentions to Own or Raise Hogs

[Complete Section 2 only if the operation shown on the label DOES NOT own hogs or raise hogs under contract, otherwise go to Section 3 on page 8.]

1. Will the operator on the label raise hogs or pigs on this operation at any time between now and June 1, 2018? [Check one.]

492

1 ☐ Yes - [Go to Section 3 on page 8.]

2 ☐ Don't Know - [Continue with item 2.]

3 ☐ No - [Continue with item 2.]

2. Does this operation (named on the label) own and operate any buildings, structures, or facilities for raising hogs or pigs? (such as buildings used for breeding, farrowing, finishing, etc.) [Check one.]

488

1 ☐ Yes

3 ☐ No

3. Has this operation sold, rented, or turned over any hog facilities to someone else?

☐ Yes - Continue ☐ No - [Go to item 5.]

4. Who is using the hog facilities now?................

[Enter the name and address of the person or firm now using the facilities.]

Operation Name ____________________

Operator Name ____________________

Address ____________________

City, St., ZIP ____________________

Phone ____________________

[Write a note to describe the current status of this operation, then continue with Section 3 on page 8.]

5. Was the operator (name on label) operating a farm or ranch on December 1, 2018? (INCLUDE growing crops or raising livestock.)

☐ Yes ☐ Don't Know ☐ No

Section 3 - Conclusion

1. Do you (the operator named on the label) make any day-to-day decisions for another hog operation?

☐ Yes - Continue ☐ No - Go to Comments

a. What is the name of the other hog operation(s)? ....

Operation Name: ____________________
Address: ____________________
City: ____________ State: _____ ZIP: _______
Phone: (______) ____________________

Comments: ____________________

2. Survey Results: To receive the complete results of this survey on the release date go to www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/

To have a brief summary emailed to you at a later date, please enter your email address. | 1095

Would you rather have a brief summary mailed to you at a later date? 1 ☐ Yes 3 ☐ No | 9990

Respondent Name:	9911 Phone:	9910 MM DD YY Date:

Thank you for your help

OFFICE USE ONLY

Response		Respondent		Mode		Enum.	Eval.	Change	Office Use for POID
1-Comp 2-R 3-Inac 4-Office Hold 5-R – Est 6-Inac – Est 7-Off Hold – Est	9901	1-Op/Mgr 2-Sp 3-Acct/Bkpr 4-Partner 9-Oth	9902	1-PASI (Mail) 2-PATI (Tel) 3-PAPI (Face-to-Face) 6-e-mail 7-Fax 19-Other	9903	9998	9900	9985	9989 __ __ __ - __ __ __ - __ __ __ **Optional Use** 9907 | 9908 | 9906 | 9916
S/E Name									

Quarterly Hogs and Pigs Methodology and December Quality Measures

ISSN: 2166-9813

Released February 15, 2018, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

Quarterly Hogs and Pigs Survey Methodology

Scope and Purpose: The Hog Survey is conducted quarterly in December, March, June, and September. The survey targets hog and pig producers in the United States. The survey collects data for total hog inventory and other components including breeding herd, market hog inventory, market hogs by weight group, farrowings, pig crop, and litter rate. Additional data is collected for death loss, on-farm and custom slaughter, inventory values, and hogs raised under contract. Data is published for 16 major states every quarter except December when every state is published.

Survey Timeline: The reference date for the Hog Survey is the first day of the quarterly month with a data collection period of 20 days. Regional Field Offices may begin data collection one day prior to the reference date. Data collection continues until a scheduled ending date and Regional Field Offices have about four or five business days to complete editing and analysis, execute the summary, and interpret the survey results. The Agricultural Statistics Board must perform the national review, reconcile state estimates to the national estimates, and prepare the official estimates for release in five or six business days. The estimates are usually released to the public by the last week in the quarterly month. The publication date may change due to the timing of federal holidays.

Sampling: The target population for the Hog Survey is all agricultural establishments with one or more hogs or pigs owned by the operation. NASS uses a dual frame approach, consisting of list frame and area frame components, to provide complete coverage of this target population. The Hog Survey is conducted for every state.

The list frame includes all known agricultural establishments. A profile, known as control data, of each establishment is maintained on the list frame to allow NASS to define list frame sampling populations for specific surveys and to employ efficient sampling designs. Only list frame records with recent positive hog control data are included in the list frame population. In December, a base sample is selected for all states in the survey. During the follow-on quarters, the list sample is split into five replicates and only a partial number of replicates are contacted. This is done to reduce the burden of multiple survey contacts on the respondents in one calendar year. The list frame hog population covers approximately 97 percent of hog inventory in the United States.

The area frame contains all land in the state and, as such, is complete. The land is stratified according to intensity of agriculture using satellite imagery. The land in each stratum is divided into segments of roughly one square mile. Segments are optimally allocated and sampled to effectively measure crops and livestock. The sampled segments are fully enumerated in June. All farms and ranches found operating tracts in these segments are checked to see if they are included in the list frame hog population. The farms and ranches that are not included in the list frame hog population, called nonoverlap tracts, are sampled for the December Hog Survey so that the target population is completely represented. The area frame component of the December Hog Survey covers approximately one percent of the December hog inventory in the United States. The area frame component is modeled for the other three quarters to reduce respondent burden.

The Hog Survey list frame sample is selected using a hierarchical stratified sampling design with strata defined by total hogs and pigs. The sample is a panel sample and is designed to achieve a standard error of one percent of the point estimate for total hogs and pigs at a national level. The United States list frame sample size for the Hog Survey in recent years is approximately 10,000 in December and 7,000 in March, June, and September. The Hog Survey nonoverlap sample uses a stratified sample design based on data collected in the June Area Frame Survey. The area frame sample size is approximately 1,000. Each list frame and area frame sampling unit is assigned a sampling weight which is used to create the survey estimates.

Data Collection and Editing: For consistency across modes, the paper version is considered the master questionnaire and the web and Computer Assisted Telephone Interview (CATI) instruments are built to model the paper instrument. Questionnaire content and format are evaluated annually through a specifications process where requests for changes are evaluated and approved or disapproved. Input may vary from question wording or formatting to a program change involving the deletion or modification of current questions or addition of new ones. If there are significant changes to either the content or format proposed, a NASS survey methodologist will pre-test the changes for usability. Prior to the start of data collection, all modes of instruments are reviewed and web and CATI instruments are thoroughly tested.

All federal data collections require approval by the Office of Management and Budget (OMB). NASS must document the public need for the data, apply sound statistical practice, prove the data does not already exist elsewhere, and ensure the public is not excessively burdened. The Hog Report questionnaire must display an active OMB number that gives NASS the authority to conduct the survey, a statement of the purpose of the survey and the use of the data being collected, a response burden statement that gives an estimate of the time required to complete the form, a confidentiality statement that the respondent's information will only be used for statistical purposes in combination with other producers, and a statement saying that response to the survey is voluntary and not required by law.

In addition to asking the specific hog inventory items, all instruments collect information to verify the sampled unit, determine any changes in the name or address, identify any partners to detect possible duplication, verify the farm still qualifies for the target population, and identify any additional operations operated by the sampled operator.

Sampled farms and ranches receive a pre-survey letter explaining the survey and informing them that they will be contacted for survey purposes only. The letter provides the questions to be asked to allow respondents to prepare in advance and also provides a pass code they can use to complete the survey on the internet. All modes of data collection are utilized for hog surveys. Regional Field Offices are given the option of conducting a mail out/mail back phase. While mail is the least costly mode of collection, the short data collection period and the uncertainty of postal delivery times limit its effectiveness. Most of the data are collected by computer-assisted telephone interviews (CATI) by Regional Field Offices and Data Collection Centers. Limited personal interviewing is done, generally for large operations or those with special handling arrangements. A program is run to determine if any sampled farms are in multiple on-going surveys, so data collection can be coordinated.

Survey Edit: As survey data are collected and captured, they are edited for consistency and reasonableness using automated systems. The edit logic ensures the coding of administrative data follows the methodological rules associated with the survey design. Relationships between data items on the current survey are verified and in certain situations those items may be compared to data from earlier surveys to make sure certain relationships are logical. The edit will determine the status of each record to be either "dirty" or "clean". Dirty records must be updated and reedited or certified by an analyst to be clean. If updates are needed, they are reedited interactively. Only clean records are eligible for analysis and summary.

Analysis Tools: Edited hog data are processed through an interactive analysis tool which displays data for all reports by item. The tool provides scatter plots, tables, charts, and special tabulations that allow the analyst to compare an individual record to other similar records within their state. Outliers and unusual data relationships become evident and Regional Field Office staff will review them to determine if they are correct. The tool also allows comparison to an operation's previously reported data to detect large changes. Suspect data found to be in error are corrected, while data found to be correct are kept.

Nonsampling Errors: Nonsampling errors are present in any survey process. These errors include reporting, recording, editing, and imputation errors. Steps are taken to minimize the impact of these errors, such as questionnaire testing, comprehensive interviewer training, validation and verification of processing systems, detailed computer edits, and the analysis tool.

Estimators: Each farm and ranch in the sample has an initial sampling weight. This is the inverse of the sampling fraction. For example, if a stratum has 1,000 farms in the population and 200 are sampled for this survey, each sampled farm has a weight of 5. In other words, each sampled farm represents 5 farms. The nonoverlap tracts sampled to measure the hogs and pigs not accounted for by the list have a weight determined by adjusting their original area frame weight by any second stage sampling weight.

Response to the Hog Survey is voluntary. Some producers refuse to participate in the survey. Others cannot be located during the data collection period and some submit incomplete reports. These nonrespondents must be accounted for if accurate estimates of hogs are to be made. For the Hog Survey, nonrespondents are accounted for by adjusting the weights of the respondents. The adjustment occurs by stratum as the bounded strata represent homogeneous groupings of similar sized farms. The largest stratum is unbounded and is made up of large and, often unique, farms. Nonrespondents in this stratum and the nonoverlap tracts must be manually imputed by Regional Field Office statisticians and their weights are not adjusted. The adjustment is performed by individual item on the questionnaire (total hogs, market hogs, pig crop) so adjustments for item nonresponse (partial reports) and unit nonresponse (refusals and inaccessibles) are done in a single calculation.

Two estimators are used to compute direct measures of the hog inventory items. The “reweighted” estimator and the “adjusted” estimator are computationally identical except in how the nonresponse adjustments are made. The reweighted estimator uses a global weight adjustment across all usable reports. Using the previous example, if 180 of the original 200 respond, the weights of the 180 will be adjusted to 1,000 divided by 180, or 5.56. The nonresponse weight adjustment for the adjusted estimator uses an additional piece of information. When a sampled farm refuses to cooperate, interviewers will probe to determine the presence of hogs even though the number is not known. This presence/absence indicator is used in the weight adjustment.

Point estimates, also called direct expansions, for both estimators are calculated by multiplying the reported value by the nonresponse weight and summing to a stratum total. A variance estimate is also computed at the stratum level. The nonoverlap tracts are treated as an additional stratum. Totals and variances are additive across strata to form a state estimate and states are additive to a national estimate.

Ratio estimates are also computed for many items. For example, market hogs can be estimated as a percent of total inventory. A matched record ratio of current quarter data to previous quarter data is used to indicate change. Ratio indications use the reweighted estimator described above for the numerator and denominator direct expansions. Both the numerator and denominator must be complete in order for that record to be used in the ratio estimator.

Estimation: When all samples are accounted for, all responses fully edited, and the analysis material is reviewed, each Regional Field Office executes summaries for their states. When all states have been summarized, Headquarters executes the national summary. Since all states conduct identical surveys, the samples can be pooled and national survey results computed. The summary results provide multiple point estimates and their standard errors for each data series being estimated. It also provides information used to assess the performance of the current survey and evaluate the quality of the survey estimates, such as strata level expansions, response rates, and percent of the expansion from usable reports.

Regional Field Offices are responsible for performing a detailed review of their survey results. Any irregularities revealed by the summary must be investigated and, if necessary, resolved. Using the historical relationship of the survey estimates to the official estimate, Regional Field Offices must interpret the survey results and submit a recommended estimate to Headquarters for all data series for which they are in the NASS program. The data are viewed in tabular and graphical form and a consensus estimate is established. Regional Field Offices see their survey results only and do not have access to other Regions’ results. For some data series, information from other sources is also utilized in the process of establishing estimates. This includes commercial slaughter data, imports, and exports.

For the national estimates, NASS assembles a panel of statisticians to serve as the Agricultural Statistics Board (ASB) which reviews the national results and establishes the national estimates. Since larger sample sizes yield more precise results, NASS employs the “top-down” approach by determining the national estimates first and reconciling the state estimates to the national number for hog inventory, pig crop, and farrowings. The ASB has the advantage of being able to examine results across states, compare the state recommendations, and utilize administrative data available only at the United States level. The same estimators used in the state summaries are produced by the national summary. The Board follows the same approach the states do in determining the national estimate. The historical relationship of the survey estimates to the official estimate is evaluated over time to determine accuracy and bias using tables and graphs. Every 5 years NASS conducts the Census of Agriculture, which is an exhaustive data collection effort for all known farm operations across the United States. The information gathered from the Census of Agriculture is used to establish "bench mark" levels by which the survey estimators can be compared and bias determined. Survey based estimators can also be impacted by outliers – individual reports that have excessive influence on the results due to either improper classification or extremely unusual data for a given operation (i.e. the operation is not representative of other operations). NASS thoroughly reviews the survey data to identify these situations and considers their impact on the survey results when establishing the official estimates.

External information (administrative data) is also utilized in the process of setting estimates. In order to be considered fit for use, these data must be deemed to be reliable and come from unbiased sources. The most common administrative data is commercial slaughter. NASS employs a balance sheet approach whenever possible to ensure that estimates are as accurate as possible. This approach typically is limited to national-level estimates. A balance sheet and its components are reviewed when the inventory numbers are established. Commercial slaughter is an important element of the balance sheet at the national level since its high degree of reliability is based on a near-actual count of animals slaughtered. Live United States imports and exports to other countries are also considered.

Subtracting the disposition components of the balance sheet from supply components should, theoretically, give the current inventory. However, each component of the balance sheet has varying degrees of possible estimation error. To be most useful as an indication of inventory, therefore, each component should be estimated on the basis of all available information. The supply components of the United States balance sheet are the beginning inventory, births, and imports (inshipments for State balance sheets). From this supply, the disposition components – commercial slaughter (marketings at State level), farm slaughter, deaths, and exports – are subtracted. The result is the indicated number on hand at the end of the period or year.

Quality Metrics for Hogs and Pigs

Purpose and Definitions: Under the guidance of the Statistical Policy Office of the Office of Management and Budget (OMB), the United States Department of Agriculture's National Agricultural Statistics Service (NASS) provides data users with quality metrics for its published data series. The metrics tables below describe the performance data for all surveys contributing to the publication. The accuracy of data products may be evaluated through sampling and non-sampling error. The measurement of error due to sampling in the current period is irrelevant for a fully enumerated data series. Non-sampling error is evaluated by response rates and the percent of the estimate from usable reports.

> **Sample size** is the number of observations selected from the population to represent a characteristic of the population. Operations that did not have the item of interest or were out of business at the time of data collection have been excluded.
>
> **Response rate** is the proportion of the above sample size that completed the survey.
>
> **Percent of expansion from usable reports** is a ratio of survey data expanded by the original sampling weight compared to survey data expanded by the nonresponse adjusted weight .
>
> **Coefficient of variation** provides a measure of the size for the standard error relative to the point estimate and is used to measure the precision of the results of a survey estimator.

Hogs and Pigs Survey Sample Size and Response Rates: To assist in evaluating the performance of the estimates in the hogs and pigs report, the sample size and response rates are displayed. Response rates overall for 2016 and 2017 are displayed.

Hogs and Pigs Survey Sample Size and Response Rates - United States: December 1, 2016-2017

	Sample size		Response rates	
	2016	2017	2016	2017
	(number)	(number)	(percent)	(percent)
United States	8,460	7,667	58.3	61.1

Quality Metrics for December 1 Hogs and Pigs – United States: 2016 and 2017

	Percent of expansion from usable reports		Coefficient of variation	
	2016	2017	2016	2017
	(percent)	(percent)	(percent)	(percent)
All hogs and pigs	89.6	92.1	1.6	0.6
Kept for breeding	90.8	92.4	0.9	0.7
Market	89.5	92.1	1.8	0.7
Sows farrowed	90.9	92.4	1.0	0.7
Litter rate	90.9	92.4	0.1	0.1
Pig crop	91.2	92.6	1.0	0.7

Hogs and Pigs Survey Sample Size and Response Rates – United States: 2016 and 2017

	Sample size		Response rate		Percent Expansion from Usable Reports		Coefficient of Variation	
	2016	2017	2016	2017	2016	2017	2016	2017
	(number)	(number)	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)
Alabama	47	51	61.7	49.0	97.7	96.0	7.4	4.0
Alaska	31	28	48.4	42.9	89.7	84.9	7.2	13.0
Arizona	50	47	48.0	57.4	99.5	99.9	0.8	0.7
Arkansas	42	36	47.6	80.6	99.7	99.8	0.7	7.0
California	78	75	51.3	49.3	93.0	96.3	11.5	4.2
Colorado	76	77	64.5	64.9	99.7	99.6	0.3	0.5
Connecticut	56	59	48.2	37.3	93.1	82.9	49.5	14.3
Delaware	25	33	36.0	39.4	88.1	94.2	16.1	5.1
Florida	104	93	43.3	50.5	81.4	76.1	32.2	26.3
Georgia	83	66	55.4	63.6	93.6	98.0	6.2	1.7
Hawaii	63	52	47.6	51.9	62.4	70.9	13.7	10.9
Idaho	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Illinois	749	682	67.3	71.7	90.5	91.5	1.2	0.7
Indiana	686	609	68.5	72.9	91.1	93.0	1.1	0.9
Iowa	1,484	1,062	53.9	54.6	82.9	88.0	4.8	1.3
Kansas	178	165	46.1	49.1	95.7	96.0	0.9	0.7
Kentucky	85	85	70.6	69.4	97.1	97.8	1.9	1.6
Louisiana	55	47	54.5	80.9	71.4	91.4	36.6	25.1
Maine	57	61	80.7	50.8	87.8	72.9	29.5	26.2
Maryland	51	45	51.0	42.2	88.6	86.2	14.9	23.1
Massachusetts	52	56	40.4	50.0	74.1	85.2	12.1	11.1
Michigan	178	177	68.5	72.9	97.2	97.5	1.0	0.7
Minnesota	656	621	54.6	57.3	76.7	83.0	5.5	4.1
Mississippi	48	35	43.8	74.3	99.2	99.9	0.9	0.2
Missouri	326	294	54.0	58.8	97.1	96.9	0.6	0.9
Montana	104	102	85.6	79.4	99.7	99.4	1.4	1.8
Nebraska	583	530	59.2	62.3	93.2	93.2	1.3	1.5
Nevada	24	27	45.8	55.6	78.3	78.0	18.4	23.8
New Hampshire	58	61	48.3	54.1	72.7	90.9	18.2	34.5
New Jersey	48	49	54.2	49.0	92.5	88.0	53.4	27.6
New Mexico	55	60	63.6	73.3	76.7	82.7	34.9	26.3
New York	97	112	52.6	50.9	88.9	84.1	11.0	17.6
North Carolina	89	95	69.7	73.7	99.6	99.7	0.3	0.3
North Dakota	91	78	47.3	53.8	93.1	91.8	4.7	5.2
Ohio	431	381	53.1	53.3	95.9	97.2	0.8	0.4
Oklahoma	76	89	68.4	75.3	99.9	99.9	0.4	0.2
Oregon	92	81	52.2	66.7	77.4	89.7	27.2	17.0
Pennsylvania	214	229	63.6	52.0	95.4	93.8	1.1	1.7
Rhode Island	31	30	48.4	46.7	79.3	68.7	10.9	36.9
South Carolina	54	59	64.8	55.9	99.6	99.2	0.7	0.9
South Dakota	258	234	60.9	67.5	93.0	91.9	1.0	1.6
Tennessee	68	79	69.1	65.8	98.9	98.9	2.8	1.9
Texas	126	132	51.6	62.1	98.1	99.0	2.2	1.5
Utah	33	46	75.8	80.4	100.0	99.9	0.1	0.5
Vermont	78	71	56.4	42.3	93.6	87.7	47.5	21.3
Virginia	53	48	52.8	75.0	98.4	98.6	1.0	3.1
Washington	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
West Virginia	76	61	72.4	85.2	92.7	95.8	26.9	27.7
Wisconsin	292	265	55.8	53.6	75.7	79.8	6.6	7.1
Wyoming	30	37	73.3	70.3	99.3	98.7	5.9	4.7
Idaho and Washington	139	155	53.2	65.8	87.3	94.5	12.1	5.6
United States	8,460	7,667	58.3	61.1	89.6	92.1	1.6	0.6

(D) Withheld to avoid disclosing data for individual operations.

Information Contacts

Process	Unit	Telephone	Email
Estimation	Livestock Branch	(202) 720-3570	HQ_SD_LB@nass.usda.gov
Data Collection	Survey Administration Branch	(202) 720-3895	HQ_CSD_SAB@nass.usda.gov
Questionnaires	Data Collection Branch	(202) 720-6201	HQ_CSD_DCB@nass.usda.gov
Sampling and Editing	Sampling Editing and Imputation Methodology Branch	(202) 720-5805	HQ_CSD_SB@nass.usda.gov
Summary and Estimators	Summary Estimation and Disclosure Methodology Branch	(202) 720-4008	HQ_SD_SMB@nass.usda.gov
Dissemination	Data Dissemination Office	(202) 720-3869	HQSDOD@nass.usda.gov
Media Contact and Webmaster .	Public Affairs Office	(202) 720-2639	HQOAPAO@nass.usda.gov

Access to NASS Reports

For your convenience, you may access NASS reports and products the following ways:

- All reports are available electronically, at no cost, on the NASS web site: www.nass.usda.gov

- Both national and state specific reports are available via a free e-mail subscription. To set-up this free subscription, visit www.nass.usda.gov and click on "National" or "State" in upper right corner above "search" box to create an account and select the reports you would like to receive.

For more information on NASS surveys and reports, call the NASS Agricultural Statistics Hotline at (800) 727-9540, 7:30 a.m. to 4:00 p.m. ET, or e-mail: nass@nass.usda.gov.

Strata Descriptions and Weights			
State	Total Hogs	Strata	Weights
Colorado	1-99	80	31.92
	100-499	82	1
	500+	98	1
Illinois	1-99	80	4.87
	100-499	82	1.21
	500-999	84	1
	1000-1999	86	1.21
	2000-2999	88	1.42
	3000-4999	90	1.07
	5000-14999	92	1.05
	15000+	98	1
Indiana	1-99	80	12.15
	100-499	82	1.29
	500-999	84	1.14
	1000-1999	86	1.12
	2000-4999	88	1.14
	5000-14999	92	1.00
	15000+	98	1.00
Iowa	1-99	80	24.00
	100-999	82	2.19
	1000-9999	86	1.53
	10000-29999	88	1.00
	30000-49999	90	1.00
	50000-89999	92	1.00
	90000+	98	1.00
Kansas	1-99	80	46.40
	100-499	82	1.00
	500-999	84	1.00
	1000-2999	86	1.00
	3000-9999	92	1.00
	10000+	98	1.00
Michigan	1-99	80	49.44
	100-999	82	3.44
	1000-4999	86	1.00
	5000+	98	1.00
Minnesota	1-99	80	17.99
	100-999	82	2.14
	1000-9999	86	1.35
	10000-39999	88	1.00

	40000+	98	1.00
Missouri	1-99	80	28.08
	100-499	82	1.39
	500-999	84	1.44
	1000-1999	86	1.37
	2000-4999	88	1.00
	5000-9999	92	1.00
	10000+	98	1.00
Nebraska	1-99	80	1.41
	100-499	82	1.08
	500-999	84	1.12
	1000-1999	86	1.06
	2000-4999	88	1.20
	5000-9999	92	1.00
	10000+	98	1.00
North Carolina	1-99	80	55.80
	100-999	82	2.155.30
	1000-4999	86	1.00
	5000-14999	92	1.00
	15000+	98	1.00
Ohio	1-99	80	37.95
	100-499	82	1.15
	500-999	84	1.16
	1000-1999	86	1.24
	2000-4999	88	1.00
	5000+	98	1.00
Oklahoma	1-99	80	31.70
	100-499	82	1.00
	500 +	98	1.00
Pennsylvania	1-99	80	49.11
	100-499	82	2.40
	500-999	84	1.00
	1000-1999	86	1.00
	2000-4999	88	1.00
	5000+	98	1.00
South Dakota	1-99	80	3.59
	100-999	82	1.51
	1000-10999	86	1.16
	11000+	98	1.00
Texas	1-99	80	130.16
	100-499	82	1.08

	500-1999	84	1.00
	2000+	98	1.00
Utah	1-49	80	71.19
	50-249	82	1.13
	250+	98	1.00

Livestock Slaughter

ISSN: 0499-0544

Released March 4, 2019, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

Red Meat and Pork Production at Record High for January

January 2018 contained 23 weekdays (including 2 holidays) and 4 Saturdays.
January 2019 contained 23 weekdays (including 2 holidays) and 4 Saturdays.

Commercial red meat production for the United States totaled 4.70 billion pounds in January, up 2 percent from the 4.59 billion pounds produced in January 2018.

Beef production, at 2.31 billion pounds, was 1 percent above the previous year. Cattle slaughter totaled 2.83 million head, up 3 percent from January 2018. The average live weight was down 13 pounds from the previous year, at 1,363 pounds.

Veal production totaled 6.6 million pounds, 1 percent below January a year ago. Calf slaughter totaled 53,800 head, 10 percent above January 2018. The average live weight was down 22 pounds from last year, at 213 pounds.

Pork production totaled 2.37 billion pounds, 4 percent above the previous year. Hog slaughter totaled 11.0 million head, 3 percent above January 2018. The average live weight was up 2 pounds from the previous year, at 288 pounds.

Lamb and mutton production, at 12.5 million pounds, was slightly below January 2018. Sheep slaughter totaled 186,800 head, 6 percent above last year. The average live weight was 134 pounds, down 8 pounds from January a year ago.

This page intentionally left blank.

Contents

Commercial Red Meat Production – United States

[Totals, accumulated totals, and percentages based on unrounded data]

Type	January 2018	December 2018	January 2019	January 2019 as % of		January		
				January 2018	December 2018	2018	2019	2019 as % of 2018
	(million pounds)	(million pounds)	(million pounds)	(percent)	(percent)	(million pounds)	(million pounds)	(percent)
Beef	2,278.0	2,115.8	2,308.8	101	109	2,278.0	2,308.8	101
Veal	6.6	6.5	6.6	99	101	6.6	6.6	99
Pork	2,289.9	2,232.1	2,373.4	104	106	2,289.9	2,373.4	104
Lamb and mutton	12.5	13.2	12.5	100	95	12.5	12.5	100
Total red meat	4,587.1	4,367.6	4,701.2	102	108	4,587.1	4,701.2	102

Federally Inspected Red Meat Production – United States

[Totals, accumulated totals, and percentages based on unrounded data]

Type	January 2018	December 2018	January 2019	January 2019 as % of		January		
				January 2018	December 2018	2018	2019	2019 as % of 2018
	(million pounds)	(million pounds)	(million pounds)	(percent)	(percent)	(million pounds)	(million pounds)	(percent)
Beef	2,248.4	2,091.4	2,278.7	101	109	2,248.4	2,278.7	101
Veal	6.5	6.3	6.4	98	101	6.5	6.4	98
Pork	2,278.7	2,221.8	2,362.4	104	106	2,278.7	2,362.4	104
Lamb and mutton	11.7	11.9	11.4	98	96	11.7	11.4	98
Total red meat	4,545.3	4,331.3	4,658.9	102	108	4,545.3	4,658.9	102

Livestock Slaughter and Average Live Weight – United States

[Totals, accumulated totals, and percentages based on unrounded data]

Species	January 2018	December 2018	January 2019	January 2019 as % of 2018	January 2018	January 2019	January 2019 as % of 2018
				(percent)			(percent)
Cattle							
Number of head							
Federally inspected 1,000	2,713.8	2,544.0	2,785.9	103	2,713.8	2,785.9	103
Other 1,000	43.7	36.2	44.3	101	43.7	44.3	101
Commercial 1,000	2,757.5	2,580.2	2,830.2	103	2,757.5	2,830.2	103
Live weight per head							
Federally inspected .. pounds	1,380	1,370	1,366	99	1,380	1,366	99
Other .... pounds	1,182	1,184	1,189	101	1,182	1,189	101
Commercial .... pounds	1,376	1,368	1,363	99	1,376	1,363	99
Calves							
Number of head							
Federally inspected 1,000	48.4	53.0	53.0	110	48.4	53.0	110
Other 1,000	0.7	0.6	0.8	115	0.7	0.8	115
Commercial 1,000	49.0	53.6	53.8	110	49.0	53.8	110
Live weight per head							
Federally inspected .. pounds	232	209	210	91	232	210	91
Other .... pounds	394	355	391	99	394	391	99
Commercial .... pounds	235	210	213	91	235	213	91
Hogs							
Number of head							
Federally inspected 1,000	10,652.8	10,402.5	10,983.3	103	10,652.8	10,983.3	103
Other 1,000	61.3	57.9	58.0	95	61.3	58.0	95
Commercial 1,000	10,714.1	10,460.5	11,041.4	103	10,714.1	11,041.4	103
Live weight per head							
Federally inspected .. pounds	286	286	288	101	286	288	101
Other .... pounds	253	244	258	102	253	258	102
Commercial .... pounds	286	286	288	101	286	288	101
Sheep and lambs							
Number of head							
Federally inspected 1,000	161.9	176.2	165.7	102	161.9	165.7	102
Other 1,000	14.3	25.6	21.2	148	14.3	21.2	148
Commercial 1,000	176.3	201.8	186.8	106	176.3	186.8	106
Live weight per head							
Federally inspected .. pounds	144	134	138	95	144	138	95
Other .... pounds	111	105	103	93	111	103	93
Commercial .... pounds	142	131	134	95	142	134	95
Goats							
Number of head							
Federally inspected 1,000	39.4	50.1	42.9	109	39.4	42.9	109
Other 1,000	7.2	12.8	9.5	133	7.2	9.5	133
Commercial 1,000	46.5	62.9	52.5	113	46.5	52.5	113
Live weight per head							
Federally inspected .. pounds	64	65	65	102	64	65	102
Other .... pounds	82	85	82	101	82	82	101
Commercial .... pounds	67	69	68	103	67	68	103
Bison							
Number of head							
Federally inspected 1,000	3.8	3.7	4.8	126	3.8	4.8	126
Other 1,000	0.5	0.6	0.6	120	0.5	0.6	120
Commercial 1,000	4.3	4.3	5.4	126	4.3	5.4	126

Commercial Red Meat Production – States and United States

[Includes total beef, veal, pork, lamb, and mutton. Totals and percentages based on unrounded data.]

State	January 2018	December 2018	January 2019	January 2019 as % of 2018
	(million pounds)	(million pounds)	(million pounds)	(percent)
Alabama	1.2	1.1	1.1	94
Alaska	0.1	(Y)	0.1	85
Arizona	43.0	33.9	37.9	88
Arkansas	0.4	0.3	0.5	103
California	130.4	125.0	126.4	97
Colorado	198.3	166.3	194.6	98
Delaware-Maryland	3.3	2.9	3.3	99
Florida	2.9	2.2	2.7	93
Georgia	12.7	13.3	14.9	117
Hawaii	0.6	0.7	0.8	120
Idaho	23.3	27.8	31.1	133
Illinois	294.6	288.2	297.2	101
Indiana	163.6	145.3	155.3	95
Iowa	653.6	661.4	702.0	107
Kansas	493.0	464.6	495.5	101
Kentucky	49.9	46.6	51.0	102
Louisiana	0.3	0.4	0.4	111
Michigan	80.7	86.5	92.2	114
Minnesota	249.1	234.3	241.5	97
Mississippi	0.5	0.6	0.6	116
Missouri	176.4	164.5	174.2	99
Montana	0.9	1.1	1.0	113
Nebraska	695.1	648.1	714.9	103
Nevada	0.1	0.1	0.1	99
New England [1]	2.1	2.1	2.1	99
New Jersey	3.0	3.6	3.4	115
New Mexico	0.4	0.3	0.3	84
New York	3.3	3.4	3.3	102
North Carolina	222.4	220.3	242.3	109
North Dakota	0.8	0.5	0.7	95
Ohio	20.1	19.4	21.4	106
Oklahoma	108.1	101.5	106.1	98
Oregon	5.5	3.6	4.2	76
Pennsylvania	127.2	122.9	135.4	106
South Carolina	9.8	9.1	8.3	85
South Dakota	130.2	123.3	137.0	105
Tennessee	21.9	22.8	21.7	99
Texas	380.0	359.1	390.2	103
Utah	48.7	43.8	52.4	108
Virginia	44.3	46.8	48.1	109
Washington	77.0	72.6	79.5	103
West Virginia	0.7	0.9	0.7	93
Wisconsin	107.2	96.0	104.6	98
Wyoming	0.5	0.3	0.4	92
United States	4,587.1	4,367.6	4,701.2	102

(Y) Less than level of precision shown.

[1] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Commercial Cattle Slaughter – States and United States: January 2018 and 2019

[Data may not add to totals due to rounding]

State	Slaughtered		Total live weight		Average live weight	
	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(1,000 pounds)	(1,000 pounds)	(pounds)	(pounds)
Alabama	0.4	0.4	406	409	1,038	1,066
Alaska	0.1	0.1	64	81	1,050	1,036
Arizona	52.0	44.6	71,665	61,518	1,379	1,380
Arkansas	0.5	0.6	505	633	969	982
California	122.7	121.9	164,403	158,154	1,350	1,307
Colorado	217.1	210.1	307,779	299,545	1,420	1,427
Delaware-Maryland	3.4	3.4	4,600	4,665	1,348	1,368
Florida	(D)	(D)	(D)	(D)	(D)	(D)
Georgia	(D)	(D)	(D)	(D)	(D)	(D)
Hawaii	0.8	1.2	938	1,241	1,155	1,081
Idaho	31.1	43.0	39,563	55,256	1,287	1,300
Illinois	(D)	(D)	(D)	(D)	(D)	(D)
Indiana	3.2	3.2	3,486	3,641	1,106	1,151
Iowa	(D)	(D)	(D)	(D)	(D)	(D)
Kansas	552.4	573.1	760,099	772,565	1,377	1,348
Kentucky	1.7	3.3	1,793	3,351	1,055	1,026
Louisiana	0.5	0.5	372	402	797	761
Michigan	46.6	(D)	66,432	(D)	1,435	(D)
Minnesota	(D)	(D)	(D)	(D)	(D)	(D)
Mississippi	0.2	0.3	199	274	820	816
Missouri	4.9	5.1	5,732	5,973	1,171	1,169
Montana	1.0	1.0	1,174	1,336	1,218	1,280
Nebraska	617.3	644.1	894,869	923,046	1,451	1,435
Nevada	0.1	0.1	131	143	1,021	1,117
New England [1]	2.0	2.2	2,386	2,538	1,172	1,152
New Jersey	3.1	3.4	3,368	3,707	1,097	1,106
New Mexico	0.4	0.4	508	356	1,160	994
New York	3.3	3.5	3,929	4,194	1,222	1,215
North Carolina	5.9	6.2	7,245	7,613	1,237	1,236
North Dakota	0.9	0.9	1,220	1,142	1,305	1,265
Ohio	5.0	5.5	5,825	7,127	1,167	1,302
Oklahoma	2.7	3.0	2,820	3,158	1,035	1,056
Oregon	3.7	1.3	4,511	1,491	1,246	1,123
Pennsylvania	93.4	96.6	114,743	118,602	1,232	1,232
South Carolina	14.8	13.1	18,616	15,737	1,263	1,207
South Dakota	34.1	40.3	49,915	58,665	1,469	1,461
Tennessee	6.1	1.1	5,827	1,166	976	1,051
Texas	473.0	490.0	622,034	639,591	1,319	1,309
Utah	57.3	60.7	78,527	83,975	1,372	1,387
Virginia	1.6	1.6	1,709	1,711	1,072	1,057
Washington	91.7	94.7	127,373	131,266	1,393	1,390
West Virginia	1.0	0.9	1,004	937	1,027	991
Wisconsin	115.6	115.3	161,515	160,170	1,406	1,398
Wyoming	0.6	0.6	683	627	1,135	1,077
United States	2,757.5	2,830.2	3,786,653	3,849,293	1,376	1,363

(D) Withheld to avoid disclosing data for individual operations.

[1] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Commercial Calf Slaughter – States and United States: January 2018 and 2019

[Data may not add to totals due to rounding]

State	Slaughtered		Total live weight		Average live weight	
	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(1,000 pounds)	(1,000 pounds)	(pounds)	(pounds)
Alabama	(Y)	(Y)	(X)	(X)	(X)	(X)
Alaska	(Y)	(D)	(X)	(D)	(X)	(D)
Arizona	(D)	(D)	(D)	(D)	(D)	(D)
Arkansas	(D)	(Y)	(D)	(X)	(D)	(X)
California	6.6	8.5	666	858	103	102
Colorado	(D)	(D)	(D)	(D)	(D)	(D)
Delaware-Maryland	(D)	(D)	(D)	(D)	(D)	(D)
Florida	0.1	0.1	26	29	437	426
Georgia	0.2	0.1	74	54	480	442
Hawaii	(D)	(D)	(D)	(D)	(D)	(D)
Idaho	2.7	3.7	231	331	84	89
Illinois	0.1	0.1	29	32	406	389
Indiana	(D)	0.4	(D)	113	(D)	279
Iowa	(D)	(D)	(D)	(D)	(D)	(D)
Kansas	(Y)	(Y)	(X)	(X)	(X)	(X)
Kentucky	(D)	(D)	(D)	(D)	(D)	(D)
Louisiana	(Y)	(Y)	(X)	(X)	(X)	(X)
Michigan	0.1	0.1	30	33	300	308
Minnesota	(Y)	(Y)	(X)	(X)	(X)	(X)
Mississippi	(Y)	(D)	(X)	(D)	(X)	(D)
Missouri	(Y)	(Y)	(X)	(X)	(X)	(X)
Montana	(Y)	(Y)	(X)	(X)	(X)	(X)
Nebraska	(D)	(D)	(D)	(D)	(D)	(D)
Nevada	(D)	(D)	(D)	(D)	(D)	(D)
New England [1]	0.3	0.3	48	51	192	191
New Jersey	1.8	2.1	661	779	371	376
New Mexico	(Y)	(Y)	(X)	(X)	(X)	(X)
New York	7.5	9.1	852	891	115	99
North Carolina	0.1	(Y)	25	(X)	386	(X)
North Dakota	(D)	(D)	(D)	(D)	(D)	(D)
Ohio	14.3	14.9	2,187	1,965	154	132
Oklahoma	(Y)	(Y)	(X)	(X)	(X)	(X)
Oregon	(D)	(D)	(D)	(D)	(D)	(D)
Pennsylvania	8.8	9.2	3,718	3,882	422	424
South Carolina	(Y)	(D)	(X)	(D)	(X)	(D)
South Dakota	(Y)	(D)	(X)	(D)	(X)	(D)
Tennessee	(Y)	(Y)	(X)	(X)	(X)	(X)
Texas	0.1	0.3	59	121	435	418
Utah	(D)	(D)	(D)	(D)	(D)	(D)
Virginia	(D)	(D)	(D)	(D)	(D)	(D)
Washington	(D)	(Y)	(D)	(X)	(D)	(X)
West Virginia	(D)	(D)	(D)	(D)	(D)	(D)
Wisconsin	5.1	4.5	2,453	2,106	483	465
Wyoming	(D)	(D)	(D)	(D)	(D)	(D)
United States	49.0	53.8	11,427	11,393	235	213

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.
(Y) Less than level of precision shown.
[1] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Commercial Hog Slaughter – States and United States: January 2018 and 2019

[Data may not add to totals due to rounding]

State	Slaughtered		Total live weight		Average live weight	
	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(1,000 pounds)	(1,000 pounds)	(pounds)	(pounds)
Alabama	3.6	3.3	1,479	1,380	407	414
Alaska	0.2	0.1	50	22	243	284
Arizona	(D)	0.1	(D)	34	(D)	262
Arkansas	0.7	0.5	182	151	262	274
California	210.0	195.6	53,522	50,009	255	256
Colorado	1.6	1.5	408	373	248	246
Delaware-Maryland	1.9	1.8	516	492	272	270
Florida	3.9	4.1	614	614	157	149
Georgia	5.0	6.1	1,207	1,467	241	241
Hawaii	0.4	0.2	97	59	238	260
Idaho	16.0	14.8	4,256	4,024	267	273
Illinois	1,062.0	1,063.1	305,434	307,557	288	289
Indiana	761.6	720.0	213,905	203,180	281	282
Iowa	2,935.6	3,168.6	838,748	907,158	286	286
Kansas	(D)	(D)	(D)	(D)	(D)	(D)
Kentucky	(D)	(D)	(D)	(D)	(D)	(D)
Louisiana	0.8	0.8	153	172	193	226
Michigan	188.8	244.1	56,071	71,627	297	293
Minnesota	1,043.1	1,014.1	287,090	280,750	275	277
Mississippi	3.0	3.4	497	521	166	154
Missouri	797.5	763.9	230,173	226,921	289	297
Montana	0.7	0.8	193	205	260	265
Nebraska	695.5	715.8	196,361	205,352	282	287
Nevada	0.1	(Y)	21	(X)	270	(X)
New England [1]	3.0	2.6	835	716	280	279
New Jersey	7.6	10.3	807	987	106	96
New Mexico	0.2	0.2	62	65	273	266
New York	2.1	1.9	543	484	262	249
North Carolina	(D)	(D)	(D)	(D)	(D)	(D)
North Dakota	0.4	0.3	117	92	300	320
Ohio	73.7	78.1	21,088	21,874	287	281
Oklahoma	504.2	490.8	139,522	138,020	277	281
Oregon	14.5	15.3	3,845	4,169	266	273
Pennsylvania	284.0	304.8	77,402	86,233	273	283
South Carolina	2.7	2.4	660	580	249	246
South Dakota	(D)	(D)	(D)	(D)	(D)	(D)
Tennessee	63.0	70.6	28,536	31,688	454	449
Texas	23.3	24.6	5,833	5,612	251	228
Utah	5.5	6.5	973	1,018	177	157
Virginia	(D)	(D)	(D)	(D)	(D)	(D)
Washington	0.9	1.0	232	270	266	261
West Virginia	0.7	0.6	199	177	300	301
Wisconsin	67.6	62.6	29,544	26,967	438	432
Wyoming	0.3	0.2	83	56	272	273
United States	10,714.1	11,041.4	3,062,142	3,175,255	286	288

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.
(Y) Less than level of precision shown.
[1] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Commercial Sheep and Lamb Slaughter – States and United States: January 2018 and 2019

[Data may not add to totals due to rounding]

State	Slaughtered		Total live weight		Average live weight	
	2018	2019	2018	2019	2018	2019
	(1,000 head)	(1,000 head)	(1,000 pounds)	(1,000 pounds)	(pounds)	(pounds)
Alabama	(Y)	(Y)	(X)	(X)	(X)	(X)
Alaska	(Y)	(Y)	(X)	(X)	(X)	(X)
Arizona	(D)	0.5	(D)	65	(D)	133
Arkansas	(Y)	(Y)	(X)	(X)	(X)	(X)
California	23.4	30.0	3,481	4,456	149	149
Colorado	67.9	68.3	11,560	11,159	170	163
Delaware-Maryland	3.8	3.0	359	285	94	94
Florida	1.0	1.2	58	64	60	53
Georgia	1.6	2.1	112	163	72	78
Hawaii	0.1	0.1	18	8	144	78
Idaho	0.2	0.1	27	17	141	147
Illinois	3.9	3.9	390	361	101	93
Indiana	3.1	3.9	374	429	122	109
Iowa	0.2	0.2	33	27	165	168
Kansas	0.3	0.3	27	33	104	95
Kentucky	1.1	1.2	135	137	122	116
Louisiana	0.3	0.4	15	22	59	62
Michigan	20.0	(D)	2,926	(D)	146	(D)
Minnesota	0.4	0.5	36	46	100	98
Mississippi	0.6	0.9	35	56	61	64
Missouri	0.9	0.9	77	73	87	83
Montana	0.3	0.3	45	40	141	127
Nebraska	0.1	(Y)	9	(X)	121	(X)
Nevada	0.1	(Y)	8	(X)	141	(X)
New England [1]	2.8	2.4	254	242	92	100
New Jersey	9.5	12.0	751	944	79	78
New Mexico	0.6	0.7	83	96	151	144
New York	4.5	4.3	478	417	106	98
North Carolina	1.0	1.1	86	78	83	69
North Dakota	(Y)	(Y)	(X)	(X)	(X)	(X)
Ohio	3.5	4.5	504	707	143	159
Oklahoma	0.4	1.0	39	106	105	107
Oregon	4.0	3.5	581	488	146	140
Pennsylvania	6.2	7.3	697	741	112	101
South Carolina	(D)	(D)	(D)	(D)	(D)	(D)
South Dakota	0.2	0.3	38	53	162	161
Tennessee	0.9	0.7	66	44	74	66
Texas	5.4	11.5	518	965	97	84
Utah	1.7	1.8	239	241	141	134
Virginia	0.8	0.8	58	58	74	74
Washington	1.7	1.4	233	198	137	138
West Virginia	(D)	(D)	(D)	(D)	(D)	(D)
Wisconsin	2.4	3.8	379	581	159	154
Wyoming	0.1	0.1	12	14	141	140
United States	176.3	186.8	24,951	25,004	142	134

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.
(Y) Less than level of precision shown.
[1] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Livestock Slaughtered Under Federal Inspection by Class – United States

[Data may not add to totals due to rounding]

Class	January 2018	December 2018	January 2019	January		January 2018	December 2018	January 2019	January	
				2018	2019				2018	2019
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(percent of total)	(percent of total)	(percent of total)	(percent of total)	(percent of total)
Cattle										
Steers	1,383.2	1,253.6	1,354.5	1,383.2	1,354.5	51.0	49.3	48.6	51.0	48.6
Heifers	747.5	753.5	837.4	747.5	837.4	27.5	29.6	30.1	27.5	30.1
All cows	544.3	498.4	556.2	544.3	556.2	20.1	19.6	20.0	20.1	20.0
Dairy cows	289.8	261.2	298.4	289.8	298.4	10.7	10.3	10.7	10.7	10.7
Other cows	254.5	237.1	257.7	254.5	257.7	9.4	9.3	9.3	9.4	9.3
Bulls	38.8	38.5	37.8	38.8	37.8	1.4	1.5	1.4	1.4	1.4
Total	2,713.8	2,544.0	2,785.9	2,713.8	2,785.9	100.0	100.0	100.0	100.0	100.0
Calves and vealers	48.4	53.0	53.0	48.4	53.0	100.0	100.0	100.0	100.0	100.0
Hogs										
Barrows and gilts	10,358.4	10,135.6	10,684.4	10,358.4	10,684.4	97.2	97.4	97.3	97.2	97.3
Sows	262.7	238.9	265.3	262.7	265.3	2.5	2.3	2.4	2.5	2.4
Boars	31.6	28.0	33.6	31.6	33.6	0.3	0.3	0.3	0.3	0.3
Total	10,652.8	10,402.5	10,983.3	10,652.8	10,983.3	100.0	100.0	100.0	100.0	100.0
Sheep										
Mature sheep	7.4	10.1	8.2	7.4	8.2	4.6	5.7	4.9	4.6	4.9
Lambs and yearlings	154.5	166.1	157.5	154.5	157.5	95.4	94.3	95.1	95.4	95.1
Total	161.9	176.2	165.7	161.9	165.7	100.0	100.0	100.0	100.0	100.0

Federally Inspected Slaughter Average Dressed Weight by Class – United States

[Data may not add to totals due to rounding]

Class	January 2018	December 2018	January 2019	January	
				2018	2019
	(pounds)	(pounds)	(pounds)	(pounds)	(pounds)
Cattle	830	824	820	830	820
Steers [1]	893	894	886	893	886
Heifers [1]	836	831	824	836	824
All cows [1]	658	633	647	658	647
Bulls [1]	893	862	875	893	875
Calves and vealers	135	120	121	135	121
Hogs	214	214	215	214	215
Barrows and gilts [2]	212	212	213	212	213
Sows [2]	303	302	300	303	300
Boars [2]	190	187	182	190	182
Sheep	73	67	69	73	69
Mature sheep [3]	69	63	64	69	64
Lambs and yearlings [3]	73	68	69	73	69

[1] Included in cattle average dressed weight.
[2] Included in hog average dressed weight.
[3] Included in sheep average dressed weight.

Federally Inspected Slaughter – Regions and United States: January 2019

[Data may not add to totals due to rounding]

Standard federal regions [1]	Cattle							Calves
	Total	Steers	Heifers	Cows			Bulls	Total
				All	Dairy	Other		
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
1	1.9	0.7	(D)	0.3	0.2	0.2	(D)	0.2
2	6.7	1.7	1.5	3.1	2.9	0.2	0.4	11.2
3	99.4	31.4	2.0	62.5	49.9	12.6	3.5	9.4
4	52.2	3.7	1.3	41.3	14.5	26.8	5.9	0.2
5	280.1	132.5	(D)	110.8	72.2	38.6	(D)	19.9
6	488.6	225.3	156.4	98.1	40.0	58.0	8.9	0.1
7	1,242.9	679.8	490.6	65.5	7.6	57.9	7.0	(Y)
8	308.4	163.5	104.8	39.0	9.3	29.7	1.1	(Y)
9	167.2	71.9	15.2	78.6	70.1	8.5	1.4	8.2
10	138.5	43.9	35.0	56.9	31.7	25.2	2.7	3.7
United States	2,785.9	1,354.5	837.4	556.2	298.4	257.7	37.8	53.0

Standard federal regions [1]	Hogs				Sheep		
	Total	Barrows and gilts	Sows	Boars	Total	Mature sheep	Lambs and yearlings
	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)	(1,000 head)
1	2.3	2.2	0.1	(Y)	2.3	0.1	2.3
2	12.1	12.0	0.1	(Y)	15.9	1.6	14.3
3	523.6	522.5	(D)	(D)	11.9	1.3	10.6
4	(D)	(D)	(D)	(D)	7.2	0.8	6.4
5	3,157.3	3,028.4	124.6	4.3	21.8	1.5	20.3
6	511.4	511.3	0.1	(Y)	3.4	0.6	2.9
7	4,662.2	4,578.0	63.3	20.9	1.1	(Y)	1.0
8	(D)	(D)	0.4	(Y)	69.9	1.3	68.6
9	192.2	192.1	0.1	(Y)	28.4	0.8	27.6
10	30.8	30.7	(Y)	(Y)	3.9	0.2	3.7
United States	10,983.3	10,684.4	265.3	33.6	165.7	8.2	157.5

(D) Withheld to avoid disclosing data for individual operations.
(Y) Less than level of precision shown.
[1] States included in regions are as follows: 1 - Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; 2 - New Jersey, New York; 3 - Delaware-Maryland, Pennsylvania, Virginia, West Virginia; 4 - Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee; 5 - Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin; 6 - Arkansas, Louisiana, New Mexico, Oklahoma, Texas; 7 - Iowa, Kansas, Missouri, Nebraska; 8- Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming; 9 - Arizona, California, Hawaii, Nevada; 10 - Alaska, Idaho, Oregon, Washington.

Federally Inspected Slaughter Percent of Total Commercial Slaughter – United States

Species	January 2018	December 2018	January 2019	January	
				2018	2019
	(percent)	(percent)	(percent)	(percent)	(percent)
Cattle	98.4	98.6	98.4	98.4	98.4
Calves	98.6	98.8	98.6	98.6	98.6
Hogs	99.4	99.4	99.5	99.4	99.5
Sheep	91.9	87.3	88.7	91.9	88.7

Statistical Methodology

Data Sources: Primary data for the *Livestock Slaughter* publication are obtained from electronic reports completed by inspectors from the Food Safety and Inspection Service (FSIS), USDA, which provide daily counts of animals slaughtered in Federally Inspected (FI) plants, in addition to total live and dressed weights. These counts are combined with data from State-administered Non-Federally Inspected (NFI) slaughter plants to derive total commercial slaughter estimates.

There are approximately 800 livestock slaughter plants in the United States operating under Federal Inspection and about 1,900 Non-Federally Inspected (State-inspected or custom-exempt) slaughter plants. Slaughter from State-inspected Talmedge-Aiken plants is included in FI totals (see Terms and Definitions, page 14). To prevent duplication in reporting between FI and NFI plants and assure all FI plants are included, certificates prepared by FSIS identifying operating status are constantly monitored.

Revision Policy: Number of head slaughtered, live weights, and dressed weights are subject to revision the following month after the monthly release. Annual totals are published in the slaughter summary each April which includes any revisions made to current and previous year's published data. Revisions are generally the result of late reports received from slaughter plants and are usually less than one-half of one percent. No revisions will be made to the previous year's data after the publication of the annual summary in April.

Procedures and Reliability: The livestock slaughter data is obtained electronically on a daily basis and summarized approximately two weeks after the week of slaughter. A computer program compares each plant's data with the historical data for that plant. Data are checked for unusual values for head kill, patterns of kill, average weights, and dressing percent, based on each plant's past operating profile. In addition, the computer program provides a listing of missing reports for follow-up contact with FSIS. Average live and dressed weights and dressing percentages by State are compared with the previous weeks as an additional check. Fluctuations are frequently the result of plants permanently or temporarily closing and a shift in the species reported.

The FSIS District Veterinary Medical Specialists (DVMS) are contacted by e-mail or telephone for missing or potentially erroneous slaughter data. This assures that plants slaughtering a large number of head or several species are accounted for each week. Any corrections FSIS makes to the slaughter data are included in the summary.

Computer imputation may be necessary for incomplete reports. The imputation of live and dressed weights is based on the current week reported data of plants of similar size and location. Imputation for live and dressed weight data for cattle and hogs is less than 10 percent and 7 percent, respectively. The imputation for calves and sheep is more frequent and variable. If no data is received electronically or by other means, for plants slaughtering fewer than 50 total head weekly of only one species, data are imputed. The imputation of head for any plant is based on the historical data for that particular plant. The imputation of head slaughtered is rare but when necessary, the imputed head kill for missing plants usually is less than 1 percent of the United States head kill totals.

FI data are summarized weekly and accumulated to a monthly total for this release. These weekly totals are published by USDA's Agricultural Marketing Service (AMS) in **Livestock, Meat, Wool Market News**, Weekly Summary, and statistics are also available on the NASS website. NFI data are summarized monthly only.

Livestock slaughter estimates are based on a census of operating plants and therefore, have no sampling error. However, they may be subject to non-sampling errors such as omissions, duplications and mistakes in reporting, recording and processing the data. These errors are minimized through rigid quality controls in the computer edit program and summarization process, and a careful review of all reported data for consistency and reasonableness.

No data are published when an individual plant's data could be divulged. If not published, as indicated with a (D), these data are still included in United States and region totals. A review of the data is made annually to determine the publishable data.

Terms and Definitions Used for Livestock Slaughter Estimates

Average Live Weight: The weight of the whole animal, before slaughter. Excludes post-mortem condemnations.

Commercial Production: Includes slaughter and meat production in federally inspected and other plants, but excludes animals slaughtered on farms. Based on packers' dressed weights.

Custom-Exempt Plants: Plants that do not sell meat but operate on a custom basis only are custom-exempt. The animals and meat are not inspected, but the facilities must meet health standards. These are considered NFI plants and head kill is included in NFI totals.

Dressed Weight: The weight of a chilled animal carcass. Beef with kidney knob in; veal with hide off; lamb and mutton with pluck out; pork with leaf fat and kidneys out, jowls on and head off.

Dressing Percent: Usually expressed as a percentage yield of chilled carcass in relation to the weight of the live animal on hoof. For example, a live hog that weighed 200 pounds on hoof and yielded a carcass weighing 140 pounds would have a dressing percentage of 70.

Federally Inspected (FI) Plants: Plants that transport meat interstate must employ federal inspectors to assure compliance with USDA standards. Any state whose commercial plants operate entirely under federal inspection may still have custom-exempt establishments for which NFI estimates are made.

Food and Meat Inspection: Includes examination, checking, or testing of a carcass and/or meat against established government standards and involves checking the facility for cleanliness, health of animals, or parts of animals and quality of the meat produced.

Non-Federally Inspected (NFI) Plants: Plants which sell and transport only intrastate. State inspectors assure compliance with individual state standards for these NFI plants. Mobile slaughtering units are excluded and are considered farm slaughter.

Number of Head: Includes post-mortem condemnations.

Plant, Slaughter: An establishment where animals are killed and butchered.

Red Meat: Red meat production is the carcass weight after slaughter excluding condemnation and is comprised of beef, veal, pork, and lamb and mutton. The FI red meat production is equal to the total carcass weight after slaughter. The NFI meat production formula is (NFI head kill) X (live weight) X (FI dressing percentage) = NFI red meat production.

Slaughter: Killing and butchering of animals primarily for food.

Slaughter, Farm: Animals slaughtered on farms primarily for home consumption. Excludes custom slaughter for farmers at commercial establishments, but includes mobile slaughtering on farms. These estimates appear only in the annual slaughter release.

Talmedge-Aiken (TA) Plants: Slaughter plants in which USDA is responsible for inspection. However, federal inspection is carried out by State employees. These plants are considered to be federally inspected.

Total Live Weight: The total weight of live animals, before slaughter. Excludes post-mortem condemnations.

Wholesome Meat Act: Legislation that specifies that all meat produced for sale in the United States must be inspected. Meat that is transported interstate must be inspected in compliance with Federal (USDA) Standards.

Information Contacts

Listed below are the commodity specialists in the Livestock Branch of the National Agricultural Statistics Service to contact for additional information. E-mail inquiries may be sent to nass@nass.usda.gov.

Travis Averill, Chief, Livestock Branch .... (202) 720-3570

Scott Hollis, Head, Livestock Section .... (202) 690-2424
    Sherry Bertramsen – Livestock Slaughter .... (202) 690-8632
    Holly Brenize – Sheep and Goats .... (202) 720-0585
    Donnie Fike – Dairy Products .... (202) 720-4448
    Heidi Gleich – Cattle, Cattle on Feed .... (202) 720-3040
    Mike Miller – Milk Production and Milk Cows .... (202) 720-3278
    Seth Riggins – Hogs and Pigs .... (202) 720-3106

Access to NASS Reports

For your convenience, you may access NASS reports and products the following ways:

- All reports are available electronically, at no cost, on the NASS web site: http://www.nass.usda.gov

- Both national and state specific reports are available via a free e-mail subscription. To set-up this free subscription, visit http://www.nass.usda.gov and in the "Follow NASS" box under "Receive reports by Email," click on "National" or "State" to select the reports you would like to receive.

For more information on NASS surveys and reports, call the NASS Agricultural Statistics Hotline at (800) 727-9540, 7:30 a.m. to 4:00 p.m. ET, or e-mail: nass@nass.usda.gov.

USDA NASS Data Users' Meeting

Tuesday, April 23, 2019

University of Chicago – Gleacher Center
450 North Cityfront Plaza Drive
Chicago, IL 60611
312-464-8787

USDA's National Agricultural Statistics Service will hold an open forum for users of U.S. domestic and international agriculture data. NASS is organizing the 2019 Data Users' Meeting in cooperation with five other USDA agencies – Agricultural Marketing Service, Economic Research Service, Farm Service Agency, Foreign Agricultural Service, and World Agricultural Outlook Board – and the Census Bureau's Foreign Trade Division. Agency representatives will provide updates on recent and pending changes in statistical and information programs important to agriculture, answer questions, and welcome comments and input from data users.

For registration details or additional information about the Data Users' Meeting, see the meeting page on the NASS website (https://www.nass.usda.gov/Education_and_Outreach/Meeting/index.php). Contact Vernita Murray (NASS) at 202-690-8141 or vernita.murray@nass.usda.gov or Patricia Snipe (NASS) at 202-720-2248 or patricia.snipe@nass.usda.gov for information.

The Data Users' Meeting precedes the Industry Outlook Conference at the same location on Wednesday, April 24, 2019. The outlook meeting brings together analysts from various commodity sectors to discuss developments and trends. For registration details or additional information about the Industry Outlook Conference, see the conference page on the LMIC website (http://lmic.info/page/meetings). Or contact Laura Lahr at 303-716-9935 or laura.lahr@lmic.info.

Adjusted Estimator

A direct expansion estimate calculated by summing over the sample the reported commodity values multiplied by the original sample weights adjusted for poststratification weights (if any), ag operation status, commodity presence status and commodity reporting status.

$$DE = \sum \frac{N}{n} A_c \frac{n}{n_a + n_{na}} \bullet \frac{n_a}{n_a + n_{ah}} \bullet \frac{n_h}{n_{gh}} y_{gh}$$

Where,

	DE	=	adjusted expansion estimate
	N	=	number of units in the population
	n	=	number of units in the sample
	A_c	=	post stratification weight for post strata c
	n_a	=	number of known ag operations in the sample (reporting unit = 1 - 8, 10, 11 or 13)
	n_{na}	=	number of known non-ag operations in the sample (reporting unit = 9)
	n_h	=	number of known commodity operations in the sample (Section completion code = 0 or 1)
	n_{ah}	=	number of known non-commodity ag operations in the sample (Section completion code = 3 and reporting unit $\neq$ 9)
	n_{gh}	=	number of positive responding commodity operations in the sample (Section completion code = 0)
	y_{gh}	=	value of the positive responding commodity operation

Assumptions:

! The probability that ag operation status will be determined is the same for all sampled units in a weighting class.

! Within a weighting class, the probability that commodity presence status will be determined is the same for all sampled units determined to be ag operations.

! Within a weighting class, the probability that commodity totals will be given is the same for all sampled units known to have the commodity.

Implications:

! Ag operation status nonrespondents (Reporting unit = 12) are similar to known ag operation respondents (Reporting unit ≠ 12) regarding the likelihood of being in business and, for those in business, of having the commodity and, for those that have the commodity, of being the same size of operation.

- Presence/absence nonrespondents (Completion code = 2) are similar to known commodity respondents (Completion code ≠ 2) regarding the likelihood of having the commodity and, for those that have the commodity, of being the same size of operation.

- Partial commodity respondents (Completion code = 1) are similar to complete commodity respondents (Completion code = 0) regarding the likelihood of being the same size of operation.

Strengths:

- Will be unbiased if there is no nonresponse, or if the model assumptions are true. All available partial information about the respondent is used to produce more efficient nonresponse weighting classes.

- Post stratification, based on control or reported data, may be used to make more homogeneous nonresponse weighting classes.

- If there is nonresponse, the bias will be smaller than for either the reweighted or adjusted estimators because respondents and nonrespondents are grouped together on the basis of having the commodity <u>and</u> of being in business, thus increasing the likelihood of being homogenous.

Weaknesses:

- Is most difficult to calculate. The addition of any post stratified weighting classes adds to the complexity of preparing for and calculating the estimate.

- There is no known exact variance formula for the estimator.

NASS Applications:

- Livestock Totals

Key Points to Remember:

- This estimator is identical to the reweighted estimator under either one of two conditions: (1) there are no non-ag sample respondents (Reporting unit = 9), or (2) the commodity status is determined for every ag operation (Completion code = 2).

- With the current (1996) cattle, sheep and hog survey designs, no post-stratified weighting classes are used because the survey strata are themselves single specie, non-integrated classes.

Animal and Plant
Health Inspection
Service

Veterinary
Services

September 2014

Swine Enteric Coronavirus Disease Testing Summary Report

Summary Report for NAHLN Laboratory Testing

April 2013 – June 2014
(Prior to the USDA Federal Order)

Table of Contents

This report was prepared by USDA-APHIS-VS Center for Epidemiology and Animal Health. For more information, contact: Dr. Brian McCluskey, VS Chief Epidemiologist, Brian.J.McCluskey@aphis.usda.gov

Section 1. Introduction

1.1 Purpose of this Report

This report summarizes swine enteric coronavirus diseases (SECD) testing results that were voluntarily provided by National Animal Health Laboratory Network (NAHLN) laboratories prior to issuance of the June 2014 Federal Order (*Reporting, Herd Monitoring, and Management of Novel Swine Enteric Coronavirus Disease, June 5, 2014).*

1.2 Background

Porcine epidemic diarrhea virus (PEDV) was first detected in the United States in the spring of 2013, and NAHLN diagnostic laboratories began collating and sharing their PEDV testing data among themselves and with swine health stakeholders on April 16, 2013. In mid-June 2013, the USDA NAHLN Program Office began to assist with this data coordination effort. Starting the week of June 16, 2013, NAHLN laboratories began voluntarily providing their PEDV testing data to the NAHLN Program Office; this cooperative effort was intended to facilitate the collation of U.S. PEDV testing information from NAHLN laboratories and sharing this information with key swine health stakeholders. The NAHLN Program Office started producing weekly reports summarizing PEDV testing on June 16, 2013. The reports provided a basic overview of the number of laboratory accessions tested and the number of positive accessions. Reports also tracked the numbers of accessions tested and positives in each State and in different production types/age classes.

In March 2014, labs began voluntarily providing their testing results for a second newly detected coronavirus, porcine deltacoronavirus (PDCoV). The reports incorporated testing information for both diseases and were referred to as Swine Enteric Coronavirus Disease (SECD) reports.

Premises identification data are essential in an outbreak to determine the number of affected herds, areas affected, and other information that enables understanding and management of the disease situation. Because premises identification information was not provided to USDA with the SECD laboratory testing results and because of the suspected occurrence of repeat testing on affected herds, it was not possible to use the NAHLN laboratory accession data to accurately determine the number of infected herds/premises. Although the number of positive accessions could be counted and summarized, it was unknown how many accessions represented repeat testing on the same herd. For example, if there were 100 positive accessions from State X, without premises identification information, it was impossible to determine if this represented 100 tests on a single herd or 100 different affected herds in that State. These data could be interpreted to represent anywhere from 1 to 100 affected herds.

In response to the significant impact novel SECDs were having on the U.S. pork industry, USDA issued a Federal Order on June 5, 2014. The Federal Order mandated reporting of SECD cases and specifically required that premises information be provided for SECD cases to allow accurate assessment of the spread of these diseases and to facilitate disease control.

This report summarizes the SECD testing information that was provided to VS prior to the Federal Order (prior to June 5, 2014). The report summarizes the number of laboratory accessions that were tested and found positive, but because of the reasons explained above, the **accessions counts do not equate to herd/premises counts.**

1.3 Data-Sharing Participants

Veterinary diagnostic laboratories that *voluntarily* reported PEDV and PDCoV testing data to the NAHLN Program office were:

- Arkansas Livestock & Poultry Commission-Veterinary Diagnostic Laboratory
- Athens Veterinary Diagnostic Laboratory, University of Georgia
- University of Illinois Veterinary Diagnostic Laboratory
- Illinois Department of Agriculture, Galesburg Animal Disease Laboratory
- Iowa State University Veterinary Diagnostic Laboratory
- Kansas State Veterinary Diagnostic Laboratory
- Michigan State University-- Diagnostic Center for Population and Animal Health
- University of Minnesota Veterinary Diagnostic Laboratory
- Veterinary Medical Diagnostic Laboratory, University of Missouri
- University of Nebraska Veterinary Diagnostic Center
- USDA National Veterinary Services Laboratories
- Rollins Diagnostic Laboratory, North Carolina Department of Agriculture
- Veterinary Diagnostic Laboratory, North Dakota State University
- Ohio Animal Disease Diagnostic Laboratory - Ohio Department of Agriculture
- Oregon State University Veterinary Diagnostic Laboratory
- Indiana Animal Disease Diagnostic Laboratory, Purdue University
- Animal Disease Research & Diagnostic Laboratory, South Dakota State University
- Texas Veterinary Medical Diagnostic Laboratory, Texas A&M University

This report does not include data from testing conducted at private diagnostic laboratories or for research purposes.

1.4 About the Data in this Report

Data in this report were compiled from PEDV and PDCOV testing results data that were voluntarily provided by the above NAHLN laboratories. Important caveats about these testing data:

- As described previously, **in this outbreak situation the number of accessions does not equate to the number of herds/premises**. Because premises identification information were not provided by laboratories or by those who submitted the samples for testing, and because of the high occurrence of repeat testing on a herd in an outbreak, it was not possible to use NAHLN accession data to determine the number of infected herds/premises or accurately monitor disease spread.

- A laboratory accession is a set of samples collected at a single premises on a single day and received at the laboratory. A laboratory accession represents a swine herd and samples within the accession represents an individual animal tested for PEDV or PDCoV on a given date. Because multiple swine within a herd are often simultaneously infected, analyses often use the laboratory accession (rather than individual sample) as the epidemiological unit of interest.
- A single accession can include samples from multiple age classes or samples tested in different weeks. Therefore, the same accession can be counted in more than one age class category or more than one testing week summary.
- The collection site State data provided in this report are based on information provided by the testing laboratory. VS notified State animal health officials when a positive accession was reported for the first time in a State. Prior to the Federal Order, however, VS did not officially confirm positive accessions.
- Data in this report include PCR test results only. Some NAHLN laboratories also provided results data from different laboratory tests (e.g., IHC, IFA, ELISA), but those results are not presented here.
- Data from feed samples are not included in this report.
- From mid-April to mid-June 2013, SECD testing data were compiled by the Iowa State University Veterinary Diagnostic Laboratory; only summary data on positive samples were provided for that time period.
- Starting the week of June 16, 2013, NAHLN laboratories began providing more granular data about PEDV testing to the USDA NAHLN Program Office; this allowed more information to be reported starting in mid-June.
- During the October 2013 federal government shutdown, the University of Minnesota Diagnostic Laboratory collected and reported PEDV testing data (weeks of Sept. 22 through Oct. 6, 2013.)
- In November 2013, NAHLN laboratories began reporting data on PEDV-negative cases, thereby allowing reporting on the numbers of samples and accessions that were tested in addition to the number that were positive. Summaries "total number tested" and "percent positive" were calculated for samples tested after November 1, 2013.
- For NAHLN laboratory reporting, age classes were defined as suckling (< 1 month old or still on sow), nursery (1 month up to 3 months), grower/finisher (3 months up to 8 months), and sow/boar (8 months or older).

Section 2. SECD Testing Overview

2.1 Testing Summary

Table 1. Summary of testing and results for PEDV and PDCoV, April 2013 through June 4, 2014 (biological accessions and PCR testing only). For PEDV, data are summarized from April 15, 2013, through June 4, 2014; numbers of accessions tested were reported starting November 2013; percent positive was calculated from November 1, 2013 through June 4, 2014. For PDCoV, data are summarized from March 23, 2014, through June 4, 2014.

	PEDV	PDCOV
Number of Positive Accessions	6,976	260
Number of Accessions Tested	21,228	2,172
Percent Positive Accessions	32.9%	12.0%
Number of States with Positive Accessions	30	15
Number of States with Accessions Tested	40	29
Number of NAHLN Labs that Provided Data	13	4
Number of Samples Tested / Result Records Processed	145,122	11,682

Section 3. Porcine Epidemic Diarrhea Virus (PEDV) Testing Summary

3.1 PEDV Time Trends

Table 2. Biological accessions and samples tested for PEDV and percent positive by month.

Month	Biological Accessions			Biological Samples		
	Tested	Positive	% Pos	Tested	Positive	% Pos
April 2013	-	3	-	-	-	-
May 2013	-	112	-	-	-	-
June 2013	-	187	-	-	327	-
July 2013	-	113	-	-	557	-
Aug 2013	-	138	-	-	425	-
Sept 2013	-	134	-	-	458	-
Oct 2013	-	267	-	-	1,150	-
Nov 2013	1,064	414	38.9%	3,850	1,460	37.9%
Dec 2013	2,294	630	27.5%	9,373	2,007	21.4%
Jan 2014	2,774	953	34.4%	11,172	3,168	28.4%
Feb 2014	3,650	1,228	33.6%	16,638	4,256	25.6%
March 2014	3,601	1,123	31.2%	15,387	3,634	23.6%
April 2014	3,775	1,053	27.9%	22,369	4,704	21.0%
May 2014	3,590	757	21.1%	26,475	3,925	14.8%
June 2014	489	84	17.2%	3,920	489	12.5%
Total	**21,228**	**6,976**	**29.4%**	**109,184**	**26,560**	**21.7%**

Table 3. Biological accessions and samples tested for PEDV and number and percent positive by week.

Week	Biological Accessions			Biological Samples		
	Tested	Positive	% Pos	Tested	Positive	% Pos
Apr 15, 2013	-	2	-	-	-	-
Apr 22, 2013	-	1	-	-	-	-
Apr 29, 2013	-	9	-	-	-	-
May 6, 2013	-	17	-	-	-	-
May 13, 2013	-	10	-	-	-	-
May 20, 2013	-	44	-	-	-	-
May 27, 2013	-	32	-	-	-	-
June 3, 2013	-	55	-	-	-	-
June 10, 2013	-	48	-	-	-	-
June 16, 2013	-	47	-	-	163	-
June 23, 2013	-	37	-	-	164	-
June 30, 2013	-	10	-	-	58	-
July 7, 2013	-	34	-	-	171	-
July 14, 2013	-	33	-	-	140	-
July 21, 2013	-	24	-	-	117	-
July 28, 2013	-	31	-	-	121	-
Aug 4, 2013	-	27	-	-	69	-
Aug 11, 2013	-	36	-	-	163	-

Week	Biological Accessions			Biological Samples		
	Tested	Positive	% Pos	Tested	Positive	% Pos
Aug 18, 2013	-	30	-	-	72	-
Aug 25, 2013	-	26	-	-	71	-
Sept 1, 2013	-	31	-	-	85	-
Sept 8, 2013	-	28	-	-	79	-
Sept 15, 2013	-	32	-	-	130	-
Sept 22, 2013	-	40	-	-	156	-
Sept 29,2013	-	41	-	-	170	-
Oct 6, 2013	-	43	-	-	196	-
Oct 13, 2013	-	57	-	-	252	-
Oct 20, 2013	-	68	-	-	288	-
Oct 27, 2013	-	84	-	-	331	-
Nov 3, 2013	219	90	41%	649	292	45%
Nov 10, 2013	221	92	42%	696	373	54%
Nov 17, 2013	239	113	47%	741	304	41%
Nov 24, 2013	338	96	28%	1,617	412	25%
Dec 1, 2013	565	139	25%	2,481	367	15%
Dec 8, 2013	572	132	23%	2,356	451	19%
Dec 15, 2013	501	185	37%	1,816	524	29%
Dec 22, 2013	418	118	28%	1,773	409	23%
Dec 29, 2013	439	122	28%	2,077	546	26%
Jan 5, 2014	693	188	27%	2,876	590	21%
Jan 12, 2014	497	215	43%	1,735	621	36%
Jan 19, 2014	816	218	27%	3,386	816	24%
Jan 26, 2014	576	267	46%	2,073	851	41%
Feb 2, 2014	917	295	32%	4,025	934	23%
Feb 9, 2014	897	306	34%	3,901	1,060	27%
Feb 16, 2014	916	315	34%	4,374	1,201	27%
Feb 23, 2014	927	313	34%	4,317	1,068	25%
Mar 2, 2014	846	281	33%	3,351	751	22%
Mar 9, 2014	949	295	31%	3,732	851	23%
Mar 16, 2014	835	270	32%	3,601	999	28%
Mar 23, 2014	831	247	30%	4,112	886	22%
Mar 30, 2014	926	260	28%	5,221	1,279	24%
Apr 6, 2014	889	272	31%	4,859	1,104	23%
Apr 13, 2014	825	222	27%	4,645	943	20%
Apr 20, 2014	798	211	26%	5,107	941	18%
Apr 27, 2014	824	198	24%	5,350	858	16%
May 4, 2014	856	192	22%	5,719	978	17%
May 11, 2014	855	190	22%	6,398	949	15%
May 18, 2014	811	158	19%	6,106	821	13%
May 25, 2014	756	143	19%	6,023	896	15%
June 1, 2014	489	84	17%	6,306	757	12%
Total	**21,228**	**6,976**	**33%**	**109,184**	**26,560**	**24%**

Figure 1A. Number of biological accessions tested for PEDV and number of positive accessions by week. Numbers of accessions tested were reported starting November 2013.

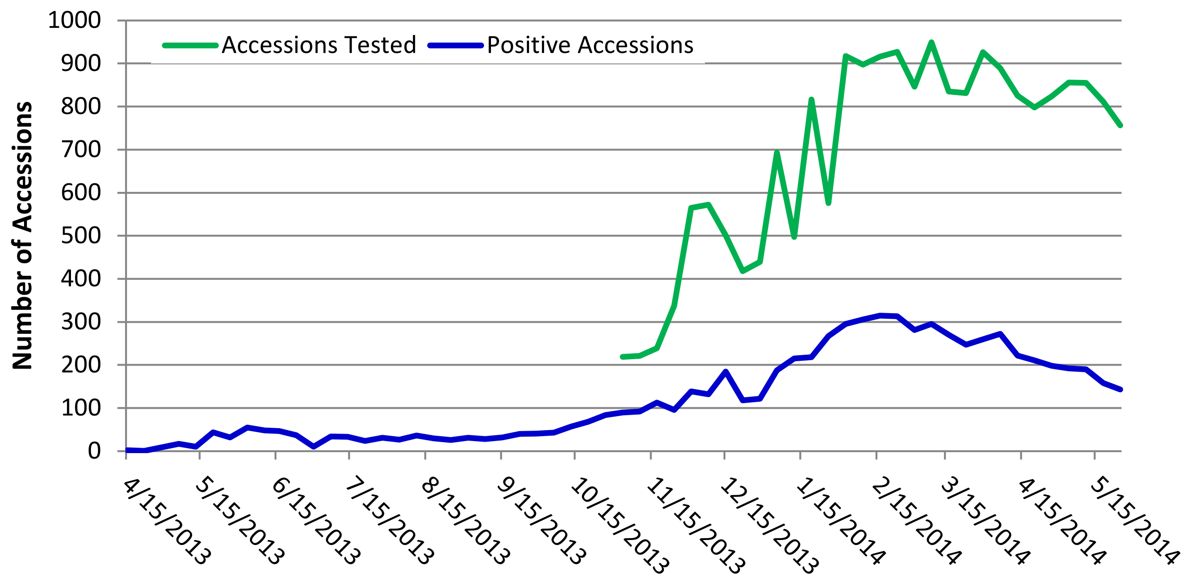
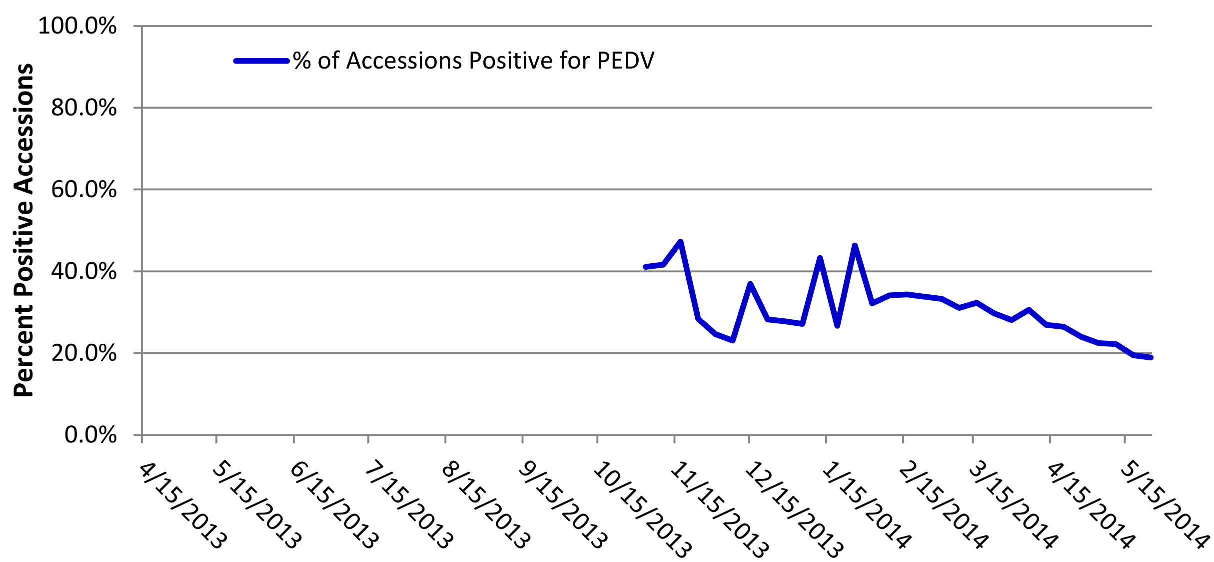


Figure 1B. Percentage of biological accessions that were positive for PEDV. Numbers of accessions tested were reported starting November 2013; percent positive was calculated from November 1, 2013 through June 4, 2014.



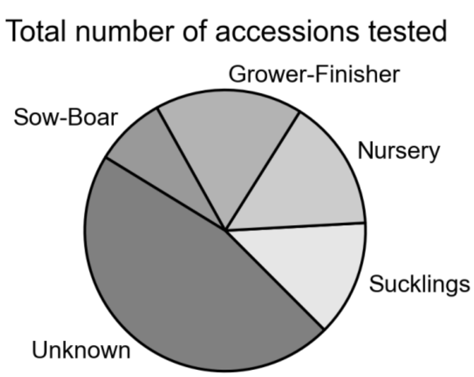
3.2 PEDV Age Class Trends

Table 4. PEDV Summary by Age Class. Biological accessions tested for PEDV and the number positive and percent positive for each farm type/age class by month.

	Suckling			Nursery			Grower / Finisher			Sow / Boar			Unk		
Month	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos
Apr 2013	-	0	-	-	0	-	-	2	-	-	0	-	-	0	-
May 2013	-	0	-	-	0	-	-	70	-	-	23	-	-	8	-
Jun 2013	-	14	-	-	12	-	-	84	-	-	36	-	-	35	-
Jul 2013	-	13	-	-	24	-	-	40	-	-	20	-	-	20	-
Aug 2013	-	57	-	-	31	-	-	19	-	-	25	-	-	12	-
Sep 2013	-	39	-	-	31	-	-	28	-	-	20	-	-	20	-
Oct 2013	-	89	-	-	47	-	-	72	-	-	39	-	-	23	-
Nov 2013	146	89	61.0%	228	105	46.1%	220	127	57.7%	61	25	41.0%	437	79	18.1%
Dec 2013	260	118	45.4%	432	138	31.9%	589	171	29.0%	154	40	26.0%	909	177	19.5%
Jan 2014	350	187	53.4%	450	190	42.2%	543	183	33.7%	168	65	38.7%	1,353	356	26.3%
Feb 2014	488	248	50.8%	609	228	37.4%	601	154	25.6%	285	110	38.6%	1,788	530	29.6%
Mar2014	515	261	50.7%	540	186	34.4%	530	118	22.3%	309	90	29.1%	1,861	505	27.1%
Apr 2014	534	229	42.9%	512	177	34.6%	589	121	20.5%	362	61	16.9%	1,924	486	25.3%
May 2014	568	199	35.0%	511	119	23.3%	595	107	18.0%	413	61	14.8%	1,663	301	18.1%
Jun 2014	82	22	26.8%	61	11	18.0%	77	10	13.0%	46	5	10.9%	236	36	15.3%
Total	**2,941**	**1,565**	**46.0%**	**3,341**	**1,298**	**34.5%**	**3,743**	**1,176**	**26.5%**	**1,797**	**573**	**25.4%**	**10,168**	**2,567**	**24.3%**

**Number* tested was reported starting November 2013; percent positive is calculated using data from Nov. 1, 2013, through current week.*

Figure 2A. Percentage of biological accessions tested for PEDV and percent positive by farm type/age class. Numbers of accessions tested were reported starting November 2013; percent positive was calculated from November 1, 2013 through June 4, 2014.



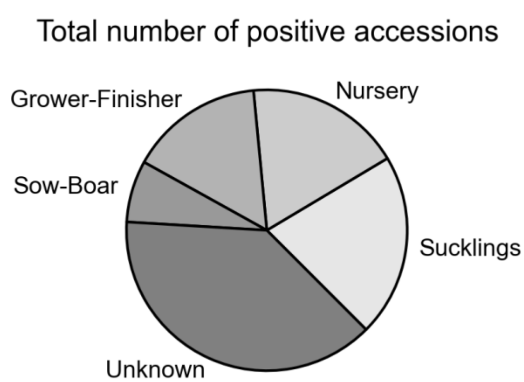
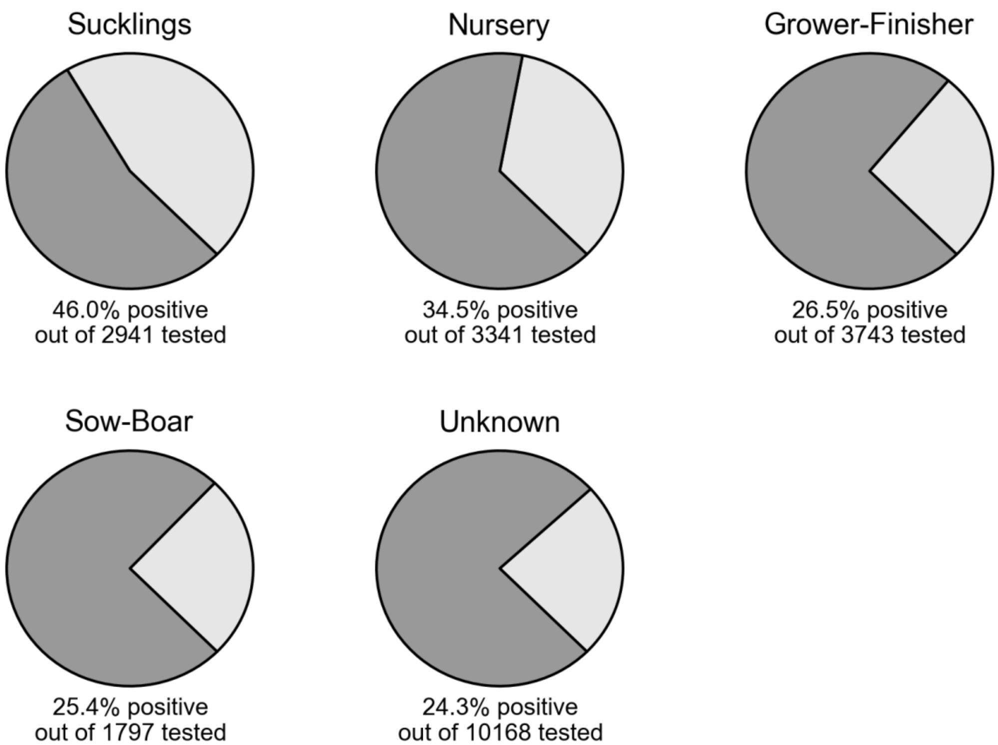
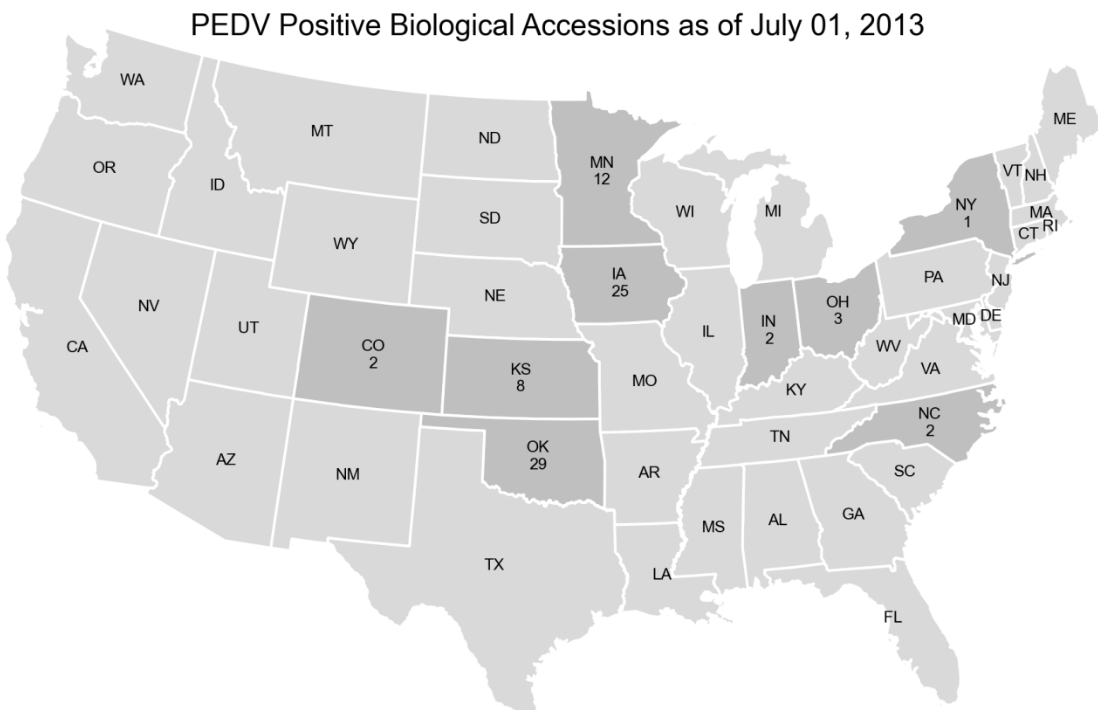


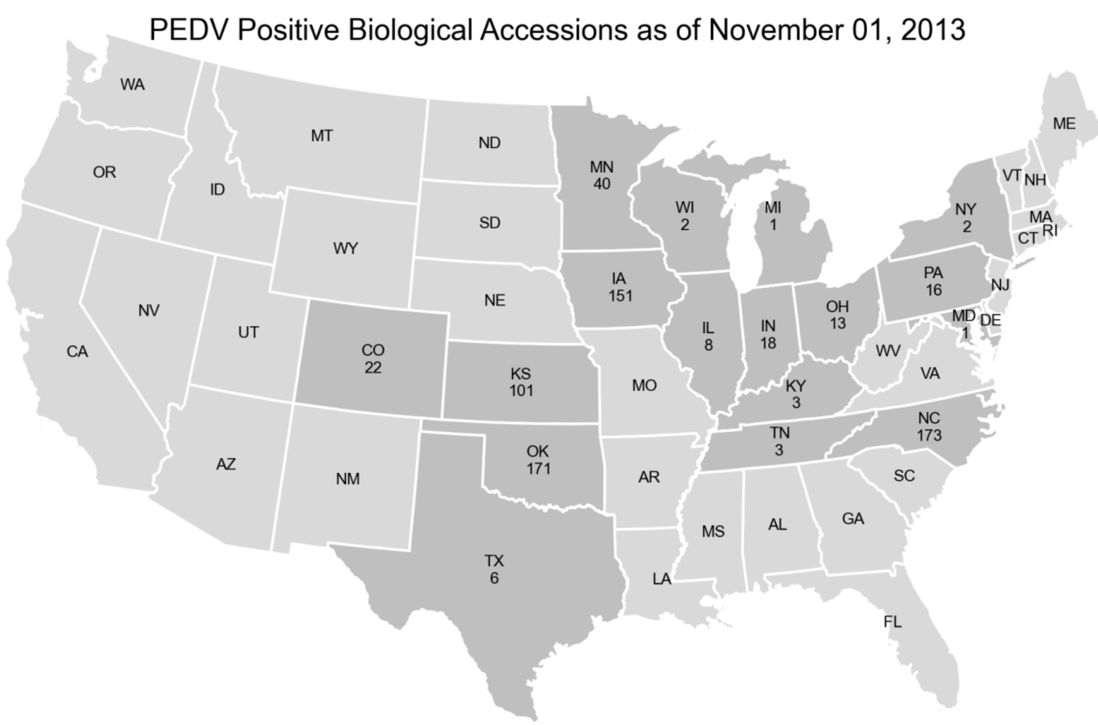
Figure 2B. Percentage of PEDV positive accessions for each farm type/age class. Numbers of accessions tested were reported starting November 2013; percent positive was calculated from November 1, 2013 through June 4, 2014.

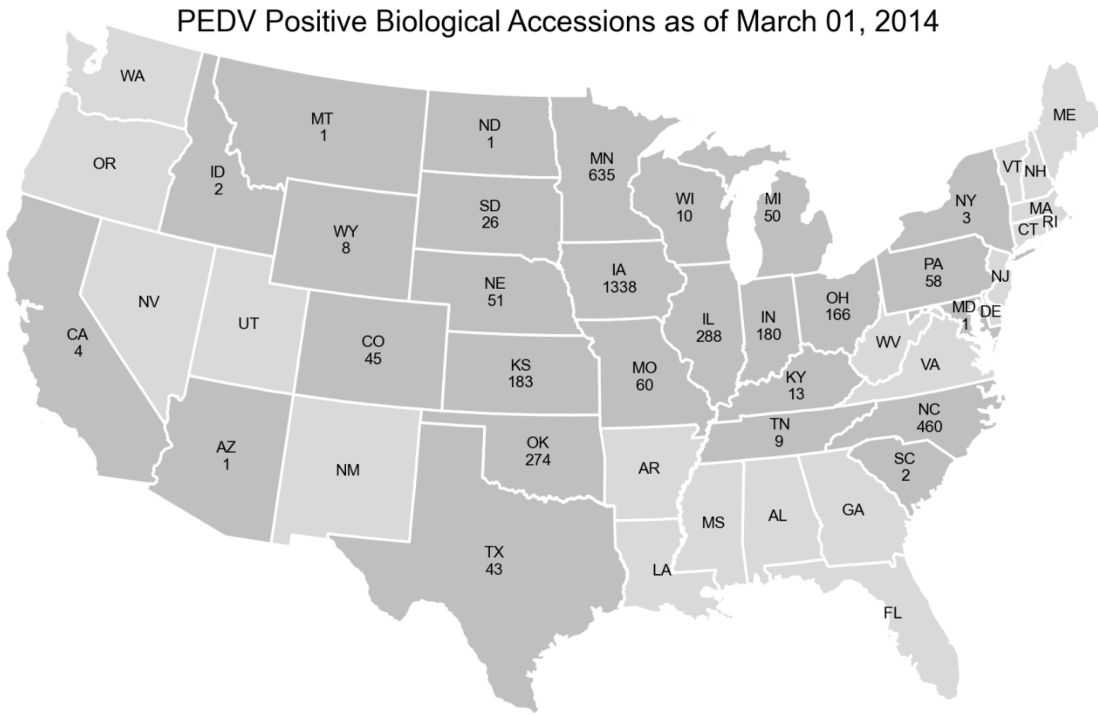


3.3 PEDV Summary by State

Figure 3. Maps showing the number of positive PEDV accessions from each State at intervals prior to the Federal Order on June 4, 2014






PEDV Positive Biological Accessions as of March 01, 2014
WA
OR
CA
4
NV
ID
2
MT
1
WY
8
UT
AZ
1
CO
45
NM
ND
1
SD
26
NE
51
KS
183
OK
274
TX
43
MN
635
IA
1338
MO
60
AR
LA
WI
10
IL
288
MS
MI
50
IN
180
KY
13
TN
9
AL
OH
166
WV
VA
NC
460
SC
2
GA
FL
PA
58
NY
3
VT
NH
ME
MA
RI
CT
NJ
MD
1
DE

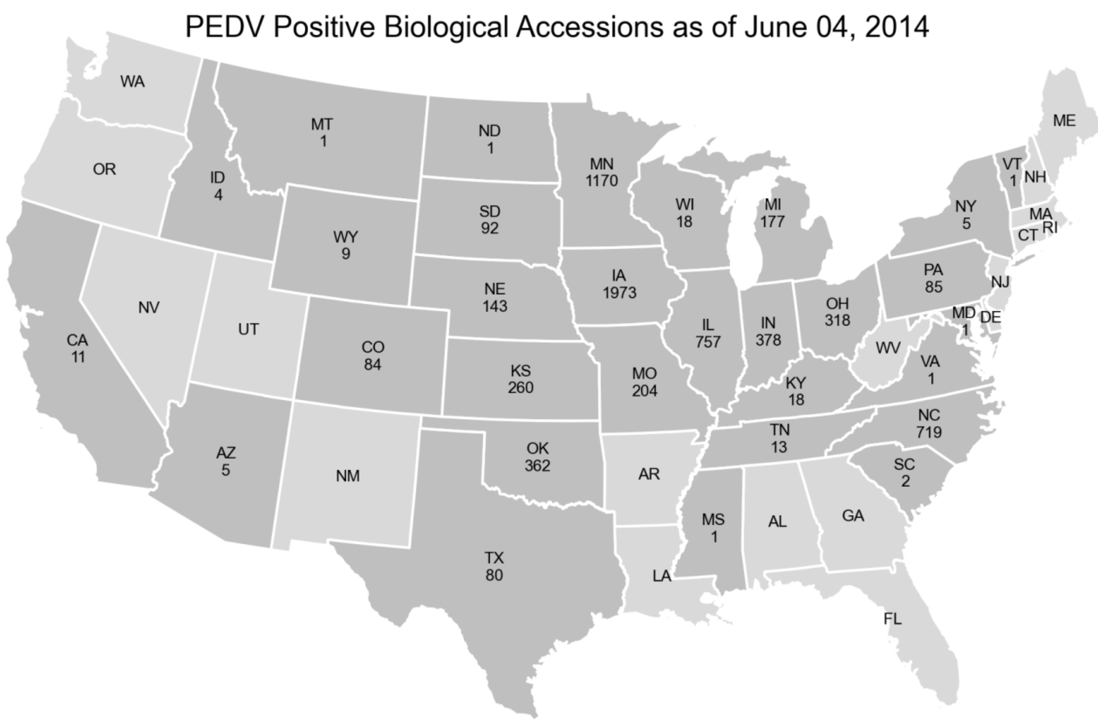

PEDV Positive Biological Accessions as of June 04, 2014
WA
OR
CA
11
NV
ID
4
MT
1
WY
9
UT
AZ
5
CO
84
NM
ND
1
SD
92
NE
143
KS
260
OK
362
TX
80
MN
1170
IA
1973
MO
204
AR
LA
WI
18
IL
757
MS
1
MI
177
IN
378
KY
18
TN
13
AL
OH
318
WV
VA
1
NC
719
SC
2
GA
FL
PA
85
NY
5
VT
1
NH
ME
MA
RI
CT
NJ
MD
1
DE

Table 5. Number of PEDV positive biological accessions in each State, by week.

	Total Positive Accessions	AZ	CA	CO	IA	ID	IL	IN	KS	KY	MD	MI	MN	MO	MS	MT	NC	ND	NE	NY	OH	OK	PA	SC	SD	TN	TX	VA	VT	WI	WY	UNK
Combined ISU data, 4/16/13-6/15/13	218			7	102		1	10	6			3	19	1							4	38	4		1							6
6/16/2013	47			1	10			1	7				8																			
6/23/2013	37			1	15			1	1				4				2					13										
6/30/2013	10				3												2				2	3										
7/7/2013	34			1	6		1	2	4				2				3				2	11										2
7/14/2013	33			2	7			4	7			1	3				2					7										
7/21/2013	24			1	6			1	3								7					4				1	1					
7/28/2013	31			1	5		1	1	7				3				2				1	10										
8/4/2013	27			1	9		1	1	6				1				2					5								1		
8/11/2013	36			6	5				13								5					7										
8/18/2013	30			1	6			1	5								1				2	14										
8/25/2013	26				2			1	3				2				4				1	10	3									
9/1/2013	31			2	6			1	8				1				4					4	5									
9/8/2013	28								7								6				1	13				1						
9/15/2013	32				7			1	3				2				12			1		5	1									
9/22/2013	40			1	3			1	5				1				24					4										1
9/29/2013	41			2	5				2				2				19					6	1				3					1
10/6/2013	43			1	6				6	1			1				21					6	1									
10/13/2013	57				10				4	1			6				21					13	2									
10/20/2013	68			1	20		2	1	9	1			2				22					9	1									
10/27/2013	84				32		4	1	3		1		5				17				1	13	2			1	3			1		
11/3/2013	90				38		1	1	6			2	7	2			14				5	10	1			1	1			1		
11/10/2013	92			1	51				1			2	8	1			15				4	5	1				3					
11/17/2013	113			1	47		5	3	5				17				12				4	11	1			1	6					
11/24/2013	96			1	25			4	1	1			19				19				9	12			1		3			1		
12/1/2013	139			2	65		10	9	4				23				8		1		5	6	3				2					1

	Total Positive Accessions	AZ	CA	CO	IA	ID	IL	IN	KS	KY	MD	MI	MN	MO	MS	MT	NC	ND	NE	NY	OH	OK	PA	SC	SD	TN	TX	VA	VT	WI	WY	UNK
12/8/2013	132				65		8	6	5			2	18	3			12				3	7	1				1					1
12/15/2013	185			1	96		15	8	3				27	5			19		1		3	5	1									1
12/22/2013	118		1		61		8	3	5			2	17	2			5		1		5	3					2					3
12/29/2013	122		1		49		13	2	4				20	4			17		2		5				2	1	1				1	
1/5/2014	188			3	81		10	2	9	1		1	46				15		1		7	4		2	1		4					1
1/12/2014	215		1	1	88		19	7	7	3		4	31	4			20		5		9	8	2		2		3			1		
1/19/2014	218			2	70		21	9	10	1		4	51	7			19		2		10	2	2		3	1	1					3
1/26/2014	267	1		2	87		39	24	3	1		2	50	7			15		7		11	4	4		3		2			1	1	3
2/2/2014	295		1	2	93	1	27	15	3	1		4	76	9		1	24		4		11	4	4		3		1			1	1	9
2/9/2014	306			2	91		27	22	7	1		9	62	4			23		9	1	21	6	3		4		2			1	2	9
2/16/14	315			3	90		35	25	7			7	59	4			24		6		22	9	7		5	1	2			2	1	6
2/23/14	313			2	79	1	41	22	1	1		10	61	8			23	1	12		19	5	12		3	1	2				2	7
3/2/14	281	1	1	1	81		32	26	6			3	47	11			26		2		19	1	3		6		5			1		9
3/9/14	295		2	7	71		43	22	13			13	52	7			16		5	1	13	9	3		7		6					5
3/16/14	270	3		2	54	1	44	21	5	1		16	40	17			17		6	1	17	9	5		6		2					3
3/23/14	247			2	48		43	14	5			9	45	16			20		9		16	5	1		5		1		1	2		5
3/30/13	260		1	1	51		41	17	9	1		17	48	8	1		24		7		17	5	1		5		2					4
4/6/14	272		2	5	48		43	17	7			10	49	12			23		10		22	10	2		2	2	3					5
4/13/14	222		1	5	42		43	16	6			9	46	7			20		2		10	4	2		4		3	1		1		
4/20/14	211			2	52		30	12	13			6	36	9			9		12		9	9	3		3	1	5					
4/27/14	198			1	44		32	15				11	40	5			16		7		12	6			5	1	2				1	
5/4/14	192				40	1	25	8	3			9	33	17			21		6		7	10	1		5		4					2
5/11/14	190			5	31		31	10	4	1		10	35	14			18		4		7	8	3		4		3			1		1
5/18/14	158			3	32		25	11	1	1		3	27	5			23		9		3	4	1		6					3		1
5/25/14	143			3	32		26	5	3			6	23	8			15		10		1	4	2		4		1					
6/1/14	84			2	9		11	5	2	1		5	16	9			13		4			4			3							1
Total	**7,178**	**5**	**11**	**91**	**2,075**	**4**	**758**	**388**	**266**	**18**	**1**	**180**	**1,189**	**205**	**1**	**1**	**719**	**1**	**143**	**5**	**322**	**400**	**89**	**2**	**93**	**13**	**80**	**1**	**1**	**18**	**9**	**89**

**A single accession may include samples tested over more than one week; total accessions is calculated as the distinct count of accessions tested rather than the sum of accessions tested by week.*

Section 4. Porcine Deltacoronavirus (PDCoV) Testing Summary

4.1 PDCoV Time Trends

Table 6. Biological accessions and biological samples tested for PDCoV and number and percent positive by month.

Month	Biological Accessions			Biological Samples		
	Tested	Positive	% Pos	Tested	Positive	% Pos
Mar 2014	45	7	15.6%	150	10	6.7%
Apr 2014	947	124	13.1%	4,095	382	9.3%
May 2014	1,042	112	10.7%	4,858	337	6.9%
Jun 2014	140	15	10.7%	660	42	6.4%
Total	**2,172**	**260**	**12.0%**	**9,763**	**771**	**7.9%**

Table 7. Biological accessions and biological samples tested for PDCoV and number and percent positive by week.

	Biological Accessions			Biological Samples		
Week	Tested	Positive	% Pos	Tested	Positive	% Pos
3/23/2014	2	-	0%	5	-	0%
3/30/2014	177	25	14%	824	92	11%
4/6/2014	241	32	13%	970	100	10%
4/13/2014	220	29	13%	856	93	11%
4/20/2014	215	28	13%	884	65	7%
4/27/2014	256	33	13%	1145	102	9%
5/4/2014	253	41	16%	1358	115	8%
5/11/2014	228	23	10%	1140	68	6%
5/18/2014	236	19	8%	986	45	5%
5/25/2014	213	15	7%	935	49	5%
6/1/2014	140	15	11%	660	42	6%
Total	**2,172**	**260**	**12%**	**9,763**	**771**	**8%**

Figure 4A. Number of biological accessions tested for PDCoV and number of positive accessions by week.

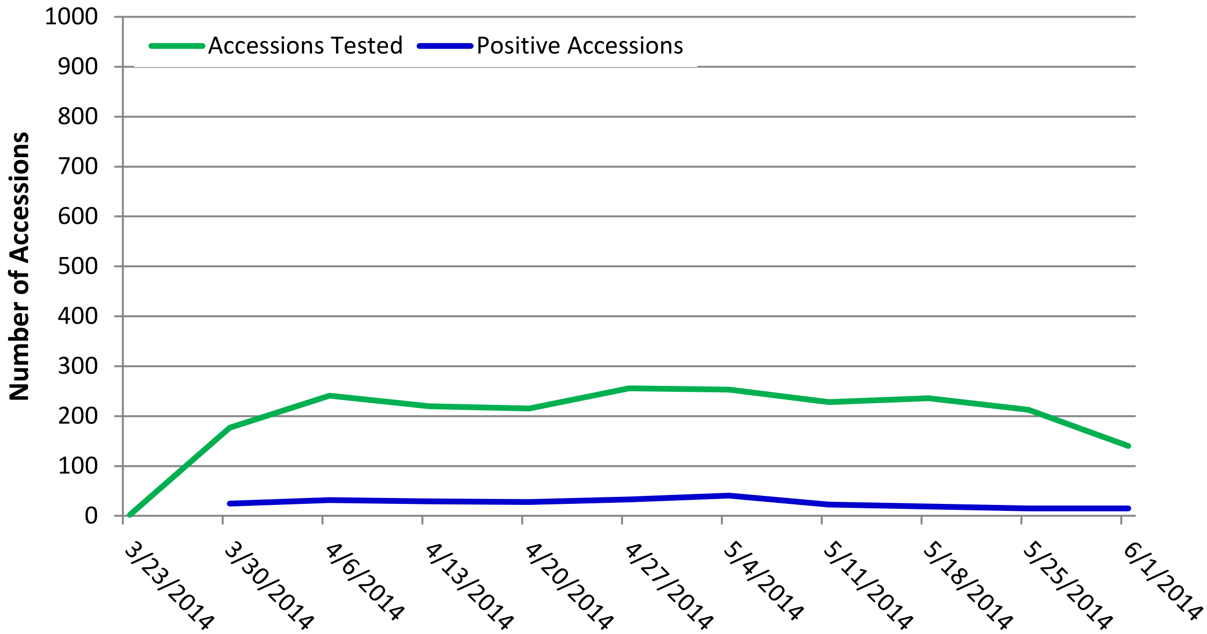
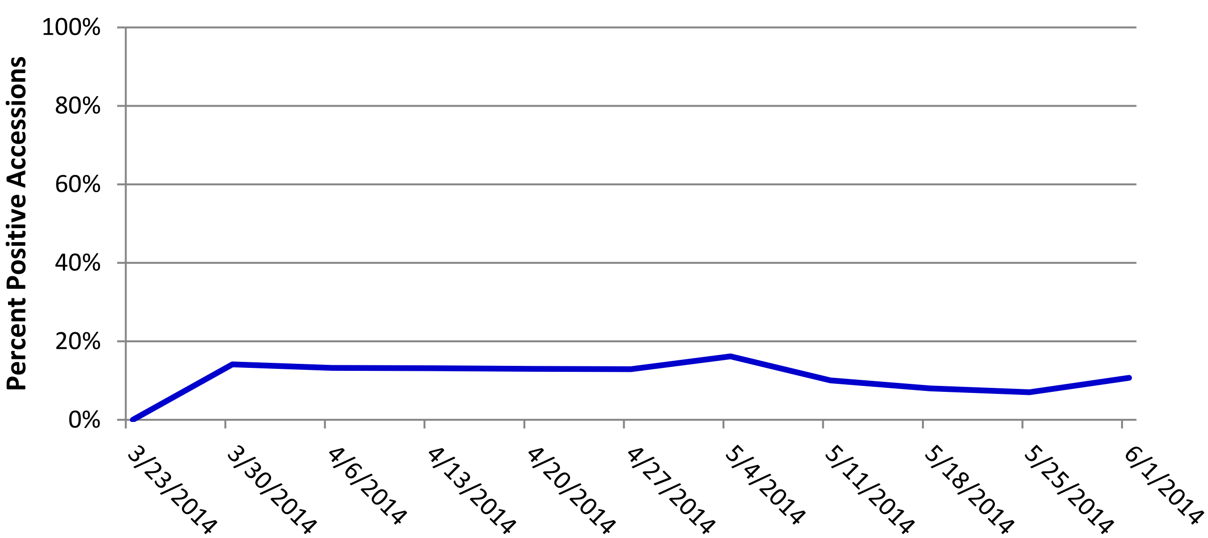


Figure 4B. Percentage of biological accessions that were positive for PDCoV.

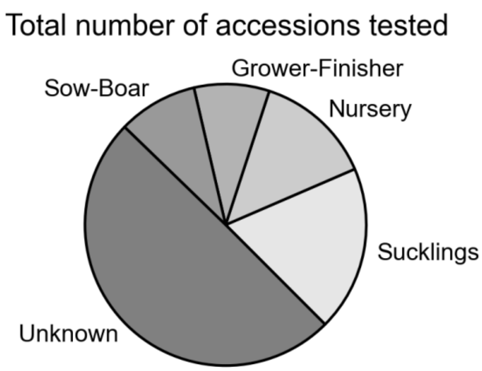


4.2 PDCoV Age Class Trends

Table 8. PDCoV Summary by Age Class. Biological accessions tested for PDCoV and the number positive and percent positive for each farm type / age class by month.

Month	Suckling			Nursery			Grower / Finisher			Sow / Boar			Unk		
	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos	Tested	Pos	% Pos
Mar2014	12	1	8.3%	10	1	10.0%	2	0	0.0%	2	1	50.0%	21	4	19.0%
Apr 2014	195	18	9.2%	141	25	17.7%	75	7	9.3%	95	11	11.6%	477	69	14.5%
May 2014	198	12	6.1%	143	17	11.9%	107	13	12.1%	93	8	8.6%	543	67	12.3%
Jun 2014	24	1	4.2%	10	1	10.0%	11	2	18.2%	16	1	6.3%	81	11	13.6%
Total	**428**	**32**	**7.5%**	**304**	**44**	**14.5%**	**195**	**22**	**11.3%**	**206**	**21**	**10.2%**	**1,121**	**151**	**13.5%**

Figure 5a. Percentage of biological accessions tested for PDCoV and percent positive by farm type/age class.



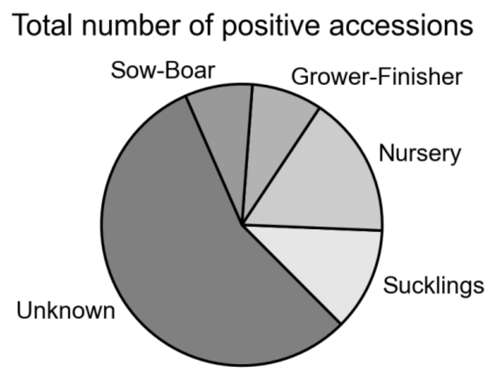
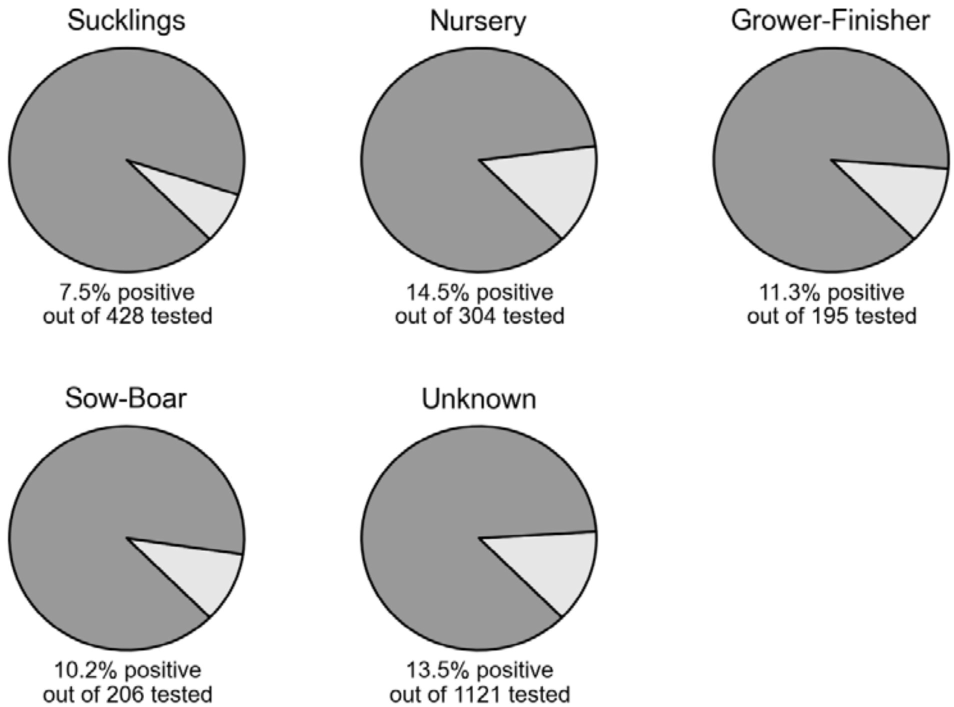


Figure 5B. Percentage of PDCoV positive accessions for each farm type/age class. Numbers of accessions tested was reported starting November 2013; percent positive was calculated from November 1, 2013 through June 4, 2014



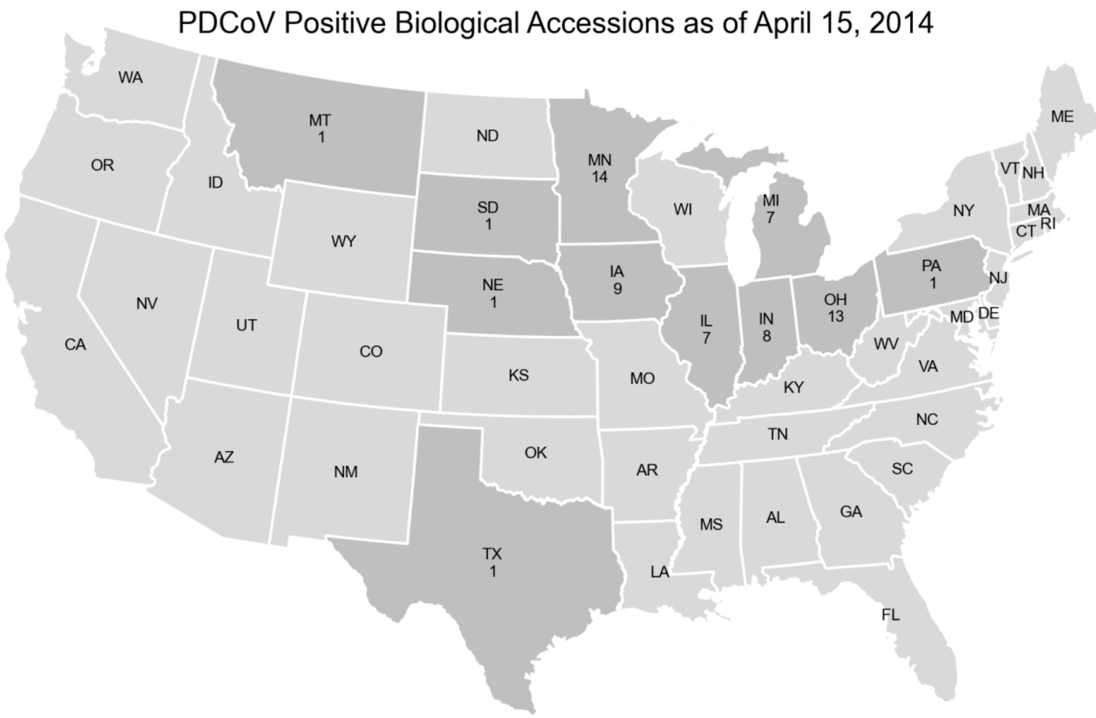
4.3 PDCoV Summary by State

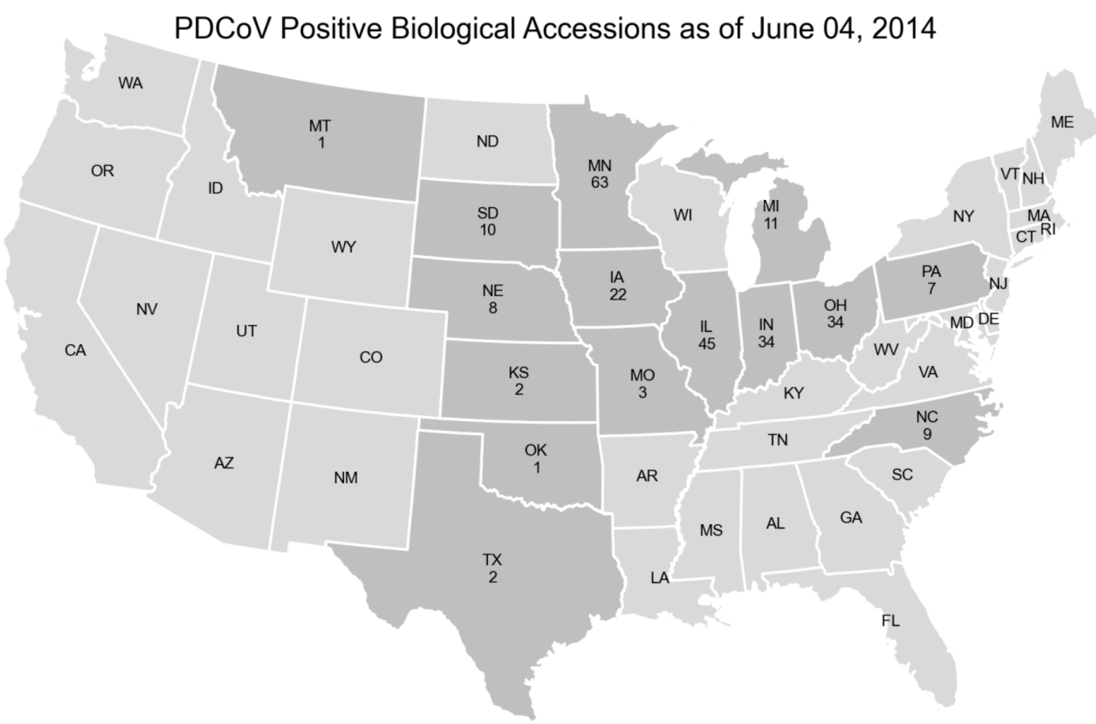
Table 9. Positive PDCoV biological accessions for each State, by week

Testing Week	Total Positive Accessions	IA	IL	IN	KS	MI	MN	MO	MT	NC	NE	OH	OK	PA	SD	TX	UNK
3/30/14	25	3	4	1		4	6		1			6					
4/6/14	32	4	2	7		2	5				1	7		1	1	1	1
4/13/14	29	5	8	4		1	7			1		1		1			1
4/20/14	28	2	3	3			10	1		1	1	3		3		1	
4/27/14	33	3	7	3	1	1	11	1		1	2	2			1		
5/4/14	41	3	10	5		2	6	1		4	2	5		1	1		1
5/11/14	23	2	2	3			8				2	3			2		1
5/18/14	19		2	3		1	5			1		3			3		1
5/25/14	15		5	2			4			1		2		1			
6/1/14	22		3	4	1		5		1			4	1		2		1
Total	**258**	**22**	**45**	**34**	**2**	**11**	**63**	**3**	**1**	**9**	**8**	**34**	**1**	**7**	**10**	**2**	**6**

A single accession may include samples tested over more than one week; total accessions is calculated as the distinct count of accessions tested rather than the sum of accessions tested by week.

Figure 6. Maps showing the number of positive PDCoV accessions from each State at intervals prior to the Federal Order on June 4, 2014.





Section 5. Environmental Testing Summary

Table 10. Environmental accessions tested for PEDV and PDCoV and percent positive by week.

Week	PEDV - Environmental Accessions			PDCoV - Environmental Accessions		
	Tested	PEDV Positive	% Pos	Tested	PDCoV Positive	% Pos
June 16, 2013	17	7	41%			
June 23, 2013	19	13	68%			
June 30, 2013	16	12	75%			
July 7, 2013	13	13	100%			
July 14, 2013	15	7	47%			
July 21, 2013	19	4	21%			
July 28, 2013	11	4	36%			
Aug 4, 2013	7	5	71%			
Aug 11, 2013	11	1	9%			
Aug 18, 2013	20	2	10%			
Aug 25, 2013	12	3	25%			
Sept 1, 2013	8	3	38%			
Sept 8, 2013	21	3	14%			
Sept 15, 2013	41	6	15%			
Sept 22, 2013	47	6	13%			
Sept 29,2013	40	9	23%			
Oct 6, 2013	19	8	42%			
Oct 13, 2013	24	5	21%			
Oct 20, 2013	27	10	37%			
Oct 27, 2013	36	9	25%			
Nov 3, 2013	51	25	49%			
Nov 10, 2013	40	17	43%			
Nov 17, 2013	68	29	43%			
Nov 24, 2013	70	25	36%			
Dec 1, 2013	69	32	46%			
Dec 8, 2013	84	26	31%			
Dec 15, 2013	101	34	34%			
Dec 22, 2013	56	18	32%			
Dec 29, 2013	42	15	36%			
Jan 5, 2014	77	32	42%			
Jan 12, 2014	84	43	51%			
Jan 19, 2014	116	38	33%			
Jan 26, 2014	82	37	45%			
Feb 2, 2014	175	77	44%			
Feb 9, 2014	117	35	30%			
Feb 16, 2014	142	66	46%			
Feb 23, 2014	144	55	38%			
Mar 2, 2014	119	45	38%			
Mar 9, 2014	160	64	40%			
Mar 16, 2014	133	51	38%			
Mar 23, 2014	150	54	36%			

Week	PEDV - Environmental Accessions			PDCoV - Environmental Accessions		
	Tested	PEDV Positive	% Pos	Tested	PDCoV Positive	% Pos
Mar 30, 2014	144	61	42%	22	6	27%
Apr 6, 2014	170	78	46%	38	5	13%
Apr 13, 2014	151	54	36%	39	2	5%
Apr 20, 2014	157	64	41%	36	4	11%
Apr 27, 2014	180	66	37%	31	5	16%
May 4, 2014	115	36	31%	37	9	24%
May 11, 2014	139	42	30%	36	3	8%
May 18, 2014	170	49	29%	36	1	3%
May 25, 2014	122	36	30%	23	1	4%
June 1, 2014	90	11	12%	14	0	0%
Total	**3,941**	**1,445**	**37%**	**312**	**36**	**12%**

Section 6. Appendices

Appendix A. PEDV - Weekly Testing Data for PEDV by State

State		Biological Accessions			Biological Samples		Environmental Samples	
	Week	Tested	Positive	% Pos	Tested	Positive	Tested	Positive
AL	11/24/2013	1		0.00%				
AL	1/12/2014	1		0.00%				
AL	3/16/2014	1		0.00%				
AL	5/25/2014	1		0.00%				
	TOTAL	**4**	**0**	**0.00%**	**0**	**0**	**0**	**0**
AR	11/10/2013	1		0.0%	1			
AR	11/17/2013	2		0.0%	23			
AR	12/8/2013	1		0.0%	2			
AR	12/15/2013	4		0.0%	45			
AR	12/22/2013	2		0.0%	11			
AR	1/5/2014	2		0.0%	9			
AR	1/19/2014	1		0.0%	4			
AR	1/26/2014	2		0.0%	11			
AR	2/23/2014	4		0.0%	16			
AR	3/2/2014	1		0.0%	5			
AR	3/9/2014	5		0.0%	18			
AR	3/16/2014	2		0.0%	12			
AR	3/23/2014	3		0.0%	8			
AR	3/30/2014	1		0.0%	6			
AR	4/6/2014	3		0.0%	4			
AR	4/13/2014	5		0.0%	33			
AR	4/20/2014	3		0.0%	7			
AR	4/27/2014	2		0.0%	7			
	TOTAL	**59**	**0**	**0.00%**	**302**	**0**	**0**	**0**
AZ	1/26/2014	1	1	100.00%	7	7	14	3
AZ	2/2/2014						14	2
AZ	2/16/2014						18	2
AZ	2/23/2014						12	
AZ	3/2/2014	3	1	33.33%	5	1		
AZ	3/9/2014	1		0.00%	2			
AZ	3/16/2014	7	3	42.86%	11	6		
AZ	3/23/2014	2		0.00%	2		25	6
AZ	3/30/2014	1		0.00%	1		20	11
AZ	4/6/2014	1		0.00%	2		20	5
AZ	4/13/2014	2		0.00%	3			
AZ	4/20/2014	1		0.00%	2		40	12
AZ	4/27/2014	1		0.00%	2		37	29
AZ	5/4/2014	1		0.00%	1		7	5

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
AZ	5/11/2014	1		0.00%	1			
AZ	5/18/2014	1		0.00%	1			
AZ	5/25/2014	1		0.00%	1		35	16
AZ	6/1/2014	1		0.00%	1			
	TOTAL	**25**	**5**	**20.00%**	**42**	**14**	**242**	**91**
CA	12/22/2013	1	1	100.00%	2	2		
CA	12/29/2013	1	1	100.00%	1	1		
CA	1/12/2014	1	1	100.00%	1	1		
CA	2/2/2014	1	1	100.00%	4	2		
CA	2/9/2014	2		0.00%	2			
CA	3/2/2014	4	1	25.00%	6	1	4	
CA	3/9/2014	9	2	22.22%	13	4		
CA	3/23/2014	3		0.00%	6			
CA	3/30/2014	3	1	33.33%	14	2		
CA	4/6/2014	3	2	66.67%	50	4		
CA	4/13/2014	3	1	33.33%	4	2		
CA	4/20/2014	2		0.00%	2			
CA	4/27/2014	1		0.00%	2			
CA	5/18/2014	2		0.00%	2			
CA	5/25/2014	1		0.00%	1			
CA	6/1/2014	1		0.00%	2			
	TOTAL	**38**	**11**	**28.95%**	**112**	**19**	**4**	**0**
CO	6/16/2013	4	1	25.00%	23	2	70	4
CO	6/23/2013	4	1	25.00%	15	6	2	1
CO	6/30/2013	3		0.00%	38			
CO	7/7/2013	3	1	33.33%	15	4		
CO	7/14/2013	4	2	50.00%	75	6	16	4
CO	7/21/2013	4	1	25.00%	26	6		
CO	7/28/2013	1	1	100.00%	20	4		
CO	8/4/2013	4	1	25.00%	32	2		
CO	8/11/2013	16	6	37.50%	46	12		
CO	8/18/2013	5	1	20.00%	23	5	16	
CO	8/25/2013	10		0.00%	78			
CO	9/1/2013	9	2	22.22%	101	26		
CO	9/8/2013	10		0.00%	37		28	2
CO	9/15/2013	1		0.00%	3		31	1
CO	9/22/2013	8	1	12.50%	29	1	73	2
CO	9/29/2013	9	2	22.22%	56	5	41	
CO	10/6/2013	4	1	25.00%	14	2		
CO	10/13/2013	6		0.00%	17		8	
CO	10/20/2013	7	1	14.29%	28	1	16	
CO	10/27/2013	4		0.00%	13			
CO	11/3/2013	3		0.00%	11			

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
CO	11/10/2013	4	1	25.00%	12	2		
CO	11/17/2013	4	1	25.00%	25	15		
CO	11/24/2013	7	1	14.29%	36	7	21	4
CO	12/1/2013	7	2	28.57%	27	5		
CO	12/8/2013	3		0.00%	10			
CO	12/15/2013	7	1	14.29%	23	4	31	1
CO	12/22/2013	1		0.00%	3			
CO	12/29/2013	3		0.00%	16			
CO	1/5/2014	8	3	37.50%	42	4	2	
CO	1/12/2014	6	1	16.67%	25	8	36	
CO	1/19/2014	5	2	40.00%	32	15	14	2
CO	1/26/2014	5	2	40.00%	28	17		
CO	2/2/2014	7	2	28.57%	55	30	35	
CO	2/9/2014	4	2	50.00%	61	25		
CO	2/16/2014	8	3	37.50%	56	29	10	1
CO	2/23/2014	5	2	40.00%	43	26	43	
CO	3/2/2014	8	1	12.50%	46	5	4	
CO	3/9/2014	14	7	50.00%	80	38	19	14
CO	3/16/2014	3	2	66.67%	41	24	13	8
CO	3/23/2014	2	2	100.00%	37	26	8	2
CO	3/30/2014	1	1	100.00%	20	20	19	
CO	4/6/2014	9	5	55.56%	106	49	45	37
CO	4/13/2014	6	5	83.33%	37	29	71	12
CO	4/20/2014	6	2	33.33%	40	22	37	25
CO	4/27/2014	14	1	7.14%	77	1	64	31
CO	5/4/2014	3		0.00%	25			
CO	5/11/2014	7	5	71.43%	100	33	123	22
CO	5/18/2014	7	3	42.86%	41	14	34	5
CO	5/25/2014	5	3	60.00%	35	8	87	36
CO	6/1/2014	6	2	33.33%	31	5	39	1
	TOTAL	**294**	**84**	**29%**	**1910**	**543**	**1056**	**215**
CT	3/16/2014	1		0.00%	1			
	TOTAL	**1**	**0**	**0%**	**1**	**0**	**0**	**0**
GA	6/23/2013						5	
GA	12/29/2013	3		0.00%	3			
GA	2/9/2014	1		0.00%	4			
GA	3/2/2014	1		0.00%	1			
GA	3/16/2014	1		0.00%	2			
GA	3/30/2014	2		0.00%	8			
GA	4/6/2014	1		0.00%	4			
GA	4/13/2014	1		0.00%	4			
GA	4/27/2014	1		0.00%	4			
GA	5/4/2014	1		0.00%	4			

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
GA	5/11/2014	1		0.00%	4			
GA	5/18/2014	2		0.00%	7			
	TOTAL	**15**	**0**	**0%**	**45**	**0**	**5**	**0**
HI	3/16/2014	1		0.00%	1			
HI	4/27/2014	1		0.00%	1			
	TOTAL	**2**	**0**	**0%**	**2**	**0**	**0**	**0**
IA	6/16/2013	17	10	58.82%	29	15	14	12
IA	6/23/2013	16	15	93.75%	27	25	2	2
IA	6/30/2013	8	3	37.50%	14	4		
IA	7/7/2013	9	6	66.67%	20	8	1	1
IA	7/14/2013	12	7	58.33%	27	17		
IA	7/21/2013	8	6	75.00%	18	10		
IA	7/28/2013	11	5	45.45%	47	23		
IA	8/4/2013	14	9	64.29%	42	23	12	12
IA	8/11/2013	11	5	45.45%	25	11	3	3
IA	8/18/2013	11	6	54.55%	60	15	1	1
IA	8/25/2013	6	2	33.33%	12	2		
IA	9/1/2013	14	6	42.86%	71	9		
IA	9/8/2013	6		0.00%	25		5	
IA	9/15/2013	15	7	46.67%	31	9	4	4
IA	9/22/2013	13	3	23.08%	29	3	3	
IA	9/29/2013	11	5	45.45%	28	16	4	4
IA	10/6/2013	14	6	42.86%	44	11		
IA	10/13/2013	15	10	66.67%	34	16	6	
IA	10/20/2013	27	20	74.07%	67	46	6	3
IA	10/27/2013	45	32	71.11%	124	83	6	2
IA	11/3/2013	57	38	66.67%	170	111	19	9
IA	11/10/2013	65	51	78.46%	175	129	31	24
IA	11/17/2013	53	47	88.68%	91	82	28	15
IA	11/24/2013	102	25	24.51%	361	49	113	10
IA	12/1/2013	190	65	34.21%	639	141	248	42
IA	12/8/2013	167	65	38.92%	481	126	141	15
IA	12/15/2013	149	96	64.43%	369	203	33	7
IA	12/22/2013	151	61	40.40%	476	115	49	12
IA	12/29/2013	141	49	34.75%	490	118	30	11
IA	1/5/2014	187	81	43.32%	589	189	106	34
IA	1/12/2014	106	88	83.02%	253	188	67	22
IA	1/19/2014	171	70	40.94%	641	173	75	8
IA	1/26/2014	110	87	79.09%	354	221	117	14
IA	2/2/2014	211	93	44.08%	699	247	190	40
IA	2/9/2014	203	91	44.83%	617	200	177	36
IA	2/16/2014	184	90	48.91%	839	223	141	56
IA	2/23/2014	165	79	47.88%	565	156	212	71

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
IA	3/2/2014	152	81	53.29%	511	152	133	27
IA	3/9/2014	178	71	39.89%	690	148	379	75
IA	3/16/2014	129	54	41.86%	510	159	227	44
IA	3/23/2014	132	48	36.36%	658	103	213	55
IA	3/30/2014	135	51	37.78%	652	171	239	81
IA	4/6/2014	136	48	35.29%	639	101	222	42
IA	4/13/2014	118	42	35.59%	577	186	212	23
IA	4/20/2014	132	52	39.39%	840	126	308	88
IA	4/27/2014	118	44	37.29%	543	120	197	50
IA	5/4/2014	122	40	32.79%	610	146	217	21
IA	5/11/2014	129	31	24.03%	762	104	216	22
IA	5/18/2014	109	32	29.36%	628	112	268	34
IA	5/25/2014	106	32	30.19%	755	123	192	31
IA	6/1/2014	55	9	16.36%	337	28	103	1
	TOTAL	**4446**	**1974**	**44%**	**17295**	**4796**	**4970**	**1064**
ID	2/2/2014	1	1	100.00%	1	1		
ID	2/9/2014	3		0.00%	3			
ID	2/23/2014	1	1	100.00%	2	2		
ID	3/16/2014	1	1	100.00%	1	1		
ID	3/23/2014	1		0.00%	1			
ID	3/30/2014	1		0.00%	2			
ID	5/4/2014	2	1	50.00%	24	17		
	TOTAL	**10**	**4**	**40%**	**34**	**21**	**0**	**0**
IL	6/16/2013	4		0.00%	4			
IL	6/23/2013	7		0.00%	24			
IL	6/30/2013	2		0.00%	4			
IL	7/7/2013	9	1	11.11%	23	4		
IL	7/14/2013	5		0.00%	10			
IL	7/21/2013	5		0.00%	8			
IL	7/28/2013	12	1	8.33%	47	6	8	
IL	8/4/2013	5	1	20.00%	8	1		
IL	8/11/2013	9		0.00%	11			
IL	8/18/2013	11		0.00%	17			
IL	8/25/2013	15		0.00%	25			
IL	9/1/2013	3		0.00%	3			
IL	9/8/2013	3		0.00%	9		7	
IL	9/15/2013	6		0.00%	8			
IL	9/22/2013	6		0.00%	7			
IL	9/29/2013	7		0.00%	9			
IL	10/6/2013	4		0.00%	8			
IL	10/13/2013	9		0.00%	12			
IL	10/20/2013	13	2	15.38%	40	17		
IL	10/27/2013	11	4	36.36%	30	23	2	

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
IL	11/3/2013	4	1	25.00%	7	3	30	24
IL	11/10/2013	12		0.00%	15		4	
IL	11/17/2013	10	5	50.00%	20	11	13	
IL	11/24/2013	8		0.00%	32		9	1
IL	12/1/2013	60	10	16.67%	235	39	15	7
IL	12/8/2013	68	8	11.76%	245	27	33	
IL	12/15/2013	44	15	34.09%	146	36	31	6
IL	12/22/2013	32	8	25.00%	161	55	13	1
IL	12/29/2013	58	13	22.41%	352	149	138	1
IL	1/5/2014	82	10	12.20%	377	69	106	20
IL	1/12/2014	61	19	31.15%	256	86	10	3
IL	1/19/2014	77	21	27.27%	330	102	19	
IL	1/26/2014	58	39	67.24%	269	149	12	1
IL	2/2/2014	93	27	29.03%	503	108	12	2
IL	2/9/2014	81	27	33.33%	365	108	25	
IL	2/16/2014	110	35	31.82%	426	190	17	3
IL	2/23/2014	91	41	45.05%	424	193	20	2
IL	3/2/2014	101	32	31.68%	344	104	30	6
IL	3/9/2014	105	43	40.95%	387	153	45	3
IL	3/16/2014	115	44	38.26%	550	211	27	5
IL	3/23/2014	96	43	44.79%	655	271	21	
IL	3/30/2014	145	41	28.28%	934	331	17	4
IL	4/6/2014	114	43	37.72%	845	345	72	15
IL	4/13/2014	115	43	37.39%	881	329	42	15
IL	4/20/2014	96	30	31.25%	826	254	125	31
IL	4/27/2014	122	32	26.23%	1126	256	101	38
IL	5/4/2014	117	25	21.37%	1009	190	45	7
IL	5/11/2014	118	31	26.27%	1225	240	89	18
IL	5/18/2014	117	25	21.37%	1102	248	115	16
IL	5/25/2014	120	26	21.67%	1200	226	93	29
IL	6/1/2014	65	11	16.92%	757	57	114	3
	TOTAL	**2641**	**757**	**29%**	**16311**	**4591**	**1460**	**261**
IN	6/16/2013	1	1	100.00%	1	1		
IN	6/23/2013	2	1	50.00%	3	2		
IN	7/7/2013	2	2	100.00%	3	3		
IN	7/14/2013	5	4	80.00%	11	8		
IN	7/21/2013	1	1	100.00%	4	4		
IN	7/28/2013	1	1	100.00%	1	1		
IN	8/4/2013	3	1	33.33%	9	1		
IN	8/18/2013	1	1	100.00%	3	2		
IN	8/25/2013	2	1	50.00%	3	2		
IN	9/1/2013	1	1	100.00%	1	1		
IN	9/8/2013	1		0.00%	1			

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
IN	9/15/2013	3	1	33.33%	15	1		
IN	9/22/2013	1	1	100.00%	1	1		
IN	10/20/2013	1	1	100.00%	2	2		
IN	10/27/2013	1	1	100.00%	1	1		
IN	11/3/2013	1	1	100.00%	2	2		
IN	11/17/2013	4	3	75.00%	9	6		
IN	11/24/2013	7	4	57.14%	20	5		
IN	12/1/2013	19	9	47.37%	35	19		
IN	12/8/2013	19	6	31.58%	27	9	1	
IN	12/15/2013	15	8	53.33%	34	15	3	1
IN	12/22/2013	12	3	25.00%	35	4		
IN	12/29/2013	9	2	22.22%	77	3		
IN	1/5/2014	14	2	14.29%	48	2		
IN	1/12/2014	12	7	58.33%	25	8	1	1
IN	1/19/2014	19	9	47.37%	41	13		
IN	1/26/2014	34	24	70.59%	69	46		
IN	2/2/2014	33	15	45.45%	71	27	9	5
IN	2/9/2014	46	22	47.83%	149	47		
IN	2/16/2014	53	25	47.17%	142	55	2	
IN	2/23/2014	54	22	40.74%	114	43	22	1
IN	3/2/2014	56	26	46.43%	159	53	4	
IN	3/9/2014	59	22	37.29%	194	49	11	2
IN	3/16/2014	47	21	44.68%	120	36	24	
IN	3/23/2014	37	14	37.84%	125	25	9	5
IN	3/30/2014	54	17	31.48%	188	47	5	
IN	4/6/2014	43	17	39.53%	160	41	9	5
IN	4/13/2014	37	16	43.24%	140	41		
IN	4/20/2014	48	12	25.00%	256	36	21	9
IN	4/27/2014	50	15	30.00%	202	41	3	2
IN	5/4/2014	39	8	20.51%	212	31	7	
IN	5/11/2014	28	10	35.71%	156	43	10	
IN	5/18/2014	37	11	29.73%	239	47	18	9
IN	5/25/2014	34	5	14.71%	226	14	7	2
IN	6/1/2014	25	5	20.00%	121	16	7	6
	TOTAL	**971**	**379**	**39.03%**	**3455**	**854**	**173**	**48**
KS	6/16/2013	13	7	53.85%	93	37	64	4
KS	6/23/2013	3	1	33.33%	12	4	47	17
KS	6/30/2013	5		0.00%	19		32	7
KS	7/7/2013	6	4	66.67%	75	47		
KS	7/14/2013	10	7	70.00%	56	35	33	16
KS	7/21/2013	5	3	60.00%	71	38	13	
KS	7/28/2013	11	7	63.64%	84	50	10	
KS	8/4/2013	10	6	60.00%	36	19		

State		Biological Accessions			Biological Samples		Environmental Samples	
	Week	Tested	Positive	% Pos	Tested	Positive	Tested	Positive
KS	8/11/2013	13	13	100.00%	90	89		
KS	8/18/2013	11	5	45.45%	26	12	48	
KS	8/25/2013	5	3	60.00%	33	14		
KS	9/1/2013	10	8	80.00%	29	20		
KS	9/8/2013	10	7	70.00%	41	25		
KS	9/15/2013	8	3	37.50%	29	16	42	3
KS	9/22/2013	6	5	83.33%	43	20	33	1
KS	9/29/2013	6	2	33.33%	31	7	44	5
KS	10/6/2013	7	6	85.71%	24	22	12	4
KS	10/13/2013	9	4	44.44%	49	27	24	1
KS	10/20/2013	9	9	100.00%	37	35	106	11
KS	10/27/2013	6	3	50.00%	15	6	34	5
KS	11/3/2013	10	6	60.00%	43	27	78	45
KS	11/10/2013	2	1	50.00%	15	14	68	6
KS	11/17/2013	9	5	55.56%	38	19	56	22
KS	11/24/2013	3	1	33.33%	20	1	5	1
KS	12/1/2013	11	4	36.36%	41	8	22	
KS	12/8/2013	12	5	41.67%	34	13	6	3
KS	12/15/2013	12	3	25.00%	60	8	61	18
KS	12/22/2013	9	5	55.56%	56	19	28	15
KS	12/29/2013	8	4	50.00%	38	14	10	2
KS	1/5/2014	22	9	40.91%	93	28	27	14
KS	1/12/2014	13	7	53.85%	37	12	4	
KS	1/19/2014	15	10	66.67%	80	40	36	14
KS	1/26/2014	10	3	30.00%	39	7	10	7
KS	2/2/2014	10	3	30.00%	124	17	14	6
KS	2/9/2014	32	7	21.88%	175	32	33	9
KS	2/16/2014	14	7	50.00%	67	25	112	23
KS	2/23/2014	6	1	16.67%	32	2	100	16
KS	3/2/2014	18	6	33.33%	121	30	44	13
KS	3/9/2014	21	13	61.90%	109	23	40	11
KS	3/16/2014	25	5	20.00%	75	22	102	14
KS	3/23/2014	13	5	38.46%	37	10	91	15
KS	3/30/2014	30	9	30.00%	122	55	20	
KS	4/6/2014	10	7	70.00%	44	36	63	28
KS	4/13/2014	16	6	37.50%	84	16	9	4
KS	4/20/2014	25	13	52.00%	198	81	47	15
KS	4/27/2014	16		0.00%	108		36	7
KS	5/4/2014	11	3	27.27%	58	3	24	4
KS	5/11/2014	13	4	30.77%	62	16	11	3
KS	5/18/2014	12	1	8.33%	45	1	44	14
KS	5/25/2014	11	3	27.27%	88	44	20	4
KS	6/1/2014	12	2	16.67%	91	5	25	

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
	TOTAL	**594**	**261**	**43.94%**	**3127**	**1151**	**1788**	**407**
KY	7/28/2013			0.00%			13	
KY	8/11/2013	1		0.00%	2			
KY	10/6/2013	1	1	100.00%	1	1		
KY	10/13/2013	1	1	100.00%	2	2		
KY	10/20/2013	1	1	100.00%	1	1		
KY	11/24/2013	1	1	100.00%	2	2		
KY	12/8/2013	2		0.00%	8			
KY	12/15/2013	1		0.00%	4			
KY	12/22/2013	4		0.00%	15			
KY	12/29/2013	3		0.00%	4			
KY	1/5/2014	6	1	16.67%	14	8	6	2
KY	1/12/2014	9	3	33.33%	21	9		
KY	1/19/2014	7	1	14.29%	12	1		
KY	1/26/2014	7	1	14.29%	12	2	5	5
KY	2/2/2014	6	1	16.67%	16	6		
KY	2/9/2014	6	1	16.67%	22	2		
KY	2/16/2014	4		0.00%	10			
KY	2/23/2014	3	1	33.33%	5	1		
KY	3/2/2014	3		0.00%	9			
KY	3/9/2014	3		0.00%	7			
KY	3/16/2014	5	1	20.00%	18	6		
KY	3/23/2014	4		0.00%	11			
KY	3/30/2014	4	1	25.00%	21	8		
KY	4/6/2014	4		0.00%	12			
KY	4/13/2014	5		0.00%	37			
KY	4/20/2014	5		0.00%	17			
KY	4/27/2014	3		0.00%	7			
KY	5/4/2014	9		0.00%	51			
KY	5/11/2014	6	1	16.67%	43	1		
KY	5/18/2014	4	1	25.00%	19	1		
KY	5/25/2014	4		0.00%	9		8	
KY	6/1/2014	2	1	50.00%	8	3		
	TOTAL	**124**	**18**	**14.52%**	**420**	**54**	**32**	**7**
MD	10/27/2013	1	1	100.00%	1	1		
MD	12/29/2013	1		0.00%	1			
MD	3/9/2014	1		0.00%	2			
MD	3/23/2014	1		0.00%	3			
MD	3/30/2014	1		0.00%	3			
MD	4/6/2014	1		0.00%	3			
MD	4/20/2014	3		0.00%	6			
MD	6/1/2014	1		0.00%	1			
	TOTAL	**10**	**1**	**10.00%**	**20**	**1**	**0**	**0**

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
ME	10/27/2013	1		0.00%	1			
	TOTAL	**1**	**0**	**0.00%**	**1**	**0**	**0**	**0**
MI	7/14/2013	1	1	100.00%	1	1		
MI	7/28/2013	1		0.00%	5			
MI	9/15/2013	1		0.00%	1			
MI	10/6/2013	1		0.00%	1			
MI	11/3/2013	3	2	66.67%	4	3		
MI	11/10/2013	3	2	66.67%	8	7		
MI	11/17/2013	2		0.00%	5			
MI	11/24/2013	1		0.00%	1			
MI	12/1/2013	7		0.00%	35			
MI	12/8/2013	9	2	22.22%	29	3		
MI	12/15/2013	3		0.00%	15		5	1
MI	12/22/2013	5	2	40.00%	16	8		
MI	12/29/2013	4		0.00%	10			
MI	1/5/2014	6	1	16.67%	8	2		
MI	1/12/2014	10	4	40.00%	23	11		
MI	1/19/2014	10	4	40.00%	39	13		
MI	1/26/2014	6	2	33.33%	10	5		
MI	2/2/2014	14	4	28.57%	41	4	10	3
MI	2/9/2014	21	9	42.86%	62	24	1	
MI	2/16/2014	11	7	63.64%	39	35		
MI	2/23/2014	14	10	71.43%	102	37		
MI	3/2/2014	7	3	42.86%	20	3		
MI	3/9/2014	23	13	56.52%	72	33		
MI	3/16/2014	20	16	80.00%	155	98	16	8
MI	3/23/2014	14	9	64.29%	135	77	3	2
MI	3/30/2014	26	17	65.38%	182	71	33	14
MI	4/6/2014	20	10	50.00%	154	82	21	14
MI	4/13/2014	15	9	60.00%	154	65	50	11
MI	4/20/2014	17	6	35.29%	145	65	11	4
MI	4/27/2014	17	11	64.71%	96	36	28	4
MI	5/4/2014	15	9	60.00%	151	76	30	2
MI	5/11/2014	20	10	50.00%	193	56	22	6
MI	5/18/2014	14	3	21.43%	484	15	24	4
MI	5/25/2014	15	6	40.00%	150	35	22	2
MI	6/1/2014	11	5	45.45%	147	53	8	
	TOTAL	**367**	**177**	**48.23%**	**2693**	**918**	**284**	**75**
MN	6/16/2013	25	8	32.00%	87	20	2	
MN	6/23/2013	47	4	8.51%	173	7		
MN	6/30/2013	28		0.00%	63			
MN	7/7/2013	21	2	9.52%	48	3	14	10
MN	7/14/2013	32	3	9.38%	67	7	14	4

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
MN	7/21/2013	33		0.00%	79		22	8
MN	7/28/2013	42	3	7.14%	144	9	14	7
MN	8/4/2013	63	1	1.59%	162	1	53	24
MN	8/11/2013	62		0.00%	208		27	
MN	8/18/2013	50		0.00%	129		17	1
MN	8/25/2013	37	2	5.41%	116	2	28	
MN	9/1/2013	34	1	2.94%	65	2	8	
MN	9/8/2013	49		0.00%	105		28	
MN	9/15/2013	53	2	3.77%	223	9	4	
MN	9/22/2013	41	1	2.44%	112	5	38	
MN	9/29/2013	45	2	4.44%	82	14	70	46
MN	10/6/2013	55	1	1.82%	151	5	121	55
MN	10/13/2013	46	6	13.04%	124	25	91	23
MN	10/20/2013	44	2	4.55%	129	27	52	8
MN	10/27/2013	59	5	8.47%	127	9	51	
MN	11/3/2013	76	7	9.21%	178	18	47	2
MN	11/10/2013	65	8	12.31%	169	37	112	19
MN	11/17/2013	77	17	22.08%	172	29	109	34
MN	11/24/2013	80	19	23.75%	193	63	87	41
MN	12/1/2013	92	23	25.00%	234	58	200	97
MN	12/8/2013	118	18	15.25%	246	33	92	27
MN	12/15/2013	115	27	23.48%	251	51	103	13
MN	12/22/2013	84	17	20.24%	244	84	16	1
MN	12/29/2013	74	20	27.03%	185	50	21	7
MN	1/5/2014	160	46	28.75%	417	87	103	36
MN	1/12/2014	129	31	24.03%	300	68	341	108
MN	1/19/2014	235	51	21.70%	428	105	134	43
MN	1/26/2014	176	50	28.41%	483	84	212	40
MN	2/2/2014	229	76	33.19%	573	129	126	71
MN	2/9/2014	218	62	28.44%	591	126	110	26
MN	2/16/2014	184	59	32.07%	519	123	109	32
MN	2/23/2014	223	61	27.35%	553	112	133	55
MN	3/2/2014	195	47	24.10%	522	103	137	34
MN	3/9/2014	218	52	23.85%	654	145	77	11
MN	3/16/2014	167	40	23.95%	521	93	98	14
MN	3/23/2014	212	45	21.23%	622	80	180	59
MN	3/30/2014	217	48	22.12%	1107	238	145	48
MN	4/6/2014	200	49	24.50%	740	91	101	18
MN	4/13/2014	218	46	21.10%	725	78	179	27
MN	4/20/2014	187	36	19.25%	672	67	63	5
MN	4/27/2014	188	40	21.28%	698	88	71	12
MN	5/4/2014	190	33	17.37%	640	68	68	17
MN	5/11/2014	195	35	17.95%	627	96	62	1

State		Biological Accessions			Biological Samples		Environmental Samples	
	Week	Tested	Positive	% Pos	Tested	Positive	Tested	Positive
MN	5/18/2014	176	27	15.34%	616	62	112	16
MN	5/25/2014	165	23	13.94%	583	77	37	2
MN	6/1/2014	93	16	17.20%	291	37	42	4
	TOTAL	**5822**	**1172**	**20.13%**	**17148**	**2725**	**4081**	**1106**
MO	6/16/2013	8		0.00%	20			
MO	6/23/2013	4		0.00%	8			
MO	6/30/2013	3		0.00%	4			
MO	7/7/2013	3		0.00%	5			
MO	7/14/2013	7		0.00%	10			
MO	7/21/2013	5		0.00%	8			
MO	7/28/2013	4		0.00%	4		8	
MO	8/4/2013	6		0.00%	11			
MO	8/11/2013	6		0.00%	9			
MO	8/18/2013	5		0.00%	7		10	
MO	8/25/2013	5		0.00%	7			
MO	9/1/2013	5		0.00%	12			
MO	9/8/2013	7		0.00%	12			
MO	9/15/2013	4		0.00%	4			
MO	9/22/2013	4		0.00%	4			
MO	9/29/2013	6		0.00%	10			
MO	10/6/2013	5		0.00%	10		1	1
MO	10/13/2013	5		0.00%	8			
MO	10/20/2013	2		0.00%	2			
MO	10/27/2013	6		0.00%	15			
MO	11/3/2013	4	2	50.00%	5	3	7	7
MO	11/10/2013	5	1	20.00%	8	4		
MO	11/17/2013	6		0.00%	9		6	6
MO	11/24/2013	3		0.00%	16		8	1
MO	12/1/2013	9		0.00%	79		56	6
MO	12/8/2013	17	3	17.65%	60	29		
MO	12/15/2013	13	5	38.46%	97	37	16	14
MO	12/22/2013	5	2	40.00%	74	15	32	
MO	12/29/2013	7	4	57.14%	23	18	10	
MO	1/5/2014	11		0.00%	35		8	8
MO	1/12/2014	11	4	36.36%	27	9	66	37
MO	1/19/2014	16	7	43.75%	59	31		
MO	1/26/2014	13	7	53.85%	52	31	2	
MO	2/2/2014	21	9	42.86%	124	39	17	1
MO	2/9/2014	23	4	17.39%	73	15	18	6
MO	2/16/2014	26	4	15.38%	74	8		
MO	2/23/2014	28	8	28.57%	97	40	8	5
MO	3/2/2014	27	11	40.74%	96	31	9	6
MO	3/9/2014	28	7	25.00%	101	24	9	6

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
MO	3/16/2014	34	17	50.00%	116	62	1	
MO	3/23/2014	34	16	47.06%	165	40	13	4
MO	3/30/2014	20	8	40.00%	191	47	29	11
MO	4/6/2014	30	12	40.00%	203	32	7	
MO	4/13/2014	28	7	25.00%	134	32	4	1
MO	4/20/2014	21	9	42.86%	56	24	68	20
MO	4/27/2014	17	5	29.41%	66	17	73	17
MO	5/4/2014	43	17	39.53%	203	45	43	
MO	5/11/2014	47	14	29.79%	389	67	84	6
MO	5/18/2014	24	5	20.83%	79	17	263	55
MO	5/25/2014	41	8	19.51%	464	41	56	27
MO	6/1/2014	39	9	23.08%	370	70	67	
	TOTAL	**751**	**205**	**27.30%**	**3715**	**828**	**999**	**245**
MS	3/30/2014	1	1	100.00%	1	1		
	TOTAL	**1**	**1**	**100.00%**	**1**	**1**		
MT	7/28/2013	1		0.00%	3			
MT	1/12/2014	1		0.00%	1			
MT	2/2/2014	1	1	100.00%	3	3		
MT	3/2/2014			0.00%			1	
MT	3/9/2014	1		0.00%	26		2	
MT	3/23/2014	1		0.00%	1		3	
MT	3/30/2014	1		0.00%	2		4	
MT	4/6/2014	1		0.00%	1			
MT	4/13/2014	1		0.00%	1			
MT	5/4/2014	1		0.00%	1			
	TOTAL	**9**	**1**	**11.11%**	**39**	**3**	**10**	**0**
NC	6/16/2013	1		0.00%	1			
NC	6/23/2013	7	2	28.57%	29	16		
NC	6/30/2013	3	2	66.67%	19	18		
NC	7/7/2013	8	3	37.50%	23	14		
NC	7/14/2013	5	2	40.00%	37	30	8	1
NC	7/21/2013	13	7	53.85%	69	42	2	
NC	7/28/2013	12	2	16.67%	24	5		
NC	8/4/2013	3	2	66.67%	10	9		
NC	8/11/2013	8	5	62.50%	29	12		
NC	8/18/2013	2	1	50.00%	4	1		
NC	8/25/2013	6	4	66.67%	76	21		
NC	9/1/2013	16	4	25.00%	70	12		
NC	9/8/2013	20	6	30.00%	113	11		
NC	9/15/2013	20	12	60.00%	146	61	1	1
NC	9/22/2013	29	24	82.76%	180	114	5	5
NC	9/29/2013	24	19	79.17%	112	90	6	6
NC	10/6/2013	36	21	58.33%	209	123	2	2

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
NC	10/13/2013	21	21	100.00%	91	91	4	4
NC	10/20/2013	22	22	100.00%	109	109	1	1
NC	10/27/2013	17	17	100.00%	127	127		
NC	11/3/2013	15	14	93.33%	50	48		
NC	11/10/2013	15	15	100.00%	120	120	15	14
NC	11/17/2013	13	12	92.31%	52	51	21	16
NC	11/24/2013	41	19	46.34%	482	164	3	2
NC	12/1/2013	56	8	14.29%	547	47	13	8
NC	12/8/2013	46	12	26.09%	773	171	27	7
NC	12/15/2013	46	19	41.30%	433	123	31	19
NC	12/22/2013	25	5	20.00%	323	66	2	1
NC	12/29/2013	48	17	35.42%	616	150	25	12
NC	1/5/2014	55	15	27.27%	589	159	23	16
NC	1/12/2014	23	20	86.96%	311	147	2	2
NC	1/19/2014	72	19	26.39%	922	238	48	13
NC	1/26/2014	17	15	88.24%	223	137	2	2
NC	2/2/2014	90	24	26.67%	627	127	525	136
NC	2/9/2014	71	23	32.39%	931	226	80	27
NC	2/16/2014	98	24	24.49%	1206	300	59	9
NC	2/23/2014	98	23	23.47%	947	200	65	17
NC	3/2/2014	73	26	35.62%	613	105	86	17
NC	3/9/2014	66	16	24.24%	415	54	214	95
NC	3/16/2014	82	17	20.73%	683	91	187	77
NC	3/23/2014	82	20	24.39%	729	126	134	50
NC	3/30/2014	92	24	26.09%	775	112	124	96
NC	4/6/2014	92	23	25.00%	719	113	374	85
NC	4/13/2014	87	20	22.99%	879	100	342	66
NC	4/20/2014	49	9	18.37%	758	55	340	92
NC	4/27/2014	86	16	18.60%	1129	115	253	91
NC	5/4/2014	88	21	23.86%	1107	228	115	25
NC	5/11/2014	92	18	19.57%	1529	95	191	18
NC	5/18/2014	123	23	18.70%	1645	205	141	35
NC	5/25/2014	89	15	16.85%	1210	124	54	5
NC	6/1/2014	60	13	21.67%	852	100	97	23
	TOTAL	**2263**	**721**	**31.86%**	**23673**	**5003**	**3622**	**1096**
ND	12/8/2013			0.00%			5	
ND	12/15/2013	1		0.00%	3			
ND	1/5/2014	1		0.00%	1		3	
ND	1/19/2014	2		0.00%	10		6	
ND	2/2/2014	3		0.00%	8		4	
ND	2/9/2014			0.00%			11	
ND	2/16/2014	3		0.00%	11		5	
ND	2/23/2014	3	1	33.33%	9	1		

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
ND	3/9/2014	3		0.00%	6			
ND	3/16/2014	5		0.00%	20		15	
ND	3/23/2014	1		0.00%	1		26	
ND	3/30/2014	3		0.00%	16			
ND	4/6/2014			0.00%			9	
ND	4/13/2014	2		0.00%	4		16	
ND	4/20/2014	2		0.00%	2		19	
ND	4/27/2014	2		0.00%	4		15	
ND	5/4/2014			0.00%			16	
ND	5/11/2014	3		0.00%	10		8	
ND	5/18/2014	4		0.00%	7			
ND	5/25/2014	1		0.00%	3		30	1
ND	6/1/2014			0.00%			25	
	TOTAL	**39**	**1**	**2.56%**	**115**	**1**	**213**	**1**
NE	6/23/2013	1		0.00%	1		14	
NE	6/30/2013			0.00%			3	
NE	7/14/2013	1		0.00%	3		4	
NE	7/21/2013	3		0.00%	11		4	
NE	7/28/2013	2		0.00%	3			
NE	8/11/2013	3		0.00%	7		12	
NE	8/18/2013	2		0.00%	2		8	
NE	8/25/2013	2		0.00%	5			
NE	9/15/2013	3		0.00%	31		5	
NE	9/29/2013	1		0.00%	1		4	
NE	10/6/2013	1		0.00%	3		3	
NE	10/13/2013	3		0.00%	5		3	
NE	10/27/2013	3		0.00%	6		29	
NE	11/3/2013	2		0.00%	8		44	
NE	11/10/2013	3		0.00%	5			
NE	11/17/2013	3		0.00%	17		25	2
NE	11/24/2013	6		0.00%	16		39	2
NE	12/1/2013	10	1	10.00%	25	3	26	
NE	12/8/2013	14		0.00%	32		36	
NE	12/15/2013	10	1	10.00%	29	1	10	4
NE	12/22/2013	21	1	4.76%	60	1	17	
NE	12/29/2013	21	2	9.52%	60	2	6	
NE	1/5/2014	29	1	3.45%	72	1	32	1
NE	1/12/2014	25	5	20.00%	78	15	23	
NE	1/19/2014	35	2	5.71%	126	3	49	2
NE	1/26/2014	32	7	21.88%	138	46	4	
NE	2/2/2014	51	4	7.84%	271	7	30	3
NE	2/9/2014	30	9	30.00%	178	68	16	
NE	2/16/2014	39	6	15.38%	207	51	13	

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
NE	2/23/2014	46	12	26.09%	285	75	27	5
NE	3/2/2014	29	2	6.90%	98	7		
NE	3/9/2014	41	5	12.20%	141	13	24	6
NE	3/16/2014	34	6	17.65%	143	28	9	
NE	3/23/2014	35	9	25.71%	189	35	30	3
NE	3/30/2014	33	7	21.21%	186	44	9	
NE	4/6/2014	42	10	23.81%	297	43	46	31
NE	4/13/2014	39	2	5.13%	194	8	42	30
NE	4/20/2014	41	12	29.27%	369	134	9	
NE	4/27/2014	33	7	21.21%	254	93	14	6
NE	5/4/2014	38	6	15.79%	265	28	11	
NE	5/11/2014	30	4	13.33%	253	38	20	2
NE	5/18/2014	23	9	39.13%	222	45	109	42
NE	5/25/2014	40	10	25.00%	378	113	44	
NE	6/1/2014	30	4	13.33%	359	95	6	
	TOTAL	**890**	**144**	**16.18%**	**5033**	**997**	**859**	**139**
NH	4/6/2014	1		0.00%	9			
NH	4/13/2014	1		0.00%	2			
	TOTAL	**2**	**0**	**0.00%**	**11**	**0**	**0**	**0**
NY	6/16/2013	1	1	100.00%	1	1		
NY	9/15/2013	1	1	100.00%	3	3		
NY	12/15/2013	1		0.00%	2		2	
NY	12/22/2013	1		0.00%	1			
NY	2/9/2014	1	1	100.00%	1	1		
NY	3/9/2014	2	1	50.00%	12	2		
NY	3/16/2014	1	1	100.00%	5	5		
NY	5/25/2014	1		0.00%	1			
NY	6/1/2014	1		0.00%	1			
	TOTAL	**10**	**5**	**50.00%**	**27**	**12**	**2**	**0**
OH	6/16/2013	5	3	60.00%	18	12		
OH	6/30/2013	4	2	50.00%	15	13		
OH	7/7/2013	3	2	66.67%	28	24		
OH	7/14/2013	2		0.00%	2			
OH	7/21/2013	3		0.00%	9			
OH	7/28/2013	3	1	33.33%	12	1	5	
OH	8/4/2013	4		0.00%	8			
OH	8/11/2013	2		0.00%	2		2	
OH	8/18/2013	2	2	100.00%	3	3	4	
OH	8/25/2013	2	1	50.00%	5	2	8	2
OH	9/1/2013			#DIV/0!			17	1
OH	9/8/2013	1	1	100.00%	16	16	28	3
OH	9/15/2013	1		0.00%	1		12	
OH	9/22/2013	6		0.00%	6		13	

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
OH	9/29/2013	4		0.00%	16		29	2
OH	10/6/2013	4		0.00%	20		14	1
OH	10/13/2013	6		0.00%	16			
OH	10/20/2013	7		0.00%	31		30	2
OH	10/27/2013	7	1	14.29%	13	1	12	5
OH	11/3/2013	16	5	31.25%	26	9	30	3
OH	11/10/2013	20	4	20.00%	67	12	26	5
OH	11/17/2013	17	4	23.53%	69	5	38	2
OH	11/24/2013	19	9	47.37%	99	56	38	5
OH	12/1/2013	39	5	12.82%	174	9	51	11
OH	12/8/2013	37	3	8.11%	168	6	23	5
OH	12/15/2013	33	3	9.09%	108	11	16	
OH	12/22/2013	24	5	20.83%	81	11	22	
OH	12/29/2013	35	5	14.29%	100	13	15	
OH	1/5/2014	35	7	20.00%	118	14	10	
OH	1/12/2014	34	9	26.47%	148	23	84	12
OH	1/19/2014	55	10	18.18%	215	27	54	17
OH	1/26/2014	51	11	21.57%	203	42	29	10
OH	2/2/2014	57	11	19.30%	402	64	85	13
OH	2/9/2014	62	21	33.87%	241	75	38	8
OH	2/16/2014	61	22	36.07%	208	55	54	18
OH	2/23/2014	48	19	39.58%	160	56	42	2
OH	3/2/2014	50	19	38.00%	232	69	20	1
OH	3/9/2014	42	13	30.95%	146	31	24	1
OH	3/16/2014	63	17	26.98%	190	32	33	4
OH	3/23/2014	56	16	28.57%	213	38	33	3
OH	3/30/2014	54	17	31.48%	203	52	33	1
OH	4/6/2014	66	22	33.33%	314	82	45	10
OH	4/13/2014	34	10	29.41%	153	16	13	
OH	4/20/2014	41	9	21.95%	171	28	29	1
OH	4/27/2014	45	12	26.67%	377	65	19	
OH	5/4/2014	45	7	15.56%	321	47	20	2
OH	5/11/2014	39	7	17.95%	284	31	21	
OH	5/18/2014	47	3	6.38%	263	15	27	
OH	5/25/2014	21	1	4.76%	143	1	26	3
OH	6/1/2014	25		0.00%	136		10	
	TOTAL	**1337**	**319**	**23.86%**	**5954**	**1067**	**1182**	**153**
OK	6/16/2013	24	16	66.67%	248	75	98	4
OK	6/23/2013	24	13	54.17%	241	104	169	72
OK	6/30/2013	12	3	25.00%	133	23	105	22
OK	7/7/2013	17	11	64.71%	195	61	47	10
OK	7/14/2013	14	7	50.00%	95	36	82	16
OK	7/21/2013	14	4	28.57%	122	10	44	16

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
OK	7/28/2013	15	10	66.67%	86	22	18	6
OK	8/4/2013	14	5	35.71%	93	10	4	1
OK	8/11/2013	16	7	43.75%	98	39	16	
OK	8/18/2013	23	14	60.87%	132	34	79	
OK	8/25/2013	18	10	55.56%	101	22	16	2
OK	9/1/2013	14	4	28.57%	109	6	3	2
OK	9/8/2013	21	13	61.90%	101	26	8	
OK	9/15/2013	12	5	41.67%	95	30	92	3
OK	9/22/2013	13	4	30.77%	71	4	8	
OK	9/29/2013	14	6	42.86%	63	18	105	3
OK	10/6/2013	11	6	54.55%	44	31	12	
OK	10/13/2013	19	13	68.42%	82	63	11	1
OK	10/20/2013	13	9	69.23%	70	49	50	6
OK	10/27/2013	20	13	65.00%	101	65	151	7
OK	11/3/2013	13	10	76.92%	88	60	60	12
OK	11/10/2013	9	5	55.56%	36	17	93	6
OK	11/17/2013	16	11	68.75%	107	56	77	46
OK	11/24/2013	36	12	33.33%	255	48	47	2
OK	12/1/2013	30	6	20.00%	240	30	12	5
OK	12/8/2013	32	7	21.88%	159	25	29	5
OK	12/15/2013	12	5	41.67%	87	30	91	9
OK	12/22/2013	12	3	25.00%	90	9	29	4
OK	12/29/2013	3		0.00%	14		9	1
OK	1/5/2014	16	4	25.00%	145	8	38	3
OK	1/12/2014	17	8	47.06%	83	18	69	15
OK	1/19/2014	20	2	10.00%	76	16	51	13
OK	1/26/2014	16	4	25.00%	79	24	56	25
OK	2/2/2014	17	4	23.53%	239	77	147	27
OK	2/9/2014	23	6	26.09%	224	68	60	6
OK	2/16/2014	32	9	28.13%	248	55	88	38
OK	2/23/2014	24	5	20.83%	481	45	73	10
OK	3/2/2014	21	1	4.76%	204	15	122	34
OK	3/9/2014	28	9	32.14%	156	50	82	11
OK	3/16/2014	31	9	29.03%	166	49	65	8
OK	3/23/2014	17	5	29.41%	104	12	111	2
OK	3/30/2014	27	5	18.52%	237	12	133	17
OK	4/6/2014	31	10	32.26%	182	43	249	140
OK	4/13/2014	33	4	12.12%	248	20	36	2
OK	4/20/2014	31	9	29.03%	243	20	73	3
OK	4/27/2014	36	6	16.67%	254	8	135	19
OK	5/4/2014	45	10	22.22%	405	74	7	
OK	5/11/2014	47	8	17.02%	381	94	208	78
OK	5/18/2014	35	4	11.43%	325	9	101	1

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
OK	5/25/2014	27	4	14.81%	306	73	52	6
OK	6/1/2014	36	4	11.11%	305	12	99	5
	TOTAL	**1101**	**362**	**32.88%**	**8447**	**1805**	**3620**	**724**
OR	3/30/2014	1		0.00%	1			
OR	4/20/2014	1		0.00%	1			
OR	4/27/2014	3		0.00%	8			
OR	5/18/2014	1		0.00%	6			
	TOTAL	**6**	**0**	**0.00%**	**16**	**0**	**0**	**0**
PA	8/25/2013	3	3	100.00%	6	6		
PA	9/1/2013	5	5	100.00%	9	9		
PA	9/15/2013	1	1	100.00%	1	1		
PA	9/29/2013	1	1	100.00%	2	2		
PA	10/6/2013	1	1	100.00%	1	1	1	1
PA	10/13/2013	2	2	100.00%	28	28		
PA	10/20/2013	1	1	100.00%	1	1		
PA	10/27/2013	2	2	100.00%	2	2	2	2
PA	11/3/2013	1	1	100.00%	1	1		
PA	11/10/2013	1	1	100.00%	21	21		
PA	11/17/2013	1	1	100.00%	5	5		
PA	11/24/2013	1		0.00%	1			
PA	12/1/2013	9	3	33.33%	24	3		
PA	12/8/2013	7	1	14.29%	18	1	23	5
PA	12/15/2013	13	1	7.69%	41	4		
PA	12/22/2013	1		0.00%	2			
PA	12/29/2013	2		0.00%	13			
PA	1/5/2014	11		0.00%	17			
PA	1/12/2014	2	2	100.00%	9	6	4	2
PA	1/19/2014	15	2	13.33%	117	2	1	
PA	1/26/2014	4	4	100.00%	11	10		
PA	2/2/2014	13	4	30.77%	32	7		
PA	2/9/2014	13	3	23.08%	16	6		
PA	2/16/2014	17	7	41.18%	27	9		
PA	2/23/2014	34	12	35.29%	79	14	4	
PA	3/2/2014	14	3	21.43%	47	10		
PA	3/9/2014	19	3	15.79%	68	3		
PA	3/16/2014	10	5	50.00%	14	7		
PA	3/23/2014	8	1	12.50%	27	1	30	30
PA	3/30/2014	9	1	11.11%	24	2		
PA	4/6/2014	10	2	20.00%	26	2	29	13
PA	4/13/2014	8	2	25.00%	75	2	1	
PA	4/20/2014	13	3	23.08%	17	3	50	1
PA	4/27/2014	1		0.00%	2			
PA	5/4/2014	11	1	9.09%	64	1		

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
PA	5/11/2014	24	3	12.50%	141	14	1	
PA	5/18/2014	8	1	12.50%	52	1	52	1
PA	5/25/2014	12	2	16.67%	36	4	1	
PA	6/1/2014	3		0.00%	3		60	
	TOTAL	**311**	**85**	**27.33%**	**1080**	**189**	**259**	**55**
SC	8/11/2013	1		0.00%	1			
SC	1/5/2014	2	2	100.00%	39	3		
SC	1/12/2014	1		0.00%	10			
SC	1/19/2014	2		0.00%	10			
SC	2/2/2014	1		0.00%	2		6	
SC	2/9/2014	1		0.00%	3			
SC	2/16/2014	5		0.00%	22		1	1
SC	2/23/2014	1		0.00%	3			
SC	3/2/2014			0.00%			4	3
SC	4/6/2014	1		0.00%	2			
SC	4/13/2014	3		0.00%	10			
SC	4/27/2014	3		0.00%	7			
	TOTAL	**21**	**2**	**9.52%**	**109**	**3**	**11**	**4**
SD	6/16/2013	2		0.00%	2		6	
SD	6/23/2013	5		0.00%	19			
SD	6/30/2013	3		0.00%	4			
SD	7/7/2013	3		0.00%	3			
SD	7/14/2013	2		0.00%	3			
SD	7/21/2013	1		0.00%	5			
SD	7/28/2013	7		0.00%	13			
SD	8/4/2013	6		0.00%	20		9	1
SD	8/11/2013	1		0.00%	3		1	
SD	8/18/2013	5		0.00%	9			
SD	8/25/2013	7		0.00%	11			
SD	9/1/2013	4		0.00%	5			
SD	9/8/2013	6		0.00%	11			
SD	9/15/2013	10		0.00%	24			
SD	9/22/2013	11		0.00%	27			
SD	9/29/2013	5		0.00%	12			
SD	10/6/2013	6		0.00%	12			
SD	10/13/2013	9		0.00%	23			
SD	10/20/2013	5		0.00%	10			
SD	10/27/2013	13		0.00%	32		4	
SD	11/3/2013	9		0.00%	41			
SD	11/10/2013	13		0.00%	31			
SD	11/17/2013	12		0.00%	29		5	
SD	11/24/2013	11	1	9.09%	30	1		
SD	12/1/2013	9		0.00%	29		5	1

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
SD	12/8/2013	11		0.00%	36			
SD	12/15/2013	16		0.00%	43		1	
SD	12/22/2013	11		0.00%	17		5	
SD	12/29/2013	11	2	18.18%	35	5		
SD	1/5/2014	26	1	3.85%	104	2	10	2
SD	1/12/2014	24	2	8.33%	64	2	7	4
SD	1/19/2014	25	3	12.00%	67	9	23	2
SD	1/26/2014	26	3	11.54%	55	4	17	1
SD	2/2/2014	30	3	10.00%	92	4	21	3
SD	2/9/2014	28	4	14.29%	52	5		
SD	2/16/2014	30	5	16.67%	64	6	6	
SD	2/23/2014	32	3	9.38%	99	10	1	1
SD	3/2/2014	42	6	14.29%	155	18	30	6
SD	3/9/2014	37	7	18.92%	150	16	11	7
SD	3/16/2014	35	6	17.14%	154	20	1	1
SD	3/23/2014	31	5	16.13%	91	7		
SD	3/30/2014	41	5	12.20%	149	21		
SD	4/6/2014	33	2	6.06%	152	4	8	3
SD	4/13/2014	35	4	11.43%	205	5	10	1
SD	4/20/2014	37	3	8.11%	194	12		
SD	4/27/2014	40	5	12.50%	183	11	8	
SD	5/4/2014	39	5	12.82%	164	8		
SD	5/11/2014	38	4	10.53%	149	8	4	4
SD	5/18/2014	42	6	14.29%	167	20	6	1
SD	5/25/2014	43	4	9.30%	220	10	3	
SD	6/1/2014	18	3	16.67%	56	8		
	TOTAL	**946**	**92**	**9.73%**	**3325**	**216**	**202**	**38**
TN	6/16/2013	1		0.00%	2			
TN	7/7/2013	1		0.00%	4			
TN	7/21/2013	1	1	100.00%	5	5		
TN	8/4/2013			0.00%			10	
TN	8/11/2013			0.00%			15	
TN	8/18/2013			0.00%			7	
TN	8/25/2013	1		0.00%	3		10	
TN	9/8/2013	1	1	100.00%	1	1		
TN	9/29/2013			0.00%			13	
TN	10/20/2013	1		0.00%	4			
TN	10/27/2013	1	1	100.00%	5	5		
TN	11/3/2013	1	1	100.00%	2	2		
TN	11/17/2013	1	1	100.00%	4	4	3	3
TN	11/24/2013	2		0.00%	10		25	
TN	12/1/2013	1		0.00%	24			
TN	12/22/2013	2		0.00%	13		5	5

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
TN	12/29/2013	3	1	33.33%	17	7		
TN	1/5/2014	4		0.00%	18			
TN	1/12/2014	6		0.00%	41		10	10
TN	1/19/2014	3	1	33.33%	15	8		
TN	1/26/2014			0.00%			22	3
TN	2/2/2014			0.00%			15	
TN	2/9/2014	1		0.00%	2		2	
TN	2/16/2014	4	1	25.00%	19	3		
TN	2/23/2014	1	1	100.00%	3	3		
TN	3/2/2014	1		0.00%	3			
TN	3/9/2014	6		0.00%	53		3	3
TN	3/16/2014	1		0.00%	1		31	4
TN	3/23/2014	3		0.00%	9			
TN	3/30/2014	1		0.00%	3			
TN	4/6/2014	5	2	40.00%	47	7		
TN	4/13/2014	1		0.00%	3		2	1
TN	4/20/2014	3	1	33.33%	8	1		
TN	4/27/2014	2	1	50.00%	8	3		
TN	5/4/2014	1		0.00%	8			
TN	5/11/2014	1		0.00%	12		7	
TN	5/25/2014	3		0.00%	9			
	TOTAL	**64**	**13**	**20.31%**	**356**	**49**	**180**	**29**
TX	6/16/2013	2		0.00%	8			
TX	6/23/2013	4		0.00%	14			
TX	7/7/2013	1		0.00%	4			
TX	7/14/2013	4		0.00%	12			
TX	7/21/2013	2	1	50.00%	6	2		
TX	7/28/2013	1		0.00%	1		2	
TX	8/4/2013	1		0.00%	6			
TX	8/11/2013	3		0.00%	10			
TX	8/25/2013	3		0.00%	7			
TX	9/29/2013	3	3	100.00%	11	10		
TX	10/6/2013	3		0.00%	4			
TX	10/13/2013	1		0.00%	5			
TX	10/20/2013	1		0.00%	1			
TX	10/27/2013	3	3	100.00%	9	7		
TX	11/3/2013	3	1	33.33%	11	3	17	
TX	11/10/2013	3	3	100.00%	13	10		
TX	11/17/2013	9	6	66.67%	66	21	17	
TX	11/24/2013	7	3	42.86%	35	13		
TX	12/1/2013	2	2	100.00%	6	4		
TX	12/8/2013	2	1	50.00%	8	4		
TX	12/15/2013	1		0.00%	5			

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
TX	12/22/2013	2	2	100.00%	10	10		
TX	12/29/2013	1	1	100.00%	6	6	12	11
TX	1/5/2014	6	4	66.67%	20	10		
TX	1/12/2014	3	3	100.00%	18	9	13	12
TX	1/19/2014	2	1	50.00%	11	9		
TX	1/26/2014	2	2	100.00%	12	4	10	
TX	2/2/2014	3	1	33.33%	15	6	10	
TX	2/9/2014	3	2	66.67%	11	8		
TX	2/16/2014	4	2	50.00%	20	8		
TX	2/23/2014	5	2	40.00%	23	10		
TX	3/2/2014	6	5	83.33%	27	20		
TX	3/9/2014	10	6	60.00%	23	10		
TX	3/16/2014	4	2	50.00%	30	3		
TX	3/23/2014	5	1	20.00%	15	3		
TX	3/30/2014	4	2	50.00%	12	4		
TX	4/6/2014	5	3	60.00%	13	9		
TX	4/13/2014	5	3	60.00%	35	10		
TX	4/20/2014	10	5	50.00%	53	13	25	14
TX	4/27/2014	8	2	25.00%	30	3	20	8
TX	5/4/2014	14	4	28.57%	232	11	33	18
TX	5/11/2014	6	3	50.00%	28	8	16	7
TX	5/18/2014	1		0.00%	6		10	
TX	5/25/2014	3	1	33.33%	15	3	59	22
TX	6/1/2014	1		0.00%	2			
	TOTAL	**172**	**80**	**46.51%**	**909**	**251**	**244**	**92**
UT	12/8/2013	1		0.00%	3			
UT	3/16/2014	1		0.00%	1			
UT	3/23/2014			0.00%			10	
UT	4/6/2014	1		0.00%	1			
UT	4/20/2014	2		0.00%	3		8	
	TOTAL	**5**	**0**	**0.00%**	**8**	**0**	**18**	**0**
VA	9/1/2013			0.00%			2	2
VA	10/27/2013	1		0.00%	1			
VA	12/1/2013	2		0.00%	22			
VA	12/8/2013	4		0.00%	8			
VA	1/12/2014	1		0.00%	2			
VA	2/2/2014			0.00%			1	
VA	2/9/2014	1		0.00%	1			
VA	3/23/2014	1		0.00%	1			
VA	4/6/2014	1		0.00%	1			
VA	4/13/2014	1	1	100.00%	1	1		
VA	4/27/2014	1		0.00%	2			
VA	5/11/2014	2		0.00%	3		8	

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
VA	5/25/2014			0.00%			2	
VA	6/1/2014	1		0.00%	40			
	TOTAL	**16**	**1**	**6.25%**	**82**	**1**	**13**	**2**
VT	3/23/2014	1	1	100.00%	3	3		
	TOTAL	**1**	**1**	**100.00%**	**3**	**3**		
WI	7/7/2013	1		0.00%	2			
WI	7/28/2013	1		0.00%	1			
WI	8/4/2013	1	1	100.00%	3	3		
WI	9/8/2013	2		0.00%	2			
WI	10/27/2013	2	1	50.00%	2	1		
WI	11/3/2013	1	1	100.00%	2	2		
WI	11/24/2013	1	1	100.00%	3	3		
WI	12/1/2013	2		0.00%	3			
WI	12/15/2013	2		0.00%	6		3	
WI	12/22/2013	2		0.00%	4			
WI	12/29/2013	2		0.00%	6		1	
WI	1/5/2014	5		0.00%	13			
WI	1/12/2014	1	1	100.00%	1	1	1	
WI	1/19/2014	9		0.00%	39			
WI	1/26/2014	2	1	50.00%	3	1	1	
WI	2/2/2014	5	1	20.00%	15	2	1	
WI	2/9/2014	3	1	33.33%	8	1	1	
WI	2/16/2014	6	2	33.33%	14	5	8	1
WI	2/23/2014	4		0.00%	4		1	
WI	3/2/2014	4	1	25.00%	4	1		
WI	3/9/2014	4		0.00%	8		8	
WI	3/16/2014	2		0.00%	2		3	
WI	3/23/2014	7	2	28.57%	15	5		
WI	3/30/2014	3		0.00%	4			
WI	4/6/2014	8		0.00%	12			
WI	4/13/2014	5	1	20.00%	12	3		
WI	4/20/2014	6		0.00%	13		3	
WI	4/27/2014	5		0.00%	56			
WI	5/4/2014	2		0.00%	2			
WI	5/11/2014	4	1	25.00%	9	1		
WI	5/18/2014	10	3	30.00%	47	6	9	1
WI	5/25/2014	5		0.00%	11			
WI	6/1/2014	2		0.00%	5			
	TOTAL	**119**	**18**	**15.13%**	**331**	**35**	**40**	**2**
WV	4/20/2014	1		0.00%	1			
WV	4/27/2014	2		0.00%	3			
	TOTAL	**3**	**3**	**100.00%**	**4**	**0**	**0**	**0**
WY	12/29/2013	1	1	100.00%	10	10		

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
WY	1/5/2014	1		0.00%	1			
WY	1/19/2014	1		0.00%	1			
WY	1/26/2014	1	1	100.00%	6	6	29	10
WY	2/2/2014	1	1	100.00%	10	1		
WY	2/9/2014	2	2	100.00%	15	10		
WY	2/16/2014	1	1	100.00%	10	10		
WY	2/23/2014	2	2	100.00%	25	15		
WY	3/2/2014			0.00%			10	5
WY	3/9/2014			0.00%			10	
WY	3/16/2014			0.00%			28	9
WY	3/23/2014			0.00%			25	4
WY	3/30/2014	1		0.00%	1		25	4
WY	4/6/2014			0.00%			26	5
WY	4/13/2014			0.00%			25	4
WY	4/20/2014			0.00%			25	4
WY	4/27/2014	2	1	50.00%	26	1		
WY	5/4/2014	2		0.00%	2			
WY	5/18/2014	1		0.00%	1		3	
WY	5/25/2014			0.00%			25	
	TOTAL	**16**	**9**	**56.25%**	**108**	**53**	**231**	**45**

Appendix B. Weekly Testing Data for PDCoV by State

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
AR	4/13/2014	3		0.00%	27			
AR	4/20/2014	2		0.00%	3			
AR	4/27/2014	1		0.00%	1			
AR	5/4/2014	1		0.00%	1			
	Total	**7**	**0**	**0.00%**	**32**	**0**	**0**	**0**
AZ	4/13/2014	1		0.00%	1			
	Total	**1**	**0**	**0.00%**	**1**	**0**	**0**	**0**
CA	5/18/2014	1		0.00%	1			
	Total	**1**	**0**	**0.00%**	**0**	**0**	**0**	**0**
CO	4/6/2014	1		0.00%	5			
CO	4/13/2014						23	
CO	4/20/2014	3		0.00%	8			
CO	4/27/2014	10		0.00%	48			
CO	5/4/2014	1		0.00%	6			
CO	5/11/2014	1		0.00%	4		5	
CO	5/18/2014	3		0.00%	18		9	

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
CO	5/25/2014	1		0.00%	3			
	Total	**20**	**0**	**0.00%**	**92**	**0**	**37**	**0**
GA	5/18/2014	1		0.00%	3			
	Total	**1**	**0**	**0.00%**	**3**	**0**	**0**	**0**
IA	3/30/2014	22	3	13.64%	65	6	18	4
IA	4/6/2014	23	4	17.39%	91	8	26	
IA	4/13/2014	25	5	20.00%	69	10	16	3
IA	4/20/2014	31	2	6.45%	105	3	24	3
IA	4/27/2014	29	3	10.34%	68	5	2	
IA	5/4/2014	20	3	15.00%	87	7	1	
IA	5/11/2014	22	2	9.09%	50	9	8	
IA	5/18/2014	25		0.00%	75		5	
IA	5/25/2014	23		0.00%	85			
IA	6/1/2014	10		0.00%	25			
	Total	**232**	**22**	**9.48%**	**726**	**48**	**100**	**10**
ID	5/4/2014	1		0.00%	7			
	Total	**1**	**0**	**0.00%**	**7**	**0**	**0**	**0**
IL	3/30/2014	24	4	16.67%	190	36	6	1
IL	4/6/2014	35	2	5.71%	224	6	34	
IL	4/13/2014	37	8	21.62%	186	35	5	3
IL	4/20/2014	24	3	12.50%	119	7	34	
IL	4/27/2014	44	7	15.91%	269	15	61	
IL	5/4/2014	29	10	34.48%	199	27	18	5
IL	5/11/2014	23	2	8.70%	254	9	29	1
IL	5/18/2014	19	2	10.53%	151	6	13	
IL	5/25/2014	36	5	13.89%	300	10	28	
IL	6/1/2014	20	2	10.00%	210	6		
	Total	**291**	**45**	**15.46%**	**2102**	**157**	**228**	**10**
IN	3/23/2014	1		0.00%	1			
IN	3/30/2014	14	1	7.14%	42	2	1	
IN	4/6/2014	20	7	35.00%	87	28	5	
IN	4/13/2014	18	4	22.22%	67	16		
IN	4/20/2014	12	3	25.00%	51	15	9	1
IN	4/27/2014	15	3	20.00%	63	12	2	
IN	5/4/2014	17	5	29.41%	65	18		
IN	5/11/2014	11	3	27.27%	55	15	5	5
IN	5/18/2014	14	3	21.43%	74	11		
IN	5/25/2014	12	2	16.67%	77	13	6	
IN	6/1/2014	9	4	44.44%	62	15		
	Total	**143**	**35**	**24.48%**	**644**	**145**	**28**	**6**
KS	3/30/2014	1		0.00%	4		3	
KS	4/6/2014	7		0.00%	22		27	
KS	4/13/2014	2		0.00%	6		8	

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
KS	4/20/2014	4		0.00%	18		12	
KS	4/27/2014	2	1	50.00%	2	1	2	
KS	5/4/2014	1		0.00%	2		4	
KS	5/11/2014	5		0.00%	17		3	
KS	5/18/2014	1		0.00%	1		2	
KS	5/25/2014	1		0.00%	1		3	
KS	6/1/2014	3	1	33.33%	11	5	12	
	Total	**27**	**2**	**7.41%**	**84**	**6**	**76**	**0**
KY	3/30/2014	1		0.00%	10			
KY	4/20/2014	2		0.00%	8			
KY	5/4/2014	5		0.00%	14			
KY	5/11/2014	1		0.00%	2			
KY	5/18/2014	1		0.00%	2			
KY	5/25/2014	1		0.00%	2			
KY	6/1/2014	2		0.00%	8			
	Total	**13**	**0**	**0.00%**	**46**	**0**	**0**	**0**
MD	3/30/2014	1		0.00%	3			
MD	4/6/2014	1		0.00%	3			
MD	4/27/2014	1		0.00%	1			
	Total	**3**	**0**	**0.00%**	**7**	**0**	**0**	**0**
MI	3/30/2014	5	4	80.00%	14	12		
MI	4/6/2014	7	2	28.57%	24	7	4	
MI	4/13/2014	6	1	16.67%	44	1	14	
MI	4/20/2014	1		0.00%	6			
MI	4/27/2014	6	1	16.67%	21	5	9	1
MI	5/4/2014	3	2	66.67%	8	2	14	2
MI	5/11/2014	11		0.00%	73			
MI	5/18/2014	4	1	25.00%	12	3	2	
MI	5/25/2014	5		0.00%	17			
MI	6/1/2014	4		0.00%	42		2	
	Total	**52**	**11**	**21.15%**	**261**	**30**	**45**	**3**
MN	3/30/2014	44	6	13.64%	199	13	10	1
MN	4/6/2014	59	5	8.47%	154	18	9	
MN	4/13/2014	56	7	12.50%	129	12	37	
MN	4/20/2014	48	10	20.83%	92	13	38	1
MN	4/27/2014	63	11	17.46%	139	24	23	4
MN	5/4/2014	61	6	9.84%	138	8	29	2
MN	5/11/2014	54	8	14.81%	138	17	17	
MN	5/18/2014	65	5	7.69%	139	14	14	
MN	5/25/2014	58	4	6.90%	131	12		
MN	6/1/2014	32	2	6.25%	71	3	6	
	Total	**540**	**64**	**11.85%**	**1330**	**134**	**183**	**8**
MO	3/30/2014	9		0.00%	50			

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
MO	4/6/2014	5		0.00%	17		6	
MO	4/13/2014	10		0.00%	64			
MO	4/20/2014	6	1	16.67%	16	1	55	
MO	4/27/2014	7	1	14.29%	20	1	11	2
MO	5/4/2014	10	1	10.00%	37	6	30	
MO	5/11/2014	11		0.00%	75		42	
MO	5/18/2014	10		0.00%	36		30	
MO	5/25/2014	3		0.00%	12			
MO	6/1/2014	4		0.00%	15			
	Total	**75**	**3**	**4.00%**	**342**	**8**	**174**	**2**
MT	3/30/2014	2	1	50.00%	3	2	4	4
MT	4/6/2014	1		0.00%	1			
	Total	**3**	**1**	**33.33%**	**4**	**2**	**4**	**4**
NC	3/30/2014	6		0.00%	21			
NC	4/6/2014	7		0.00%	33			
NC	4/13/2014	11	1	9.09%	28	2	13	
NC	4/20/2014	6	1	16.67%	21	9	28	
NC	4/27/2014	17	1	5.88%	176	11	41	5
NC	5/4/2014	12	4	33.33%	114	17	58	6
NC	5/11/2014	11		0.00%	67		30	1
NC	5/18/2014	12	1	8.33%	85	2	48	1
NC	5/25/2014	12	1	8.33%	50	10	34	1
NC	6/1/2014	6		0.00%	20		2	
	Total	**100**	**9**	**9.00%**	**615**	**51**	**254**	**14**
ND	3/30/2014	1		0.00%	1			
ND	4/20/2014	2		0.00%	2			
ND	4/27/2014	1		0.00%	5			
ND	5/18/2014	3		0.00%	10		4	
ND	6/1/2014			0.00%			25	
	Total	**7**	**0**	**0.00%**	**18**	**0**	**29**	**0**
NE	3/30/2014	4		0.00%	9			
NE	4/6/2014	4	1	25.00%	9	1	30	
NE	4/13/2014	5		0.00%	32		23	
NE	4/20/2014	10	1	10.00%	179	3		
NE	4/27/2014	7	2	28.57%	90	19	8	
NE	5/4/2014	12	2	16.67%	68	5	5	
NE	5/11/2014	10	2	20.00%	82	8	10	
NE	5/18/2014	6		0.00%	32		10	
NE	5/25/2014	8		0.00%	25		6	
NE	6/1/2014	1		0.00%	7		6	
	Total	**67**	**8**	**11.94%**	**533**	**36**	**98**	**0**
NY	5/25/2014	1		0.00%	1			
	Total	**1**	**0**	**0.00%**	**1**	**0**	**0**	**0**

State	Week	Biological Accessions Tested	Biological Accessions Positive	Biological Accessions % Pos	Biological Samples Tested	Biological Samples Positive	Environmental Samples Tested	Environmental Samples Positive
OH	3/23/2014	1		0.00%	4			
OH	3/30/2014	28	6	21.43%	97	21	25	12
OH	4/6/2014	42	7	16.67%	197	23	27	10
OH	4/13/2014	15	1	6.67%	43	1	13	
OH	4/20/2014	22	3	13.64%	64	7	17	
OH	4/27/2014	17	2	11.76%	89	5	17	
OH	5/4/2014	31	5	16.13%	309	20	12	
OH	5/11/2014	23	3	13.04%	147	6	13	
OH	5/18/2014	26	3	11.54%	150	4	17	
OH	5/25/2014	17	2	11.76%	102	3	22	
OH	6/1/2014	17	2	11.76%	55	5	8	
	Total	**239**	**34**	**14.23%**	**1257**	**95**	**171**	**22**
OK	3/30/2014	4		0.00%	59		24	
OK	4/6/2014	5		0.00%	25		125	
OK	4/13/2014	10		0.00%	77		6	
OK	4/20/2014	12		0.00%	58		24	
OK	4/27/2014	10		0.00%	76		9	
OK	5/4/2014	16		0.00%	175		6	
OK	5/11/2014	12		0.00%	65		27	
OK	5/18/2014	14		0.00%	103		53	
OK	5/25/2014	6		0.00%	21		11	
OK	6/1/2014	15	1	6.67%	54	1	10	
	Total	**104**	**1**	**0.96%**	**713**	**1**	**295**	**0**
PA	3/30/2014	3		0.00%	7			
PA	4/6/2014	5	1	20.00%	12	1	2	2
PA	4/13/2014	2	1	50.00%	2	1	1	
PA	4/20/2014	7	3	42.86%	14	6		
PA	5/4/2014	3	1	33.33%	3	1		
PA	5/11/2014	8		0.00%	31			
PA	5/18/2014	3		0.00%	7			
PA	5/25/2014	3	1	33.33%	4	1		
PA	6/1/2014	1		0.00%	1			
	Total	**35**	**7**	**20.00%**	**81**	**10**	**3**	**2**
SD	3/30/2014	5		0.00%	30			
SD	4/6/2014	7	1	14.29%	27	1	8	2
SD	4/13/2014	13		0.00%	38		9	
SD	4/20/2014	15		0.00%	52			
SD	4/27/2014	20	1	5.00%	50	4	8	
SD	5/4/2014	18	1	5.56%	65	3		
SD	5/11/2014	21	2	9.52%	65	2	4	
SD	5/18/2014	18	3	16.67%	51	3	2	
SD	5/25/2014	22		0.00%	86		3	
SD	6/1/2014	11	2	18.18%	30	4		

State	Week	Biological Accessions			Biological Samples		Environmental Samples	
		Tested	Positive	% Pos	Tested	Positive	Tested	Positive
	Total	**150**	**10**	**6.67%**	**494**	**17**	**34**	**2**
TN	4/6/2014	2		0.00%	8			
TN	4/20/2014	1		0.00%	3			
	Total	**3**	**0**	**0.00%**	**11**	**0**	**0**	**0**
TX	4/6/2014	4	1	25.00%	12	1		
TX	4/13/2014	2		0.00%	16			
TX	4/20/2014	3	1	33.33%	23	1		
TX	4/27/2014	1		0.00%	2			
TX	5/4/2014	2		0.00%	5			
TX	5/11/2014	3		0.00%	9		1	
TX	5/25/2014	2		0.00%	8			
	Total	**17**	**2**	**11.76%**	**75**	**2**	**1**	**0**
UT	4/6/2014	1		0.00%	1			
UT	4/20/2014			0.00%			8	
	Total	**1**	**0**	**0.00%**	**1**	**0**	**8**	**0**
WI	4/13/2014	2		0.00%	7			
WI	4/20/2014	1		0.00%	1			
WI	4/27/2014	1		0.00%	4			
WI	5/18/2014	1		0.00%	1			
WI	5/25/2014	1		0.00%	4			
	Total	**6**	**0**	**0.00%**	**17**	**0**	**0**	**0**
WY	5/18/2014	1		0.00%	1			
	Total	**1**	**0**	**0.00%**	**1**	**0**	**0**	**0**

Chapter 4 Appendix

Contents

The Use of Signal Filtering for Hog Inventory Estimation

Stephen Busselberg

National Agricultural Statistics Service
3251 Old Lee Hwy; Fairfax, VA 22030

Abstract

The National Agricultural Statistics Service (NASS) uses probability surveys of hog owners to estimate quarterly hog inventories in the United States at the national and state levels. NASS receives data from external sources on the number of Canadian hog imports and exports; Canadian feeder pigs; and farm and commercial slaughter counts. A panel of commodity experts which forms the Agricultural Statistics Board (ASB) reviews the proprietary survey results and industry transaction data and compares them against a set of inter-inventory relationship constraints. Given the internal survey data, external transaction data, and the set of inventory relationship constraints, the ASB establishes the NASS official published hog inventory estimates for the estimation quarter. The goal of this paper is to propose the estimation of hog inventories by combining the NASS proprietary survey results, the non-proprietary hog transaction data, the ASB panel expert analysis, and the inter-inventory relationship constraints using statistically defensible methodology. In order to achieve this goal, this paper demonstrates the expression of hog inventories in State-Space representation for use with an Extended Kalman Filter. Allocation of the U.S. level inventory estimates to the state level is formulated using Restricted Least Squares theory.

Hog Estimation Overview

The current process used in hog inventory estimation has been stationary for many decades. The sheer length of this probationary period leads to the question – why change the process now? The answer to this question requires a clear grasp of the scope of hog inventory estimation. To this end, the paper is structured to introduce fundamental concepts that provide a necessary foundation for understanding the current hog estimation process. This includes descriptions of the full spectrum of hog inventory items; background on the survey design and types of survey estimates; details about the non-proprietary inventory transaction data and its sources, and some explanation as to why the data provides a highly influential role in hog inventory estimation; a breakdown of the inter-inventory relationship constraints and their role in hog inventory estimation; information on the ASB and its origin and function in hog inventory estimation; and lastly, a brief introduction to key Office of Management and Budget (OMB) standards and guidelines for survey estimation. Once the fundamental details of hog inventory estimation have been conveyed, the paper will provide a brief overview of State-Space representation and the system equations relevant to hog inventory estimation. Following the overview of the State-Space system equations, the paper will then derive the system equations that express hog inventories in State-Space form. Hog inventories expressed in State-Space form will be used in conjunction with the Extended Kalman Filter in order to estimate those inventories given the survey results, non-proprietary inventory transaction data, inter-inventory relationship constraints, and the ASB analysis. The paper will then cover hog inventory estimation at the U.S. and state levels followed by a comparison of empirical results calculated from three different parameterizations of the hog inventory system equations. The three different parameterizations or “treatments” pertain to various ways of handling the ASB expert analysis and its role in the estimation of hog inventories.

1 Published Hog Inventory Items

This section provides an overview of the scope of published hog inventory items. It describes the level of detail at which inventories are published and how they relate.

The National Agricultural Statistics Service (NASS) publishes quarterly hog inventory estimates in terms of the number of hogs living on hog operations in a domain of reference at the end of that quarter. Hog owners, including contractors, are the target population. The quarters estimated are March, June, September, and December. The interpretation of a March inventory count means the number of hogs living on hog operations for the corresponding domain on March 1st. Likewise, a June inventory count refers to the number of hogs on June 1st. For a given domain and quarter of reference, hog inventories are provided for ten categories of inventory. The first of these categories is the sum total of all hogs and pigs. The total number of hogs and pigs is also partitioned into market weight group classes. The first of these market weight group classes is the number of market hogs weighing less than 50 lbs. The second group is those market hogs between 50 and 119 lbs. The third and fourth market weight groups are comprised of market hogs between 120 and 179 lbs, and market hogs over 180 lbs, respectively. The sum total of these four weight classes is reported as total market hogs. Additional categories cover hog reproduction and include the number births which survive weaning, the number of sows farrowed, and breeding herd size. The ratio of pig crop (weaned births) to sows farrowed is reported as the litter rate and can be interpreted as the mean number of pigs which survive past weaning born to a sow. The sum of the four weight classes equals the total number of market hogs, and the sum of total market hogs plus breeding herd equals the total number of hogs and pigs. Pig crop is contained within market hogs less than 50 lbs and market hogs 50-119 lbs. Sows farrowed are contained within breeding herd. In the estimation quarter of December 2009, the first two weight groups were redefined to the present day definitions. The first weight class of market hogs less than 50 lbs had been previously reported as market hogs less than 60 lbs, and the second weight class of market hogs between 50 and 119 lbs had been previously reported as market hogs between 60 and 119 lbs. Table 1 contains a summary list of the hog inventory items published at the U.S. and state levels in the National Agricultural Statistics Service's quarterly Hog Report[1].

Table 1

Item Number	Inventory Item	Notation	Relationship
1	Total Hogs and Pigs	H	
2	Pig Crop (weaned births)	P	
3	Sows Farrowed	S	
4	Market Hogs less than 50 lbs	G_1	
5	Market Hogs 50 – 119 lbs	G_2	
6	Market Hogs 120 – 179 lbs	G_3	
7	Market hogs greater than 180 lbs	G_4	
8	Market Hogs	M	$\sum_{k=1}^{4} G_k$
9	Breeding Herd	B	$H - M$
10	Litter Rate	T	$\frac{P}{S}$

[1] http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1086

2 Hog Survey Measurements

This section covers the hog inventory survey including sampling frames, design, and types of estimators.

Survey estimates of inventory are calculated from a stratified simple random sample design. The strata are partitioned according to size of hog operation with respect to the number of total hogs and pigs stored in NASS's list frame. The sampling unit is any hog operation with the capacity to raise breeding or market hogs. In addition to the hog operation population list frame estimate referred to as the ADXX list frame survey estimate, there is also a multiframe estimate (ADMW). The ADMW estimate contains the inference for the hog operation population list frame plus an area frame component. The area frame component estimates the number of hogs belonging to owners who are Not On the List (NOL) frame. This NOL component is estimated using a separate area frame sampling design. The area frame survey is conducted on an annual frequency; however, the results are used to calculate quarterly estimates of the NOL component for total hogs and pigs, pig crop, sows farrowed, and breeding herd. The market weight group multiframe estimates are calculated on an annual basis in the quarter of December, and the other quarters are adjusted based on the December ADXX and NOL ratio. The NOL component adjusts for undercoverage of the list frame component. U.S. and state-level estimates of the variance of the survey estimates are also calculated according to the sampling design. Historical plots comparing NASS official ASB estimates and the ADXX and ADMW survey results are shown in Figure 1 through Figure 10.

Figure 1

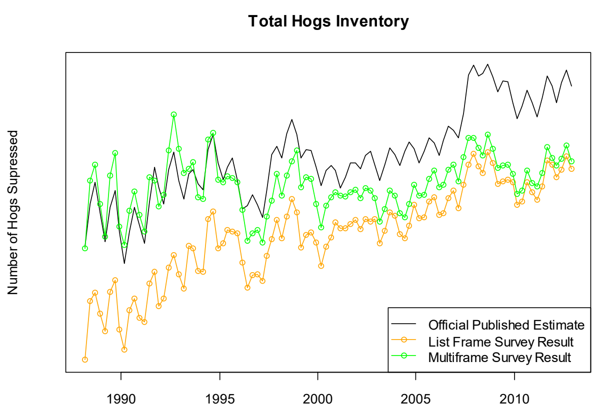


Figure 2

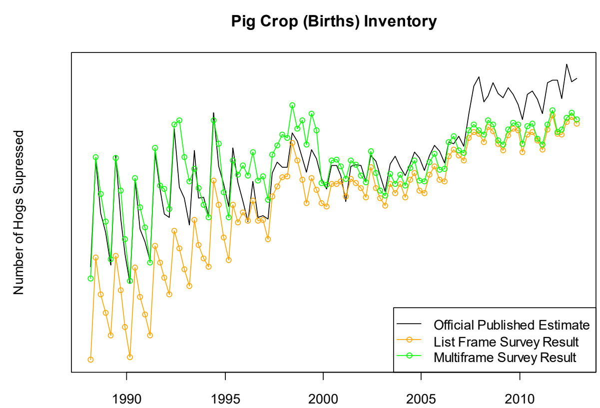


Figure 3

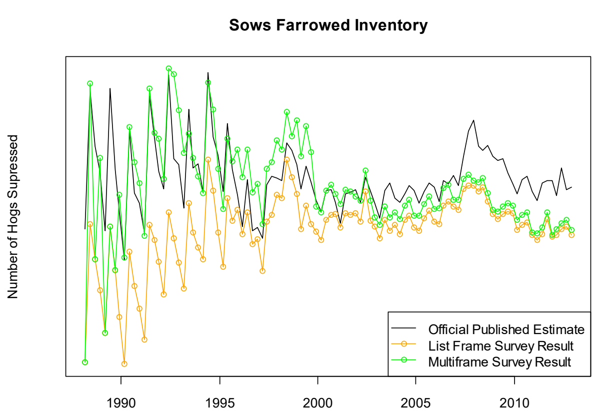


Figure 4

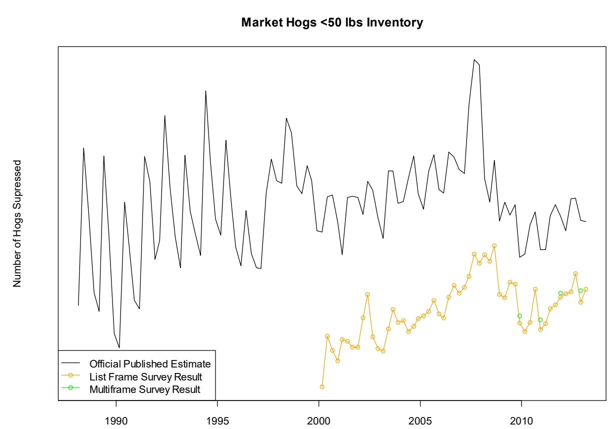


Figure 5

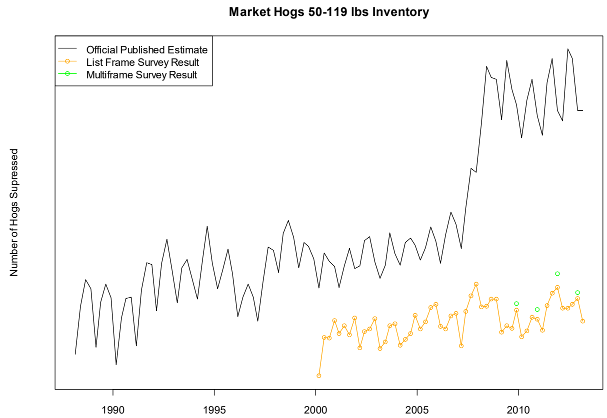


Figure 6

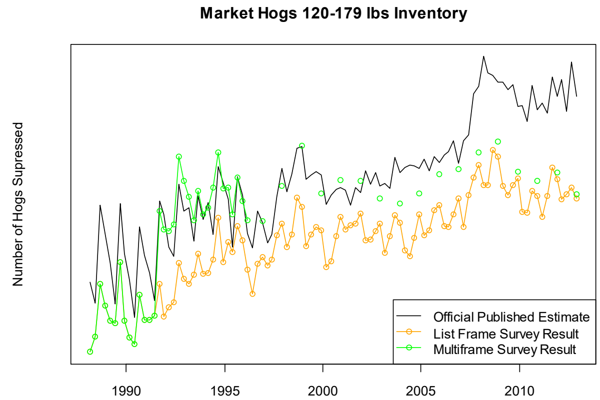


Figure 7

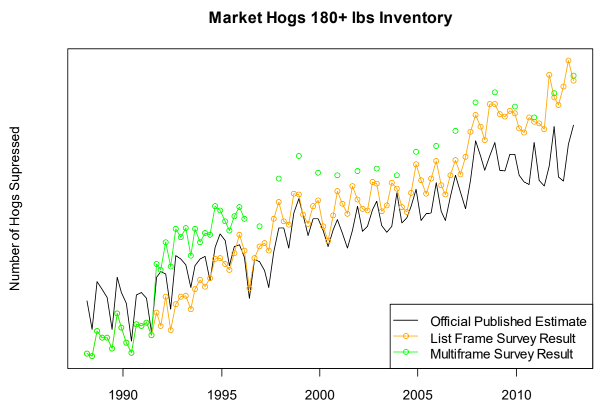


Figure 8

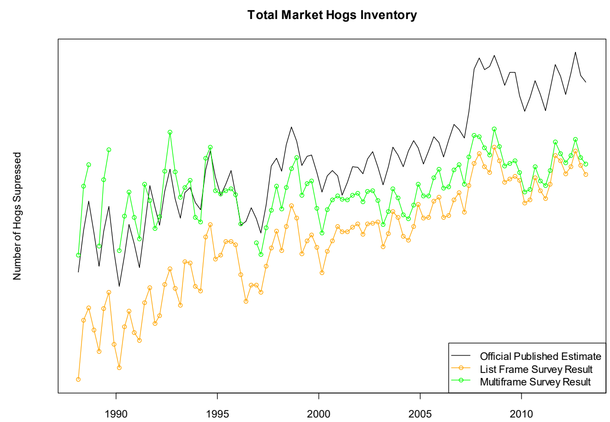


Figure 9

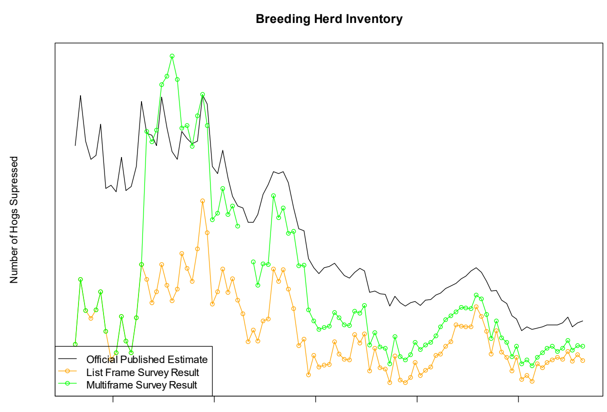
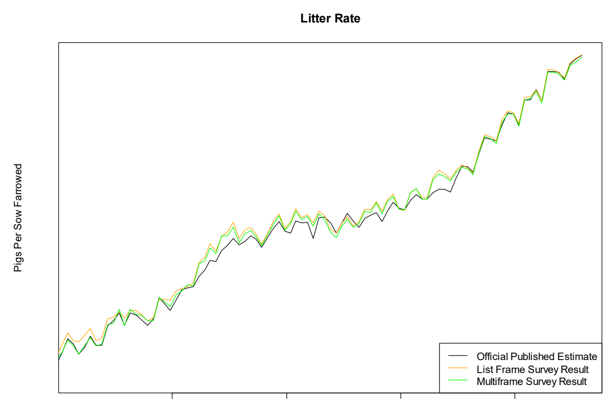


Figure 10



For each of the graphs, the differences between survey results and published inventory are attributed to the additional information provided by the non-proprietary inventory transaction data and a set of assumptions in the form of constraints on how inventory items relate one to another. These assumptions build the foundation for the system equations of the signal filter that will be derived in this paper. Actual survey results and their variances are never released to the public.

3 Non-proprietary Inventory Transaction Data

This section provides details on the inventory transaction data referred to in the previous section which NASS obtains from external sources. This data is highly influential in the differences between the survey results and the NASS official published estimates determined by the ASB. The transaction data plays a key role in inter-inventory relationship constraints that will be introduced in the next section.

The life of a hog from birth to slaughter is approximately six months. This implies that the reported pig crop in a given quarter is reflected in slaughter estimates two quarters later. Slaughter data is obtained from the Agricultural Marketing Service (AMS) and is partition into farm slaughter, federally inspected commercial slaughter, and non-federally inspected commercial slaughter. According to AMS data, federally inspected commercial slaughter amounts to roughly 99% of total slaughter. This is significant because the majority of slaughter is federally inspected. Although NASS does not receive variance estimates for any of the hog commodity transaction data from outside sources, the slaughter estimates are assumed to have very low variance due to federal inspection. In addition to hog slaughter, NASS receives data on hog imports and exports to and from Canada from the Department of Commerce through the Foreign Agricultural Service. The transaction data is available at the U.S. level only. Table 2 lists the inventory transaction data and the notation required to formulate the hog inventory constraints which will be given in section 4.

Table 2

Item Number	Data	Notation	Function
1	Slaughter	L	
2	Imports	I	
3	Exports	E	
4	Canadian Feeder Pigs	C	
5	Death Loss	D	
6	Balance Sheet Net	BSN	$I - E - D - L$

4 Hog Inventory Relationship Constraints

This section introduces the inter-inventory relationship constraints. These constraints are mathematical expressions which relate inventory items to each other and to the external transaction data. The survey results are not published because they do not satisfy these constraints.

The justification for publishing inventory estimates other than the survey results is the satisfaction of a set of assumed constraints. These constraints relate current inventory to past inventory, relate current and past inventory to the external transaction data, and reflect the hog growth cycle. The survey results do not satisfy the constraints. True hog and pig inventories are assumed to satisfy the constraints introduced in this section. The constraints will be given as mathematical expressions using the notation from Table 1 and Table 2. The subscript *t* will be used to index time, where the interval between t and $t + k$ represents k quarters, or k consecutive three month intervals. The quarter of reference for $t = 1$ refers to the first quarter, and the quarter of reference $t = n$ refers to the last quarter in the time series. In general, $t = n$ refers to the most recent quarter of inventory estimates. All constraints pertain to the U.S. level of estimation.

4.1 The Balance Sheet Equation

Total hog inventory can be compared to a deposit account; an accounting system composed of deposits and withdrawals. Deposits are analogous to increases in inventory such as births and imports. Withdrawals are the decreases in inventory which consist of slaughter, exports, and death loss. This balance sheet concept forms the balance sheet equation where one quarter's total hogs and pigs inventory is equal to the previous quarter's total hogs and pigs inventory plus the quarter's deposits minus the quarter's withdrawals. The balance sheet equation is then

$$\begin{aligned} H_t &= H_{t-1} + P_t + I_t - E_t - D_t - L_t \\ &= H_{t-1} + P_t + BSN_t \end{aligned}$$

Let BSR_t be defined as the balance sheet residual at time t and

$$BSR_t = H_t - H_{t-1} - P_t - BSN_t$$

If $BSR_t = 0$ then $H_t = H_{t-1} + P_t + BSN_t$ and the system is in balance. In setting published total hogs and pigs inventory, the balance sheet residual is allowed to vary at most by approximately one day's slaughter (approximately 500,000 hogs). It then follows that

$$\begin{aligned} |BSR_t| &\leq 500{,}000 \\ |H_t - H_{t-1} - P_t - BSN_t| &\leq 500{,}000 \end{aligned}$$

We will now define the three month, six month, and twelve month balance sheet constraints as

$$\left| \sum_{k=0}^{K} H_{t-k} - H_{t-1-k} - P_{t-k} - BSN_{t-k} \right| \leq 500{,}000 \tag{1}$$

with $K = 0$, $K = 1$, and $K = 3$, respectively.

Figure 11

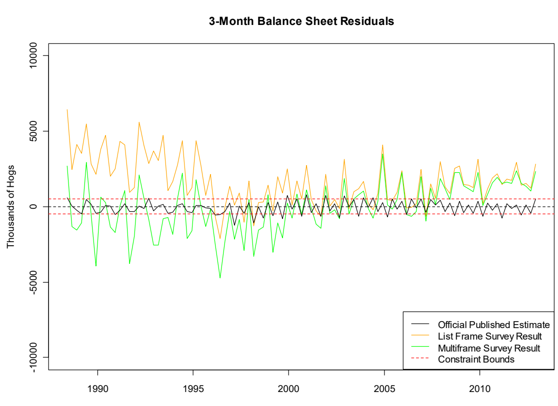


Figure 12

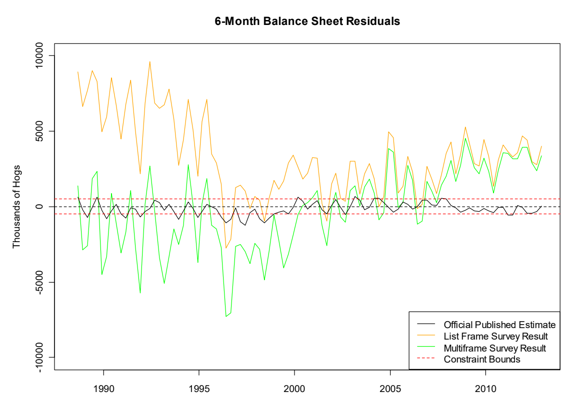


Figure 13

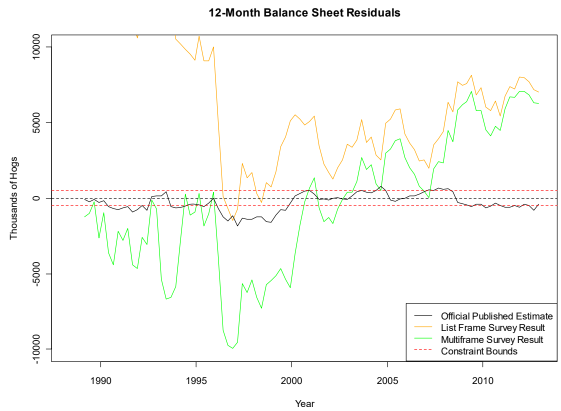


Figure 11, Figure 12, and Figure 13 plot the 3-month, 6-month, and 12-month balance sheet residuals for the ADXX (list frame) and ADMW (multiframe) survey results. The balance sheet residuals of the published ASB estimates are included for comparison with those of the survey results. The plots demonstrate the ASB's attempt to contain the balance sheet residuals of the published estimates within the 500 thousand hogs bounds.

4.2 Death Loss Ratio

The concept of the Death Loss Ratio is to acknowledge that there is a quantity of pig crop that dies and therefore cannot be counted in the market weight groups. These pigs survive past weaning and are within scope of the definition of pig crop. The weight of pigs born during a quarter is distributed between the first and a proportion of the second weight group. We will call that proportion α. If we look at these concepts in terms of annual increases, we have

$$\frac{P_t + C_t}{P_{t-4} + C_{t-4}} > \frac{G_{1_t} + \alpha_t G_{2_t}}{G_{1_{t-4}} + \alpha_{t-4} G_{2_{t-4}}} \tag{2}$$

Canadian Feeder Pigs are grouped with the births. Conceptually, this expression conveys that the annual increase in the number of pigs born and are weaned is greater than the annual increase in the first two market weight groups. The inequality implies disappearance from the weight group increase due to death loss after weaning that quarter. The value for α_t is time dependent due to a change in definition of the first two weight groups which happened in December 2009. Prior to December 2009, weight group 1 consisted of those market hogs weighing less than 60 lbs. Weight group 2 was composed of those market hogs weighing between 60 and 119 lbs. The parameter α_t is evaluated as follows:

$$\alpha_t = \begin{cases} 0.33 & t \text{ is prior to 2008} \\ 0.42 & \text{otherwise} \end{cases}$$

The values for alpha were determined by commodity analysts. The current commodity analysts enforce bounds which give the following Death Loss "Difference" constraint:

$$0.0041 \leq \frac{P_t + C_t}{P_{t-4} + C_{t-4}} - \frac{G_{1_t} + \alpha_t G_{2_t}}{G_{1_{t-4}} + \alpha_{t-4} G_{2_{t-4}}} \leq 0.0043 \tag{3}$$

The Death Loss Ratio constraint in equation (4) is the true ratio version of the Death Loss Difference in equation (3). Figure 14 plots the historical Death Loss Ratio of the published inventory items.

$$1.0041 \lesssim \frac{P_t + C_t}{P_{t-4} + C_{t-4}} \left(\frac{G_{1_t} + \alpha_t G_{2_t}}{G_{1_{t-4}} + \alpha_{t-4} G_{2_{t-4}}} \right)^{-1} \lesssim 1.0043 \quad (4)$$

Figure 14

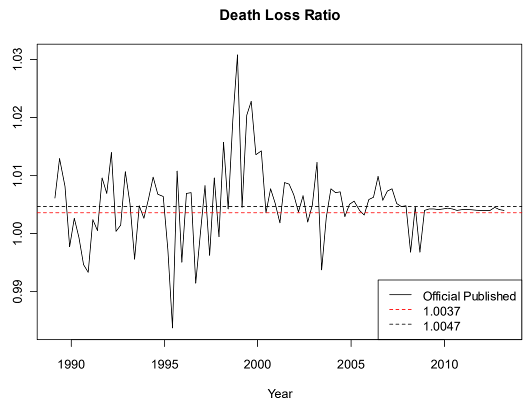


Figure 15 graphs the ASB death loss relationship by comparing the right side of equation (2) versus the left. Figure 16 graphs the left and the right sides of equation (2) using the ADXX survey result.

Figure 15

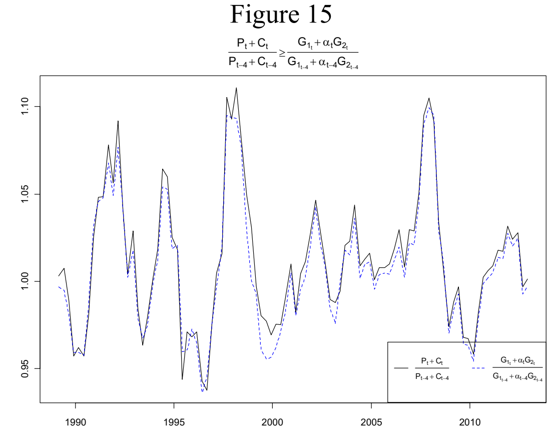
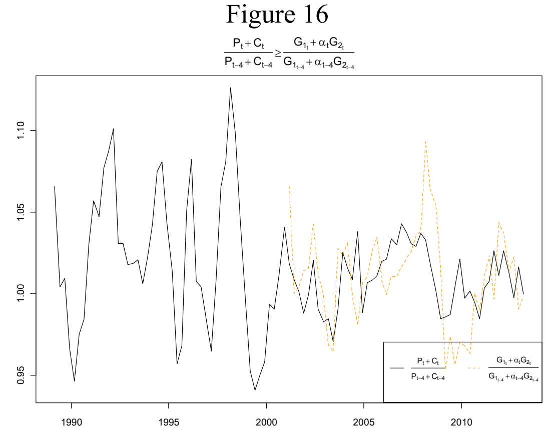


Figure 16



4.3 Weight Group Transition

Where the Death Loss Ratio maps hog births to their corresponding weight classes during the quarter, the Weight Group Transition constraint maps those births and their weights to the heavier weight groups the following quarter. The Weight Group Transition constraint is an assumption about the growth of pigs within weight classes. It links the lighter two weight classes to the heavier two weight classes over the passing of a quarter.

$$\frac{(1-\alpha_t)G_{2_t} + G_{3_t} + G_{4_t}}{(1-\alpha_{t-4})G_{2_{t-4}} + G_{3_{t-4}} + G_{4_{t-4}}} \geq \frac{G_{1_{t-1}} + \alpha_{t-1} G_{2_{t-1}}}{G_{1_{t-5}} + \alpha_{t-5} G_{2_{t-5}}} \quad (5)$$

This constraint implies that the annual increase in weight groups three, four and a proportion of the second is the annual increase in weight group one and a proportion of the second one quarter in the past.

Figure 17

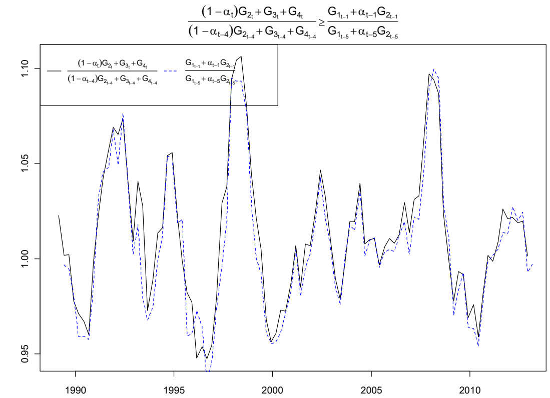


Figure 18

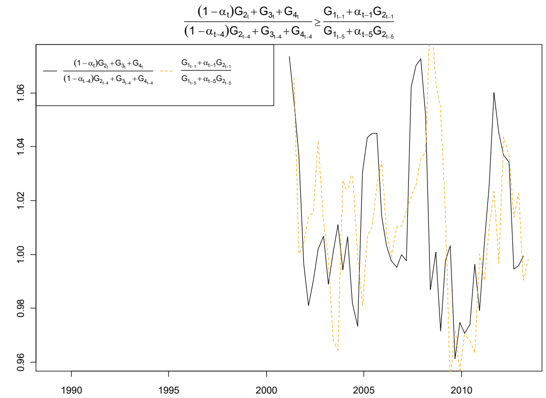


Figure 17 plots the right side and left side of the inequality (5) using the ASB values. The right side of inequality (5) is the lagged version of the right side of equation (2). Figure 18 plots the right side and left side of the inequality (5) using the list frame ADXX values. The Death Loss Ratio constraint and the Weight Group Transition constraint represent the flow of hogs from pig crop births through the market weight groups until slaughtered.

4.4 Pig Crop – Slaughter Ratio

The time between birth and slaughter for a pig is approximately six months or two quarters. This implies that hogs born in quarter t are slaughtered in quarter $t + 2$. The commodity analysts translate this concept into a ratio constraint where the annual increase in slaughter is equivalent to the increase in births two quarters in the past. This constraint is formulated as

$$\frac{L_t}{L_{t-4}} = \frac{P_{t-2}}{P_{t-6}} \tag{6}$$

Figure 19

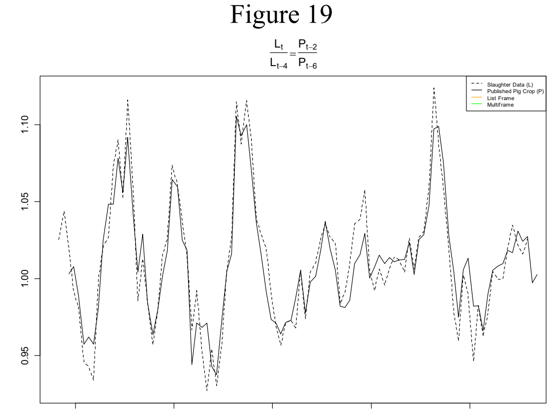


Figure 20

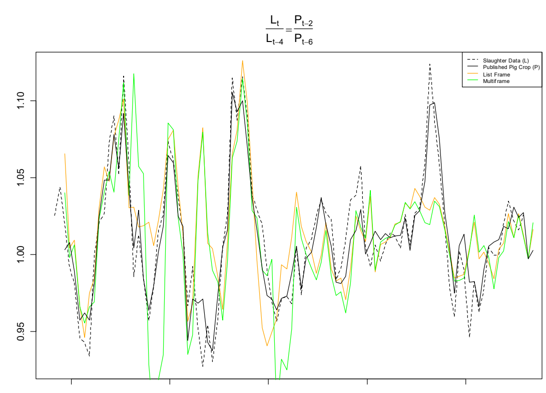


Figure 19 graphs the left side slaughter ratio versus the right side of equation (6) with substituted ASB values, and Figure 20 adds substituted survey values for the right side of equation (6) for comparison of the survey performance versus the ASB published estimates.

4.5 Market Hogs – Slaughter Ratio

Constraint 4.4 is extended to include all market hogs by the annual increase in six months of slaughter.

$$\frac{L_t + L_{t-1}}{L_{t-4} + L_{t-5}} = \frac{\sum_{i=1}^{4} G_{i_{t-2}}}{\sum_{j=1}^{4} G_{j_{t-6}}} = \frac{M_{t-2}}{M_{t-6}} \tag{7}$$

Equation (**7**) encompasses all four weight classes and conveys that the annual increase in total hogs with the exception of those hogs reserved for breeding is essentially the annual incease in two quarters of slaughter. Figure 21 plots the left and right sides of equation (7) in terms of the ASB published values. Figure 22 substitutes the ADXX list frame survey results into the right side of equation (7).

Figure 21

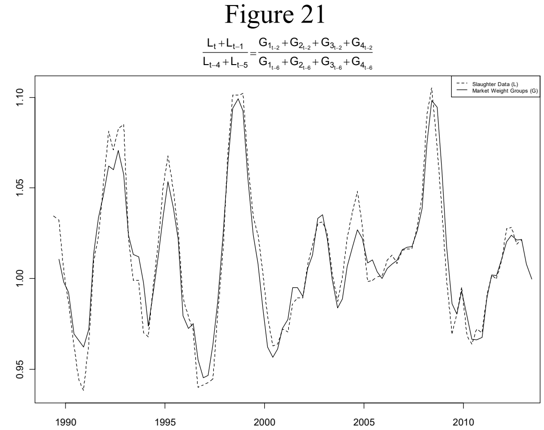
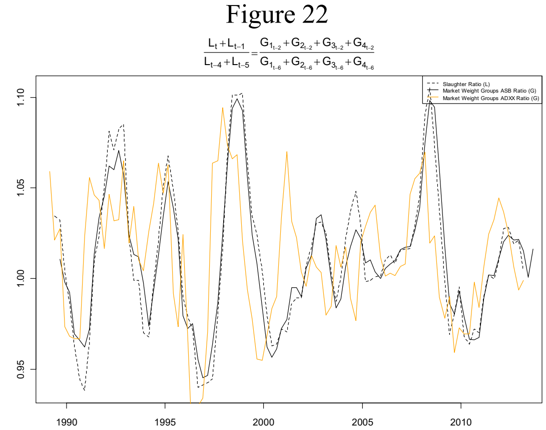


Figure 22



4.6 Market Hogs over 180 lbs – Slaughter Ratio

A third slaughter constraint relates those market hogs over 180 lbs to the slaughter occurring during the estimation quarter following the reference quarter. Although this quarter is in progress, weekly slaughter information is available that provides inference about those hogs slaughtered from the fourth weight group market hogs over 180 lbs. At the time of the board which is the most recent quarter $t = n$, there are approximately five weeks of slaughter into the next quarter $t = n + 1$. If we use L_t^{5WK} to denote the inventory slaughtered during the first five weeks of quarter t, then we can formulate this constraint as

$$\frac{L_{t+1}^{5WK}}{L_{t-3}^{5WK}} = \frac{G_{4_t}}{G_{4_{t-4}}} \tag{8}$$

Figure 23

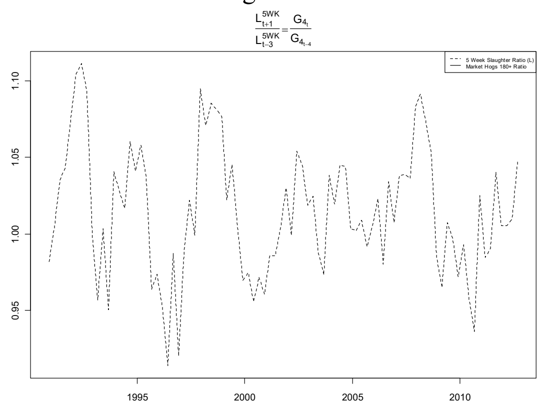


Figure 24

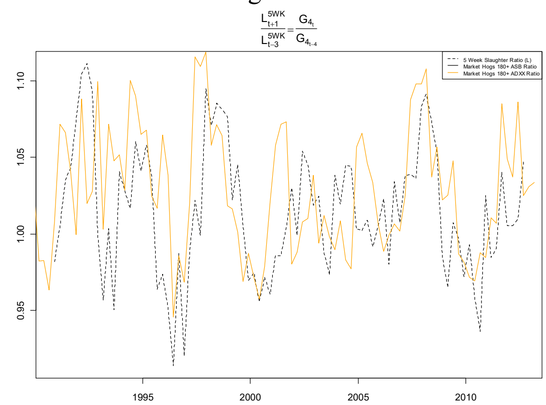


Figure 23 compares the left and right sides of equation (8) substituting ASB values. Figure 24 substitutes the list frame ADXX survey result into the right side of equation (8).

4.7 Sows Farrowed and Breeding Herd

The last constraint concerns the ratio of sows farrowed to breeding herd. The assumption is that sows farrowed make up one half of the previous quarter's breeding herd.

$$0.5 = \frac{S_t}{B_{t-1}} \qquad (9)$$

Figure 25

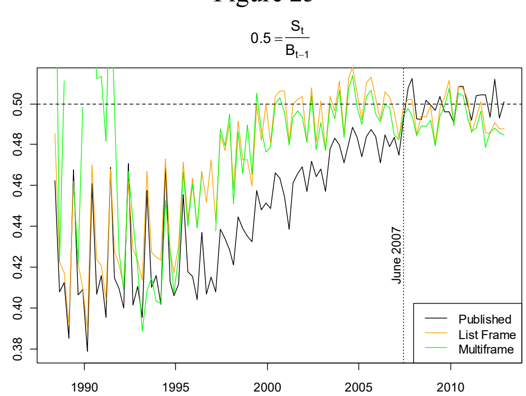


Figure **25** plots the ratio of sows farrowed to the previous quarter's breeding herd for the ADMW and ADXX survey results and the ASB published estimates.

5 Agricultural Statistics Board Estimation of Published Hog Inventories

This section introduces the Agricultural Statistics Board and its role in hog inventory estimation. The Agricultural Statistics Board is the panel of analysts that set the official published inventory items covered in section 1*; given the* *survey results described in section 2, transaction data from section 3, and inventory relationship constraints from section 4.*

The NASS official published estimates are determined by a panel of individuals that form an entity called the Agricultural Statistics Board (ASB). The ASB is comprised of individuals that participate in various aspects of the hog estimation process. These individuals consist of commodity analysts from selected NASS state offices; commodity analysts from NASS headquarters; representatives from survey administration; and representatives from survey summarization. The ASB meets during the week prior to the release of hog inventory numbers. The analysts examine annual changes in slaughter counts; hog imports and exports from Canada; death loss and inventory counts measured by the survey estimators; and the various inventory ratios in order to establish inventory recommendations or "targets" for the ASB panel. Additional targets or recommendations for inventory for presentation to the ASB panel are produced by the survey summarization analyst and the commodity analysts in the individual states. The set of target inventory numbers from the respective analysts are then presented to the ASB panel and the ASB panel establishes the published inventory estimates.

6 Office of Management and Budget Standards and Guidelines

This section provides legislative justification for the research and implementation of statistically defensible inventory estimation methodology beyond the current operational survey and ASB program. It emphasizes official standards and guidelines that require accepted theory and methods; and publication of measures of error.

Sections 1 through 3 introduce the published hog inventory items, the measurements of these items via a survey instrument, and the external transaction data available from external data collection sources. Section 4 covers the mathematical relationships between these data items and section 5 describes the operational process by which the information covered in all preceding sections is combined in order to set published inventory estimates. Section 6 touches briefly on policy standard and guideline incentives to make modifications to the methodology by which hog inventory estimation is conducted. The Office of Management and Budget (OMB) Standards and Guidelines Standard 4.1 reads as follows:

> "Agencies must use accepted theory and methods when deriving direct survey-based estimates, as well as model-based estimates and projections that use survey data. Error estimates must be calculated and disseminated to support assessment of the appropriateness of the uses of the estimates or projections. Agencies must plan and implement evaluations to assess the quality of the estimates and projections."

NASS calculates survey standard errors consistent with the sample design for the survey estimates. However, these standard errors are no longer applicable to the estimates that have been established by the ASB. This paper proposes methodology that provides a statistically defensible solution to compliance issues with OMB Standards and Guidelines.

7 Inventory Estimation Using Signal Filtering

This section introduces hog inventory estimates using Signal Filtering methodology; a methodology which will address the compliance issues with the OMB Standards and Guidelines. This section provides references to other literature and texts that give in depth coverage on State Space modeling and the Kalman Filter, Extended Kalman Filter, and other Signal Filtering applications.

NASS surveys its sampling frame of hog operations, obtains non-proprietary hog inventory transaction data, and submits these data to the ASB panel with the purpose of establishing quarterly hog inventory estimates that make sense from an historical standpoint, reflect congruency with inventory transaction data, and maintain inter-inventory consonance. This paper will demonstrate that the goals of NASS and the ASB, and the goals of the OMB Standards and Guidelines can be achieved using an Extended Kalman Filter. The Kalman Filter is a signal filtering tool for which there is an abundance of literature, supporting its use as statistically defensible methodology. Durbin and Koopman write, "the object of filtering is to update our knowledge of the system each time a new observation is brought in (Durbin and Koopman 2012)." Filtering is a methodology which can combine all observations of hog inventory; including the survey measurements from section 2, the inventory transaction data from section 3, the relationship constraints from section 4, and the ASB analyst measurements from section 5; in order to provide estimates for the inventory items in section 0 given all aforementioned data. Background on the Kalman Filter and its scientific applications can be found in Shumway & Stoffer (2006), Anderson & Moore (1979), and Durbin and Koopman (2012).

8 State-Space Representation

Section 8 provides an overview of State-Space representation and gives the general forms of the State-Space system equations necessary to estimate hog inventories using the Kalman Filter. The State-Space form notation will be provided for both linear and nonlinear relationships (Extended Kalman Filter).

Estimation of hog inventories via the Kalman Filter requires that hog inventories be represented in State-Space form. State-Space form is expressed through two system equations – a transition equation and an observation equation. These system equations are functions which describe the behavior of the *state* of a system. *State* refers to the condition or stage in the physical being of a system[2]. Throughout the remainder of this paper, "state" (non-italicized) refers to a geographic/political boundary within the U.S., and "*state"* (italicized) refers to the unobserved true *state* of a system, or the true signal as defined. In the case of hog inventory estimation, the *state* refers to true hog inventories. Sections 8.1 and 8.2 provide the forms of the transition and observation equations used in hog inventory estimation.

8.1 The Transition Equation

The transition equation defines how the *states* (hog inventories) are related over time. It *transitions* the state from one time index to the next. The linear transitions are modeled by equation (10)

$$x_t = \Phi x_{t-1} + w_t \tag{10}$$

where x is an $m \times 1$ *state* vector, Φ is the $m \times m$ transition matrix representing the linear relationship between x_{t-1} and x_t, and w is an $m \times 1$ process noise vector with a Gaussian distribution. The first and second moments are $E[w_t] = 0 \;\forall\; t$ and $E[w_t w'_{t-i}] = \begin{cases} Q & i = 0 \\ 0 & i \neq 0 \end{cases}$. If the transition relationship over time is nonlinear, equation (11) is used where $G(\cdot)$ represents the system of nonlinear transition relationships as a function of the lagged *state*.

$$x_t = G(x_{t-1}) + w_t \tag{11}$$

---

[2] Merriam-Webster Dictionary.

8.2 The Observation Equation

The observation equation relates a set of measurements or observations of the *state* to the *state*. In this paper, “observations” and “measurements” will be used interchangeably. The linear observations are modeled by the relationship

$$y_t = A_t x_t + v_t \tag{12}$$

where y is a $k \times 1$ vector of measurements, A is a $k \times m$ measurement matrix which defines the linear relationship between the *state* x_t and the observations y_t, and v_t is a $k \times 1$ observation noise vector with a Gaussian distribution. The first and second moments are $E[v_t] = 0 \;\forall\; t$ and $E\left[v_t v'_{t-j}\right] = \begin{cases} R & j = 0 \\ 0 & j \neq 0 \end{cases}$. In addition, $E\left[w_{t-i} v'_{t-j}\right] = 0 \;\forall\; i, j$. If the relationship between the measurements and the *state* is nonlinear, equation (13) is used where $H(\cdot)$ represents the system of nonlinear measurement relationships as a function of the *state*.

$$y_t = H_t(x_t) + v_t \tag{13}$$

9 Hog Inventory Transition Equations

This section derives the hog inventory State-Space transition equations by putting equations (10) and (11) in terms of the published hog inventory items from Table 1 so that hog inventories can be estimated using the Extended Kalman Filter. This will be done using the constraints listed in section 4.

In order to estimate hog inventories using a Kalman Filter, they must be formulated in State-Space representation. This involves defining the *state* vector from the published items in Table 1, determining the parametric transition relationships for each *state* vector element that conform to the transition equations (10) and (11), and determining the parametric relationships of all measurements and observations to the *state* which conform to the observation equations (12) and (13). The constraints listed in section 4 define the behavior rules that can be adapted into State-Space form which will be demonstrated in this section. Before establishing the *state* vector, we must define some weight group functions and a linear filter operator which will assist in formulating the transition relationships. We define the weight group functions f_1, f_2, f_3, and f_4 as

$$f_{1_t} = G_{1_t} + G_{2_t} \tag{14}$$

$$f_{2_t} = \ln\left(\frac{G_{1_t} + \alpha_t G_{2_t}}{P_t + C_t}\right) \tag{15}$$

$$f_{3_t} = \ln\left[(1 - \alpha_t) G_{2_t} + G_{3_t} + G_{4_t}\right] \tag{16}$$

$$f_{4_t} = \ln\left(G_{4_t}\right) \tag{17}$$

These functions should be familiar from the terms in the hog inventory constraints in section 4. We will use them to develop *state* transition relationships. In addition, we will use the linear filter operator of the first and fourth difference

$$\Delta(x_t) = x_t - x_{t-1} - x_{t-4} + x_{t-5} \tag{18}$$

Given the weight group function equations (14) - (17) and the linear filter equation (18), the hog inventory *state* vector elements and corresponding transitions are listed in Table **3** and Table **4**, respectively.

Table 3

Item	Element of $\boldsymbol{x_t}$	Values of k (x)
1	$\Delta(H_{t-k})$	$k \in \{0,1,2,3\}$
2	$\Delta(P_{t-k})$	$k \in \{0,1,2,3\}$
3	$\Delta(S_{t-k})$	$k \in \{0,1,2,3\}$
4	$\Delta\left(f_{1_{t-k}}\right)$	$k \in \{0,1,2,3\}$
5	H_{t-k}	$k \in \{1,2,3,4,5\}$
6	P_{t-k}	$k \in \{1,2,3,4,5\}$
7	S_{t-k}	$k \in \{1,2,3,4,5\}$
8	$f_{1_{t-k}}$	$k \in \{1,2,3,4,5\}$
9	$f_{2_{t-k}}$	$k \in \{0,1,2,3,4,5,6\}$
10	$f_{3_{t-k}}$	$k \in \{0,1,2,3,4,5,6\}$
11	$f_{4_{t-k}}$	$k \in \{0,1,2,3,4\}$
12	u_{x_t}	$x \in \{H, P, S, f_1, f_2, f_3, f_4\}$

Table 4

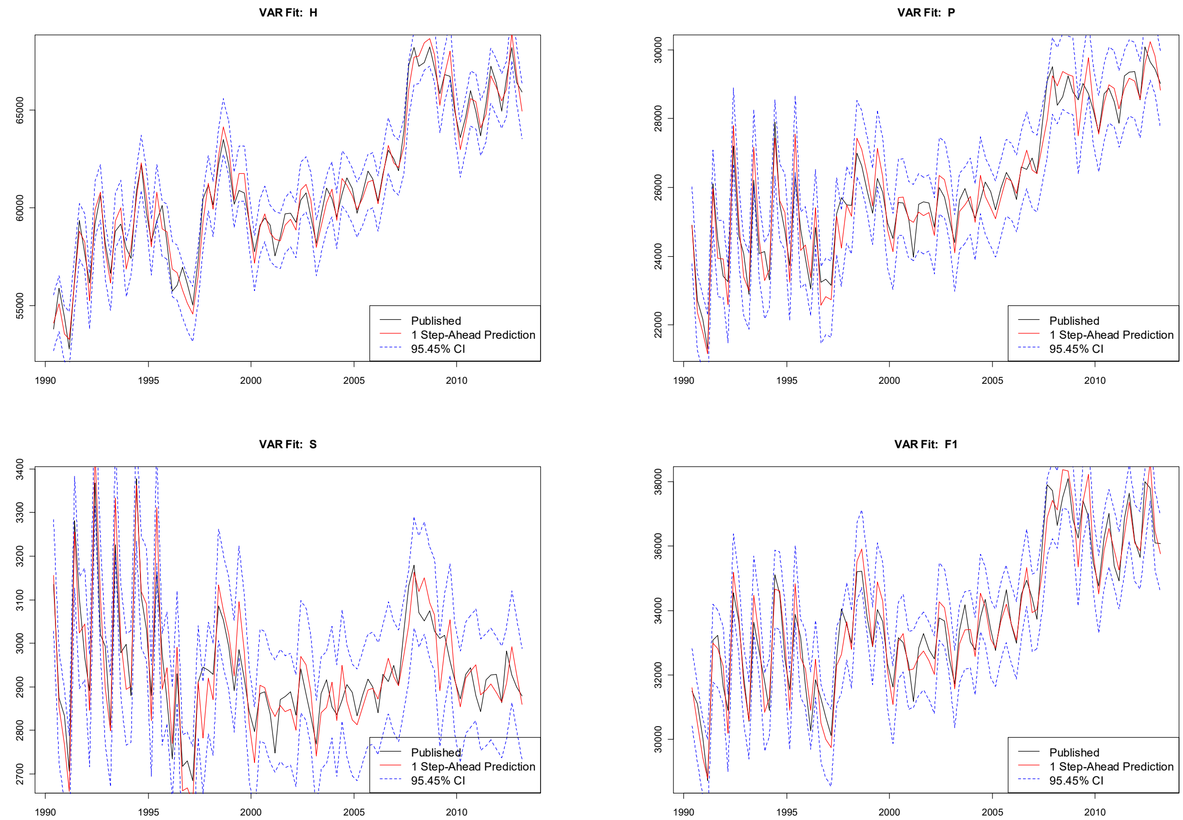
Item	Section	Element	Transition Function
1	9.1	$\Delta(H_t)$	$\begin{bmatrix}\Delta(H_t)\\ \Delta(P_t)\\ \Delta(S_t)\\ \Delta\left(f_{1_t}\right)\end{bmatrix} = \sum_{i=1}^{4} \boldsymbol{\Phi}_{\mathbf{i}} \begin{bmatrix}\Delta(H_{t-i})\\ \Delta(P_{t-i})\\ \Delta(S_{t-i})\\ \Delta\left(f_{1_{t-i}}\right)\end{bmatrix}$
2	9.1	$\Delta(P_t)$	
3	9.1	$\Delta(S_t)$	
4	9.1	$\Delta\left(f_{1_t}\right)$	
5	9.2	f_{2_t}	$f_{2_t} = f_{2_{t-4}} - \ln(1.0042)$
6	9.3	f_{3_t}	$f_{3_t} = \ln\left[\frac{e^{f_{2t-1}}(P_{t-1} + C_{t-1})}{e^{f_{2t-5}}(P_{t-5} + C_{t-5})}\right] + f_{3_{t-4}}$
7	9.4	f_{4_t}	$f_{4_t} = \ln\left(f_{1_{t-1}}\right) - \ln\left(f_{1_{t-5}}\right) + f_{4_{t-4}}$
8	10.2	u_{x_t}	$u_{x_t} = u_{x_{t-1}}$

The additive process noise term w_t has been omitted for convenience from Table 4. In sections 9.1-9.4 we will develop justification for the transition relationships with the exception of Table 4 item 8 which is an estimate of the true survey bias which will be introduced in section 10.2. The true survey bias u of inventory item x defined as u_x must be introduced here because it will be estimated and therefore must be defined as part of the state and given a transition.

9.1 Hogs, Pig Crop, Sows Farrowed, and Weight Group Function f_1

We transition total hogs, pig crop, sows farrowed, and f_1 using a Vector Autoregressive (VAR) model. Figure **26** illustrates the VAR transition model step-ahead predictions compared to ASB published numbers.

Figure 26



From visual inspection, the VAR model appears to be a reasonable transition. A 95.45% (two standard deviations of a Gaussian distribution) confidence interval is included to demonstrate the error term variance estimate. The VAR error term is analogous to the process noise in State-Space representation. For a simple comparison of the VAR prediction performance between inventory items, we can look at a bar plot of Coefficients of Variation calculated by the square-root of the VAR error term variance estimates divided by the series' means.

Figure 27

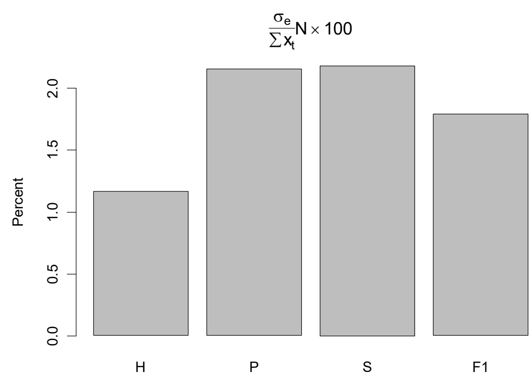


Figure 27 supports the general assumption that total hog and pigs is the "most stable" item to model at the U.S. level, meaning that the estimate of the standard error of the noise process is the smallest relative to the mean size for total hogs and pigs in comparison to the other inventory items' process noise standard errors and mean sizes. It should also be noted that the Vector Autoregressive order is fixed at 4. The order that provides the minimum for canonical fit statistics such as Akaike's Information Criterion (AIC) changes depending on the time window used to estimate the VAR model. Common AR orders of 3 and 4 as well as a couple outlier orders have been empirically produced. The order 4 was chosen because it was the mode and is more intuitive; an order of 4 will transition one year of data.

9.2 Weight Group Function f_2

Weight group function f_2 and its transition are derived from the Death Loss Ratio constraint in section 4.2. Defining λ_t as the death loss ratio at time t, we can rewrite the Death Loss Ratio as a true ratio (commodity analysts calculate it as a difference) in terms of the weight group function f_2.

$$\begin{aligned}\lambda_t &= \left(\frac{P_t + C_t}{P_{t-4} + C_{t-4}}\right)\left(\frac{G_{1_t} + \alpha_t G_{2_t}}{G_{1_{t-4}} + \alpha_{t-4} G_{2_{t-4}}}\right)^{-1} \\ &= e^{f_{2_{t-4}} - f_{2_t}}\end{aligned} \tag{19}$$

The death loss ratio in equation (19) is expressed in terms of true hog and pig inventories. We can collect all terms of equation (19) at time $t - k|k = 0$ on the left side of the equation and all terms at time $t - k|k > 0$ on the right side of the equation which yields equation (20).

$$\frac{G_{1_t} + \alpha_t G_{2_t}}{P_t + C_t} = \frac{1}{\lambda_t}\frac{G_{1_{t-4}} + \alpha_{t-4} G_{2_{t-4}}}{P_{t-4} + C_{t-4}} e^{w_t} \tag{20}$$

We have added multiplicative process noise term e^{w_t}. By taking the natural log of both sides of equation (20), we can model a linear transition of f_2 with the process noise error term w_t in state space representation by

$$f_{2_t} = f_{2_{t-4}} - \ln(\lambda_t) + w_t \tag{21}$$

$$\ln(\lambda_t) = \ln(\lambda_{t-1}) + w_{\lambda_t} \tag{22}$$

Equation (21) incorporates the natural log of the death loss ratio as part of the *state* vector with its own random walk transition and process noise in equation (22). The death loss ratio is essentially formulated here as a time variant level in the *state* vector. This parameterization is more reflective of the true historical death loss ratio in Figure 14. However, to conform to the assumptions of the current commodity analysts, we will assume the death loss ratio λ_t is distributed symmetrically with constant mean value between its bounds of 1.0041 and 1.0043. Therefore, $E[\lambda_t] = 1.0042$. We replace λ_t in the f_2 transition with the fixed value of its expectation 1.0042 and the f_2 transition becomes

$$f_{2_t} = f_{2_{t-4}} - \ln(1.0042) + w_t \tag{23}$$

Figure 28 plots the official published ASB values for f_2 and the expectation of its transition in equation (23). It is more intuitive to examine the plot of $e^{f_{2t}}(P_t + C_t) = G_{1_t} + \alpha_t G_{2_t}$ in Figure 29, which represents those pigs in market weight group 1 and a proportion of those in market weight group 2.

Figure 28

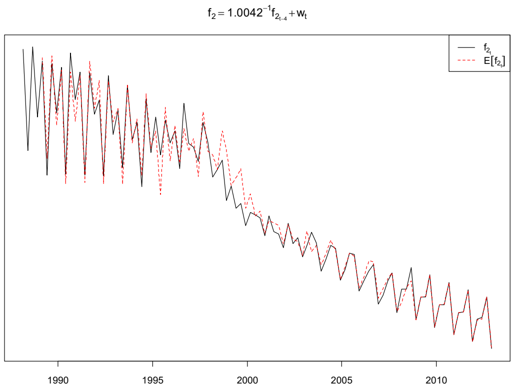
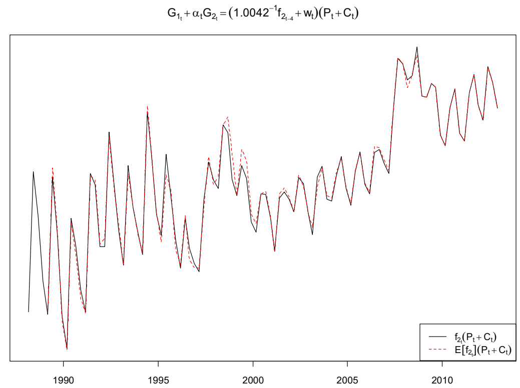


Figure 29



Canadian Feeder Pigs C_t is treated as a fixed parameter. The value is known as it is supplied as external inventory transaction data.

9.3 Weight Group Function f_3

The weight group function f_3 transition follows a similar derivation to f_2. The constraint 4.3 can be written in terms of f_2 and f_3.

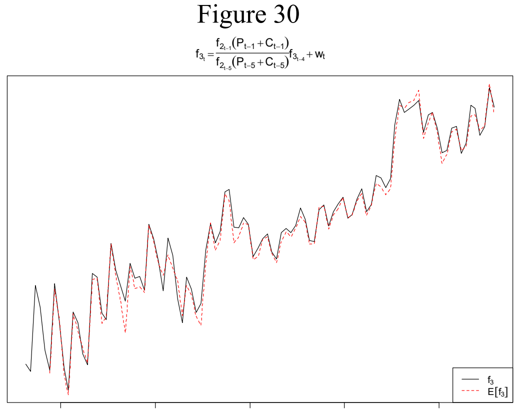
$$\frac{e^{f_{3t}}}{e^{f_{3t-4}}} \geq \frac{e^{f_{2t-1}}(P_{t-1} + C_{t-1})}{e^{f_{2t-5}}(P_{t-5} + C_{t-5})} \tag{24}$$

Collection of terms at time $t - k|k = 0$ on the left and $t - k|k > 0$ on the right followed by taking the natural log of both sides of equation (24) yields the transition equation

$$f_{3_t} = \ln\left[\frac{e^{f_{2t-1}}(P_{t-1} + C_{t-1})}{e^{f_{2t-5}}(P_{t-5} + C_{t-5})}\right] + f_{3_{t-4}} + w_t \tag{25}$$

The model noise process is multiplicative with e^{w_t}. Figure 30 illustrates the official published ASB estimate of f_3 and its expected transition.

Figure 30



9.4 Weight Group Function f_4

The transition for weight group 4 from Table 4 is not derived from any of the constraints from section 4.

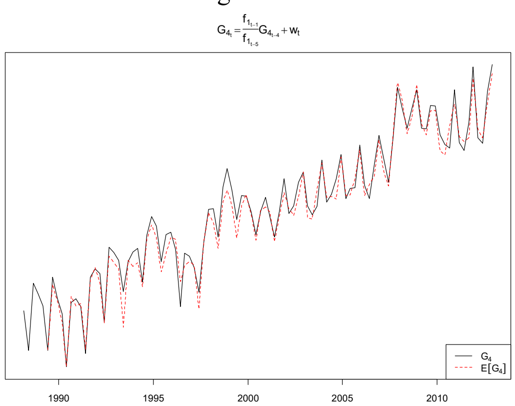
$$G_{4_t} = \frac{G_{1_{t-1}} + G_{2_{t-1}}}{G_{1_{t-5}} + G_{2_{t-5}}} G\_4_{t-4} \tag{26}$$

If we take the natural log of both sides of (26) with the multiplicative error term e^{w_t}, we have the transition equation

$$f_{4_t} = \ln\left(f_{1_{t-1}}\right) - \ln\left(f_{1_{t-5}}\right) + f_{4_{t-4}} + w_t \tag{27}$$

Its performance is illustrated below in Figure 31.

Figure 31



10 The Hog Inventory Observation/Measurement Equations

This section derives the hog inventory State-Space observation equations by putting equations (12) and (13) in terms of the published hog inventory items from Table 1 so that hog inventories can be estimated using the Extended Kalman Filter. This will be done using the constraints listed in section 4.

In order to put the measurements of inventory into the observation system of equations, we group the observations related to hog inventories into three categories according to source. We are using signal filtering methodology to estimate an unobserved signal for which we have "noisy" measurements. These measurements include the published ASB estimates, the survey results, and the non-proprietary hog inventory transaction data. We will categorize the ASB measurements of inventory as "expert analysis" measurements. The three categories of hog inventory observations are therefore expert analysis measurements, survey measurements, and external inventory transaction data. The categorization into these three groups helps distinctly separate how the types of measurements are treated. The relationships between inventory transaction data and hog inventories are defined in the observation equations through the relationship constraints introduced in section 4. Farm and commercial slaughter, hog imports and exports from Canada, and death loss estimates comprise this group. The survey results are treated as biased measurements of true inventories. The question remains how to treat the expert analysis measurements relative to true inventory. Sections 10.1 - 10.3 address the parameterization of each observation category.

10.1 Expert Analysis Estimates and True Inventory

The current hog inventory estimation process involves a panel of experts that take all given hog inventory data from internal surveys and external sources in order to find a solution that satisfies a set of assumptions in the form of constraints. This paper does not argue the validity or appropriateness of the constraints; rather, it proposes to incorporate the current process into a signal filtering model analog of the current hog estimation process. In order to maintain a smooth transition from the published board inventory estimates to published signal filter model estimates, the historical published ASB estimates must be included in the observation vector. Assuming that hog inventories will be estimated indefinitely, that particular observation or measurement must be continued. An example of methodology that eliminates ASB measurements and at the same time continues from where the ASB ends is to include a measurement in the observation vector that is the published measurement. The published inventory measurements are the ASB measurements before implementation of signal filtering methodology, and the model estimates become the published measurements post implementation of the Filter. This parameterization does require that certain complications be addressed, such as published revisions as new slaughter data and other data become available. In addition, model output becomes an observation, which is model input. An alternative approach is to continue using the ASB measurement as an "expert analysis" measurement. The previously published inventory becomes the past expert analysis measurements in the observation vector. Instead of publishing that ASB measurement, it is put into the signal filter with the other survey measurements and observation data. The Kalman Filter estimates are published together with their standard errors in the official release. Sections 10.1.1, 10.1.2, and 10.1.3 discuss various treatments and parameterizations of the ASB expert analysis measurements.

10.1.1 ASB Expert Analysis as an Unbiased Observation

Incorporating Signal Filtering methodology as an analogue of the current estimation process implies continuing to supply an ASB measurement. There are many ways this can be done. The inclusion of ASB inventory measurements allows expert opinion the possibility to exert some influence in a statistically defensible model. One concern is the possibility that expert opinion will exert too much influence on the filter estimates relative to the other measurements so that filter estimates are simply "perturbed" ASB estimates. This concern will be addressed in later sections with model results for various proposed parameterizations.

In order to establish a relationship between true inventory and measurements of true inventory, we must make some assumptions about true inventory. The ASB assumes that the survey results are biased and therefore publishes its own estimates of inventory rather than the survey results. Let us first assume that the ASB expert analysis estimates of true inventory are unbiased estimates of inventory. This is parameterized as

$$x_t^{ASB} = x_t + v_t \tag{28}$$

where $x \in \{H, P, S\}$. Another implication of this parameterization is $var(x_t^{ASB}) = R$. The variance estimate of the observation noise is parameterized as an estimate of the variance of the ASB estimate. Equation (28) is straightforward for total hogs, pig crop and sows farrowed. The four market weight groups add complexity because they are included as nonlinear functions in the *state*. If we use the ASB estimates in the weight group functions as the measurements for the weight groups, we can eliminate the nonlinearities in the system equations.

For f_1, we have

$$\begin{aligned} G_{1_t}^{ASB} + G_{2_t}^{ASB} &= G_{1_t} + G_{2_t} + v_t \\ f_{1_t}^{ASB} &= f_{1_t} + v_t \end{aligned} \tag{29}$$

For f_2, we have

$$\ln\left(\frac{G_{1_t}^{ASB} + \alpha_t G_{2_t}^{ASB}}{P_t^{ASB} + C_t}\right) = \ln\left(\frac{G_{1_t} + \alpha_t G_{2_t}}{P_t + C_t}\right) + v_t$$
$$f_{2_t}^{ASB} = f_{2_t} + v_t \quad (30)$$

For f_3, we have

$$\ln\left[(1-\alpha_t)G_{2_t}^{ASB} + G_{3_t}^{ASB} + G_{4_t}^{ASB}\right] = \ln\left[(1-\alpha_t)G_{2_t} + G_{3_t} + G_{4_t}\right] + v_t$$
$$f_{3_t}^{ASB} = f_{3_t} + v_t \quad (31)$$

For f_4, we have

$$\ln\left(G_{4_t}^{ASB}\right) = \ln\left(G_{4_t}\right) + v_t$$
$$f_{4_t}^{ASB} = f_{4_t} + v_t \quad (32)$$

10.1.2 ASB Expert Analysis as a Biased Observation

An argument can be made that the ASB estimates are also biased. If this is the case, we can also treat the bias as an unobserved signal and measure it in the *state*. Inclusion of the bias in the *state* requires a transition model for the bias terms in the system of transition equations. This parameterization is important in the analysis of the decomposition and the influence of ASB measurements in the observation vector which will be shown in section 13. We will be able to compare the influence of the ASB measurements on the estimates in the case that the ASB is treated as unbiased against the case in which the ASB measurements are allowed to contain possible bias. We express biased ASB measurements as

$$x_t^{ASB} = x_t + b_{x_t} + v_t$$
$$b_{x_t} = b_{x_{t-1}} + w_t \quad (33)$$

where b_{x_t} is the bias term of item x and is transitioned as a random walk.

For the initial conditions of the filter, we set the bias parameters of all ASB measurements of inventory items to zero, allowing the filter to assess the biases starting with an initial assumption of zero bias.

10.1.3 Published Inventory as an Observation

Transitioning operationally from ASB published to Filter published is possible without the inclusion of ASB measurements of inventory when the published is treated as an unbiased measurement of inventory. The ASB sets an estimate for the current quarter and makes revisions to past estimates up to two quarters back in time. The backward revisions are due to the new slaughter data which give information on those hog inventories two quarters in the past. This can be implemented by the Filter operationally if the Kalman Filter estimates two quarters or more in the past become the observations. This is essentially the equivalent of using the fixed lag smoother $E[x_{t-2}|y_t]$ as a measurement in the observation vector. Given that $t = k$ is the quarter of the last published ASB estimates before implementation of the Kalman Filter and $t = n$ is the most recent estimate quarter, the published inventory observation is defined below in equation (34).

$$x_t^{PUB} = x_t + v_t$$

$$x_t^{PUB} = \begin{cases} x_t^{ASB} & 1 \le t \le k \\ E[x_t | y_{t+2}] & k < t < n-2 \\ missing & t \ge n-2 \end{cases} \tag{34}$$

For any time point equal to or more recent than two quarters in the past relative to the target quarter of estimation $t = n$, the published observation is coded as missing in the Kalman Filter. This is because a fixed lag smoother of lag 2 is not yet available for $t \in \{n-1, n\}$ and the observation will be created for $t = n - 2$ during the quarter.

10.2 Survey Estimates and True Inventory

Figure 1-Figure 10 illustrate the degree of bias between the ASB estimate and the survey estimates for each inventory item. That bias demonstrated by the difference between survey results and the ASB published inventory estimates changes over time. In order to account for the bias in the survey measurements, we estimate it as part of the *state*. If x_t^{ADXX} represents the ADXX survey result for inventory item x, we write

$$x_t^{ADXX} = x_t + u_{x_t} + v_t \tag{35}$$

The above representation of the survey result for inventory item *x* shows the decomposition into the true inventory plus the bias term plus an observational noise process. This is a similar decomposition to the treatment of the biased ASB estimate in section 10.1.2 except that we use u to represent the survey bias and b to represent the ASB bias. As the bias is part of the *state*, we also need a transition model which defines how the bias is correlated over time (if at all). If we assume that the ASB published estimate for total hogs and pigs is true inventory, the bias for the ADXX list frame survey result for total hogs and pigs can be modeled with an ARIMA(1,0,0)x(0,1,1)$_4$. This bias model fit is demonstrated in Figure 32.

Figure 32

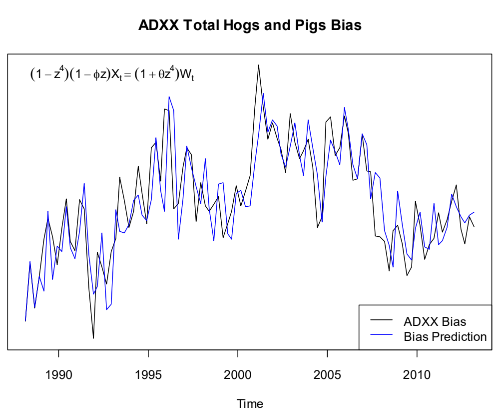
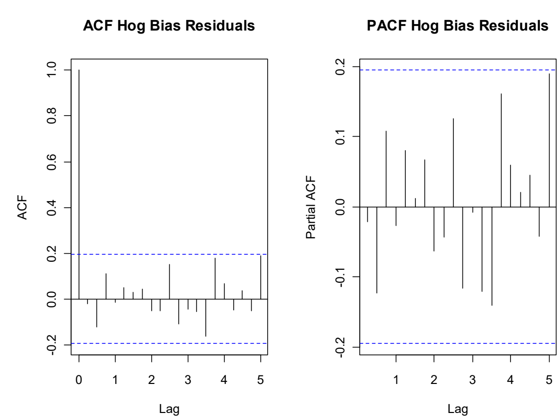


Figure 33



An ARIMA(0,1,0)x(0,1,1)$_4$ could slightly reduce Akaike's Information Criterion for the fit, however, does not fully remove autocorrelation in the residuals. Figure 33 gives the autocorrelation function and partial autocorrelation function of the residuals of the model fit from Figure 32, thereby providing evidence that this model removes significant autocorrelation structure.

Pig crop and sows farrowed ADXX biases could be modeled similarly conditioned on the assumption that the ASB is unbiased. This ARIMA model does add significant complexity to the state-space model, particularly in dramatically increasing the dimension of the *state* in order to reflect this transition over multiple inventory items. Additionally it would require estimation of the measurement matrix in order to reflect the seasonal moving average terms. It is more reasonable to assume that the ASB estimates are in fact estimates of true inventory and may possibly contain biases of their own. In light of this assumption, we would not want to use a transition model that reflected biased bias terms. For the sake of model parsimony, we represent the survey bias term transitions for all survey inventory items with a random walk. Equation (36) is the transition of the survey bias term.

$$u_{x_t} = u_{x_{t-1}} + v_t \tag{36}$$

For the survey litter rate, we base the observation equation on the ASB assumption

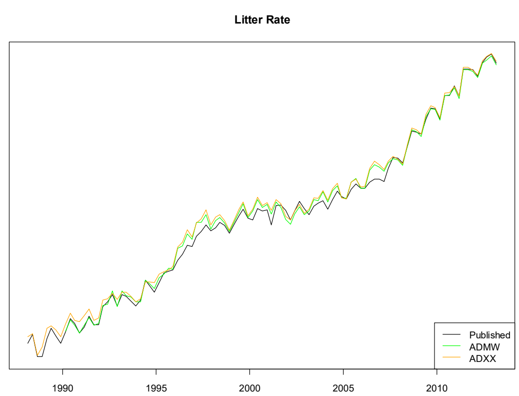
$$E\left[\frac{P_t^{ADXX}}{S_t^{ADXX}}\right] \approx \frac{P_t}{S_t}$$

This implies that the ASB believes the survey litter rate is unbiased. The observation equation for the litter rate with multiplicative observational noise becomes

$$\begin{gathered} \frac{P_t^{ADXX}}{S_t^{ADXX}} = \frac{P_t}{S_t} e^{v_t} \\ \ln(T_t^{ADXX}) = \ln(P_t) - \ln(S_t) + v_t \end{gathered} \tag{37}$$

The relationship between the ASB litter rate and the survey litter rates is shown in Figure 34.

Figure 34



10.3 External Data and True Inventory

Section 4 listed all of the hog inventory constraints. These constraints define how inventories relate to the various inventory items, and also how they relate to a number of external data items. The death loss ratio constraint from 4.2 and the weight group transition constraint from 4.3 were included in the transition equation. These constraints involved transitional relationships of the multidimensional *state* over time. The remainder of the constraints from section 4 involves external transaction data and can be expressed in the observation equation.

10.3.1 Balance Sheet Equation

The balance sheet constraint was introduced in section 4.1 and the balance sheet net was defined in Table 2 of section 3. The balance sheet relationship is

$$H_t = H_{t-1} + P_t + BSN_t + BSR_t \tag{38}$$

If we define $BSR_t = -v_t$, the above can be written as

$$BSN_t = H_t - H_{t-1} - P_t + v_t \tag{39}$$

The balance sheet equation is now in state-space form with the observation noise process equated to the balance sheet residual. In terms of elements of the state vector, the three month balance sheet measurement equation is

$$BSN_t = \Delta(H_t) + H_{t-4} - H_{t-5} - \Delta(P_t) - P_{t-1} - P_{t-4} + P_{t-5} + v_t \tag{40}$$

The six month balance sheet measurement equation is

$$\sum_{k=0}^{1} BSN_{t-k} = \Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5} - H_{t-2} - \Delta(P_t) - 2P_{t-1} - P_{t-4} + P_{t-5} + v_t \tag{41}$$

The twelve month balance sheet measurement equation is

$$\sum_{k=0}^{3} BSN_{t-k} = \Delta(H_t) + H_{t-1} - H_{t-5} - \Delta(P_t) - 2P_{t-1} - P_{t-2} - P_{t-3} - P_{t-4} + P_{t-5} + v_t \tag{42}$$

10.3.2 Breeding Herd "Smoother"

Stricter constraints on the market weight groups and total hogs and pigs cause breeding herd to absorb some of the noise process due to the deterministic relationship they share. When uncontrolled, it is manifested in high frequency oscillations. Contrary to what these high frequency oscillations suggest, breeding herd should be a more stable inventory item, meaning that it does not change dramatically from quarter to quarter. This can be represented as an observation constraint where the change in breeding herd has "fixed" bounds. The measurement for this constraint is 1, and the bounds can be set by a fixed diagonal element of the covariance matrix $R = E[v_t v_t']$. The constraint is then

$$\begin{aligned} 1 &= \frac{B_t}{B_{t-1}} e^{v_t} \\ 0 &= \ln(B_t) - \ln(B_{t-1}) + v_t \end{aligned} \tag{43}$$

The remainder of the external constraints was introduced in section 4. Table **5** lists all observation equations as a function of the *state* specified in Table **3**. The observation noise term is omitted for convenience.

Table 5

Item	Section	Obs Vector Element	Observation Equation	
1	0	X_t^{ASB}	$X_t^{ASB} = \Delta(X_t) + X_{t-1} + X_{t-4} - X_{t-5}$	$X \in \{H, P, S\}$
2	0	$f_{1_t}^{ASB}$	$f_{1_t}^{ASB} = \Delta(f_{1_t}) + f_{1_{t-1}} + f_{1_{t-4}} - f_{1_{t-5}}$	
3	0	$f_{2_t}^{ASB}$	$f_{2_t}^{ASB} = f_{2_t}$	
4	0	$f_{3_t}^{ASB}$	$f_{3_t}^{ASB} = f_{3_t}$	
5	0	$f_{4_t}^{ASB}$	$f_{4_t}^{ASB} = f_{4_t}$	
6	10.2	X_t^{ADMW}	$X_t^{ADMW} = X_t + u_{X_t}^{ADMW}$	$X \in \{H, P, S\}$
7	10.2	X_t^{ADXX}	$X_t^{ADXX} = X_t + u_{X_t}^{ADXX}$	$X \in \{H, P, S\}$
8	10.2	$\ln\left(\frac{P_t^X}{S_t^X}\right)$	$\ln\left(\frac{P_t^X}{S_t^X}\right) = \ln(P_t) - \ln(S_t)$	$X \in \{ADMW, ADXX\}$
10	0	BSN_t	$BSN_t = \Delta(H_t) + H_{t-4} - H_{t-5} - \Delta(P_t) - P_{t-1} - P_{t-4} + P_{t-5}$	
11	0	$\sum_{k=0}^{1} BSN_{t-k}$	$\sum_{k=0}^{1} BSN_{t-k} = \Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5} - H_{t-2} - \Delta(P_t) - 2P_{t-1} - P_{t-4} + P_{t-5}$	
12	0	$\sum_{k=0}^{3} BSN_{t-k}$	$\sum_{k=0}^{3} BSN_{t-k} = \Delta(H_t) + H_{t-1} - H_{t-5} - \Delta(P_t) - 2P_{t-1} - P_{t-2} - P_{t-3} - P_{t-4} + P_{t-5}$	
13	4.4	$\ln\left(\frac{L_t}{L_{t-4}}\right)$	$\ln\left(\frac{L_t}{L_{t-4}}\right) = \ln\left(\frac{P_{t-2}}{\Delta(P_{t-1}) - P_{t-1} + P_{t-2} + P_{t-5}}\right)$	
14	4.5	$\ln\left(\frac{L_t + L_{t-1}}{L_{t-4} + L_{t-5}}\right)$	See Market Slaughter*	
15	4.6	$\ln\left(\frac{L_{t+1}^{5WK}}{L_{t-3}^{5WK}}\right)$	$\ln\left(\frac{L_{t+1}^{5WK}}{L_{t-3}^{5WK}}\right) = f_{4_t} - f_{4_{t-4}}$	
16	4.7	$\ln(.5)$	$\ln(.5) = \ln\left\{\frac{\Delta(S_t) + S_{t-1} + S_{t-4} - S_{t-5}}{H_{t-1} - \left[(P_{t-1} + C_{t-1})e^{f_{2_{t-1}}} + e^{f_{3_{t-1}}}\right]}\right\}$	
17	10.3.2	0	See Breeding Herd Smoother**	

*Market Slaughter

$$\ln\left(\frac{L_t + L_{t-1}}{L_{t-4} + L_{t-5}}\right) = \ln\left[\frac{(P_{t-2} + C_{t-2})e^{f_{2_{t-2}}} + e^{f_{3_{t-2}}}}{[\Delta(P_{t-1}) - P_{t-1} + P_{t-2} + P_{t-5} + C_{t-6}]e^{f_{2_{t-6}}} + e^{f_{3_{t-6}}}}\right]$$

**Breeding Herd Smoother

$$0 = \ln\left\{\frac{\Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5} - \left[(\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t)e^{f_{2_t}} + e^{f_{3_t}}\right]}{H_{t-1} - \left[(P_{t-1} + C_{t-1})e^{f_{2_{t-1}}} + e^{f_{3_{t-1}}}\right]}\right\}$$

11 Kalman Filter Estimates of U.S. Level Hog Inventories

Given the hog inventory system equations in State-Space form from sections 9 and 10, the Extended Kalman Filter is used to estimate the state *vector and its standard errors. The* state *vector contains functions of inventory items, and the standard errors estimated by the filter are standard errors of the functions of inventory items. This section covers the transformations from* state *vector to U.S.-level inventory items.*

If $t = n$ represents the most recent target survey period of reference, we are interested in estimating the vector

$$q_n = [H_n \quad P_n \quad S_n \quad G_{1_n} \quad G_{2_n} \quad G_{3_n} \quad G_{4_n} \quad M_n \quad B_n \quad T_n]'$$

and its variance. The vector q_n represents all published inventory items from Table 1 at the U.S. level. The vector of *state* elements at time $t = n$ from Table **3** is however

$$x_n = \left[\Delta(H_n) \quad \Delta(P_n) \quad \Delta(S_n) \quad \Delta\left(f_{1_n}\right) \quad f_{2_n} \quad f_{3_n} \quad f_{4_n} \dots\right]'$$

We express the vector of inventory items to be published as a vector of functions of the *state* vector.

$$q_n = F(x_n)$$

The vector of functions $F(x_n)$ contains both linear and nonlinear functions. The Extended Kalman Filter (EKF) uses a first order Taylor Series approximation of the first and second central moments. For linear functions, this will be the exact mean and variance. A first order Taylor Series expansion of hog inventories $q_n = F(x_n)$ about $E[x_n]$ is

$$F(x_n) = F(E[x_n]) + F^{\nabla}(E[x_n])(x_n - E[x_n])$$

where $F^{\nabla}(\cdot)$ represents the Jacobian of $F(\cdot)$. Taking the first order approximation and subtracting its expectation yields

$$F(x_n) - E[F(x_n)] = F^{\nabla}(E[x_n])(x_n - E[x_n])$$
$$var[F(x_n)] = \Sigma_{q_n} = F^{\nabla}(E[x_n])P_n F^{\nabla}(E[x_n])'$$

The first order Taylor Series approximation of q_n and its covariance matrix are therefore

$$q_n = F(E[x_n]) \tag{44}$$
$$\Sigma_{q_n} = J_n P_n J_n' \tag{45}$$

where $J_n = F^{\nabla}(E[x_n])$, and $P_n = E[(x_n - E[x_n])(x_n - E[x_n])']$.

The vector of functions of Kalman Filter estimates of hog inventories $q_t = F(x_t)$ is as follows:

$$H_t = \Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5}$$
$$P_t = \Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5}$$
$$S_t = \Delta(S_t) + S_{t-1} + S_{t-4} - S_{t-5}$$
$$G_{1_t} = \frac{\alpha_t}{\alpha_t - 1}\left[\Delta\left(f_{1_t}\right) + f_{1_{t-1}} + f_{1_{t-4}} - f_{1_{t-5}}\right] + \frac{\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t}{1 - \alpha_t} e^{f_{2_t}}$$
$$G_{2_t} = \frac{1}{1 - \alpha}\left[\Delta\left(f_{1_t}\right) + f_{1_{t-1}} + f_{1_{t-4}} - f_{1_{t-5}}\right] - \frac{\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t}{1 - \alpha_t} e^{f_{2_t}}$$
$$G_{3_t} = -\left[\Delta\left(f_{1_t}\right) + f_{1_{t-1}} + f_{1_{t-4}} - f_{1_{t-5}}\right] + [\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t]e^{f_{2_t}} + e^{f_{3_t}} - e^{f_{4_t}}$$
$$G_{4_t} = e^{f_{4_t}}$$
$$M_t = [\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t]e^{f_{2_t}} + e^{f_{3_t}}$$
$$B_t = \Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5} - \left\{[\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5} + C_t]e^{f_{2_t}} + e^{f_{3_t}}\right\}$$
$$T_t = \frac{\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5}}{\Delta(S_t) + S_{t-1} + S_{t-4} - S_{t-5}}$$

12 State-Level Inventories

This section covers Restricted Least Squares allocation of the Kalman Filter estimates of U.S.-level inventories to the states. State-level survey results must be calibrated to sum to the U.S. estimates for each of the inventory items with the exception of the litter rate.

At the state level, there is no formal ASB panel analogous to the one at the U.S. level. However, the state commodity analysts set a "state recommendation" which most often differs from the survey results. When a state believes its survey results to be biased, they choose to recommend inventory estimates differing from the survey results. This is often due to significant undercoverage or nonresponse from extreme operators – those farms which are so large, they form a majority of the hog production in a given state. The constraints that we have formulated in State-Space representation for the Kalman Filter estimates of U.S.-level hog inventories are U.S.-level constraints. This is attributed to the fact that the external data is available at the U.S. level only. The states' inventory estimates must sum to the U.S.-level inventory estimates for total hogs, pig crop, sows farrowed, the market weight groups, and breeding herd. The state-level estimates must be adjusted for this constraint to hold. This is accomplished using Restricted Least Squares techniques.

We now establish notations and definitions in order to derive the Restricted Least Squares methodology for estimating state-level inventory. The time subscript *t* may be omitted for convenience unless $t \neq n$.

Notation	Definition
$x_{n\|n}$	The expected value of the *state* at time $t = n$ given measurements of the state at time $t \in \{1,2,\dots,n\}$ or $E[x_n \| y_n]$. This is the vector of Kalman Filter estimates of the *state* for the most recent estimation quarter for hog inventory items.
$P_{n\|n}$	The covariance matrix of $x_{n\|n}$ from the Kalman Filter. $P_{n\|n} = E\left[(x_n - x_{n\|n})(x_n - x_{n\|n})' \| y_n\right]$
y_n	Vector of measurements of inventory for time $t = n$.
β_{SV}	Vector of list frame survey results ordered by inventory item and state at time $t = n$.
β_{SV}^*	Vector of list frame survey results ordered by subset of inventory items and state at time $t = n$. The subset of inventory items consists of pig crop (P), sows farrowed (S), market hogs <50 lbs (G1), market hogs 50-119 lbs (G2), market hogs 120-179 lbs (G4), market hogs over 180 lbs (G4), and breeding herd (B).
$\overline{\beta_{SV}^*}$	Vector of list frame survey results ordered by subset of inventory items and state at time $t = n$. The subset of inventory items consists of total hogs and pigs (H), total market hogs (M), and litter rate (T). These are the inventory items that can be derived from β_{SV}^*.
β_{SR}^*	Vector of state recommendations ordered by subset of inventory item and state at time $t = n$. The subset of inventory items consists of pig crop (P), sows farrowed (S), market hogs <50 lbs (G1), market hogs 50-119 lbs (G2), market hogs 120-179 lbs (G3), market hogs over 180 lbs (G4), and breeding herd (B).
β_{KF}	Vector of state-level estimates of inventory derived from the U.S.-level Kalman Filter estimates of inventory using Restricted Least Squares allocation. The vector elements are ordered by inventory item and state.
β_{KF}^*	Vector of state-level estimates of a subset of inventory items derived from the U.S.-level Kalman Filter estimates of inventory using Restricted Least Squares allocation. The vector elements are ordered by inventory item and state. The subset of inventory items consists of pig crop (P), sows farrowed (S), market hogs <50 lbs (G1), market hogs 50-119 lbs (G2), market hogs 120-179 lbs (G4), market hogs over 180 lbs (G4), and breeding herd (B).
$\overline{\beta_{KF}^*}$	Vector of state-level estimates of a subset of inventory items derived from the U.S.-level Kalman Filter estimates of inventory using Restricted Least Squares allocation. The vector elements are ordered by inventory item and state. The subset of inventory items consists of total hogs and pigs (H), total market hogs (M), and litter rate (T).

Notation	Definition
$\delta(\beta^*_{KF})$	The vector of functions that calculates $\overline{\beta^*_{KF}}$ from β^*_{KF}. $$\delta(\beta^*_{KF}) = \begin{bmatrix} B_t + G_{1_t} + G_{2_t} + G_{3_t} + G_{4_t} \\ G_{1_t} + G_{2_t} + G_{3_t} + G_{4_t} \\ \frac{P_t}{S_t} \end{bmatrix} = \begin{bmatrix} H_t \\ M_t \\ T_t \end{bmatrix}$$
$\delta^{\nabla}(\beta^*_{KF})$	The Jacobian of $\delta(\beta^*_{KF})$.
D	Diagonal weight matrix containing the difference $\beta^*_{SR} - \beta^*_{SV}$
q_{SV}	Vector of list frame survey results at the U.S. level at time $t = n$.
q^*_{SV}	Vector of a subset of list frame survey results at the U.S. level at time $t = n$. The subset of inventory items consists of pig crop (P), sows farrowed (S), market hogs <50 lbs (G1), market hogs 50-119 lbs (G2), market hogs 120-179 lbs (G4), market hogs over 180 lbs (G4), and breeding herd (B).
$\overline{q^*_{SV}}$	Vector of a subset of list frame survey results at the U.S. level at time $t = n$. The subset of inventory items consists of total hogs and pigs (H), total market hogs (M), and litter rate (T).
q_{KF}	Vector of Kalman Filter estimates of hog inventory at the U.S. level at time $t = n$. $q_{KF} = F(x_{n\|n})$.
q^*_{KF}	Vector of a subset of Kalman Filter estimates of hog inventory at the U.S. level at time $t = n$. The subset of inventory items consists of pig crop (P), sows farrowed (S), market hogs <50 lbs (G1), market hogs 50-119 lbs (G2), market hogs 120-179 lbs (G4), market hogs over 180 lbs (G4), and breeding herd (B). $q^*_{KF} = F^*(x_{n\|n})$.
$\overline{q^*_{KF}}$	Vector of a subset of Kalman Filter estimates of hog inventory at the U.S. level at time $t = n$. The subset of inventory items consists of total hogs and pigs (H), total market hogs (M), and litter rate (T). $\overline{q^*_{KF}} = \overline{F^*}(x_{n\|n})$
U	A linear operator such that $q^*_{SV} = U\beta^*_{SV}$ and $q^*_{KF} = U\beta^*_{KF}$. $U = [\boldsymbol{I}\otimes\mathbf{1}]'$ where $\mathbf{1}$ is a 50×1 vector of 1s and $\boldsymbol{I}$ is a 7×7 identity matrix representing the seven inventory items $P, S, G_1, G_2, G_3, G_4, B$.
Σ_x	The covariance matrix of x, or $E[(x - E[x])(x - E[x])']$
Σ_{xy}	The covariance matrix of x and y, or $E[(x - E[x])(y - E[y])']$
K_n	The Kalman Gain from the Kalman Filter at time $t = n$.
J_n	The Jacobian of the vector of functions $F(x_{n\|n})$.
J^*_n	The Jacobian of the vector of functions $F^*(x_{n\|n})$
p_j	Pig crop for state j.
s_j	Sows farrowed for state j.
$\sum_j p$	Pig crop at the U.S. level summed over all states.
$\sum_j s$	Sows farrowed at the U.S. level summed over all states.
$\sigma^2_{p_j}$	Variance of list frame survey result for pig crop for state j.
$\sigma^2_{s_j}$	Variance of list frame survey result for sows farrowed for state j.
$\sigma_{p_j s_j}$	Covariance of list frame survey results for pig crop and sows farrowed for state j. $\sigma_{p_j s_j} = \sigma_{s_j p_j}$

We define β_{ij} to be the state-level inventory for inventory item i from Table 1 state j. $\beta = [\beta_{ij}]'$ for $i \in \{1,2,\ldots,10\}$ and $j \in \{1,2,\ldots,50\}$ ordered by i then j. $\beta^* = [\beta_{ij}]'$ for $i \in [2,3,4,5,6,7,9]$. $\overline{\beta^*}$ will be used to denote the complement of β^*. $\beta_{SR} = \beta^*_{SR} \cup \overline{\beta^*_{SR}}$ represents the vector of state recommendations, and $\beta_{SV} = \beta^*_{SV} \cup \overline{\beta^*_{SV}}$ represents the vector of state survey results. We define $U = [I\otimes 1]'$ where 1 is a 50×1 vector of 1s and I is a 7×7 identity matrix. $q^*_{SR} = U\beta^*_{SR}$ is the U.S.-level summed state recommendation vector for the appropriate subset of inventory items and $q^*_{SV} = U\beta^*_{SV}$ is the U.S.-level summed survey results vector of the subset of inventory items. The vector q_{KF} contains all hog inventory items estimated by the Kalman Filter at the U.S. level. The Restricted Least Squares

(RLS) estimate for the Ordinary Least Squares (OLS) regression parameter in the model $y = X\beta + E$ with $E \sim N(0, \Sigma_E)$ is

$$\beta_{RLS} = \beta_{OLS} + (X'X)^{-1}U'[U(X'X)^{-1}U']^{-1}(q - U\beta_{OLS}) \tag{46}$$

A derivation can be found in Green (2000). Equation (46) can be rewritten as

$$\beta_{KF}^{*} = \beta_{SV}^{*} + DU'[UDU']^{-1}(q_{KF}^{*} - U\beta_{SV}^{*}) \tag{47}$$

where $D = diag(\beta_{SR}^{*} - \beta_{SV}^{*})$ is a diagonal weight matrix. This formulation creates the adjustments to the survey results according to the assumed degree of bias. If the state recommendations are the state survey results, the diagonal element or weight is equal to zero and the RLS adjustment is zero. The survey results are published. The degree of adjustment to the survey results is therefore correlated with the assumed bias. The Kalman Filter Restricted Least Squares state-level hog inventory estimates are

$$\begin{aligned} \beta_{KF}^{*} &= (I - ZU)\beta_{SV}^{*} + Zq_{KF}^{*} \\ \overline{\beta_{KF}^{*}} &= \delta(\beta_{KF}^{*}) \\ \beta_{KF} &= [\beta_{KF}^{*} \quad \overline{\beta_{KF}^{*}}]' \end{aligned}$$

where $Z = DU'[UDU']^{-1}$ and $\delta(\cdot)$ is the vector of functions that gives total hogs (summation), total market hogs (summation), and litter rate (ratio of sums). The covariance matrix is given by

$$\begin{aligned} \Sigma_{\overset{*}{KF}} &= (I - ZU)\Sigma_{\overset{*}{SV}}(I - ZU)' + ZJ_n^{*}P_nJ_n^{*\prime}Z' + (I - ZU)\Sigma_{\overset{*}{SV}Y_n}K_n'J_n^{*\prime}Z' + ZJ_n^{*}K_n\Sigma_{Y_n\overset{*}{SV}}(I - ZU)' \\ \Sigma_{\overline{\overset{*}{KF}}} &= \delta^{\nabla}(\beta_{KF}^{*})\Sigma_{\overset{*}{KF}}\delta^{\nabla}(\beta_{KF}^{*})' \\ \Sigma_{\overset{*}{KF}\overline{\overset{*}{KF}}} &= (I - ZU)\left[\Sigma_{\overset{*}{SV}}(I - ZU)' + \Sigma_{\overset{*}{SV}Y_n}K_n'J_n^{*\prime}Z'\right]\delta^{\nabla}(\beta_{KF}^{*})' + Z\left[J_n^{*}K_n\Sigma_{Y_n\overset{*}{SV}}(I - ZU)' + J_n^{*}P_nJ_n^{*\prime}Z'\right]\delta^{\nabla}(\beta_{KF}^{*})' \\ \Sigma_{KF} &= \begin{bmatrix} \Sigma_{\overset{*}{KF}} & \Sigma_{\overset{*}{KF}\overline{\overset{*}{KF}}} \\ \Sigma_{\overline{\overset{*}{KF}}\overset{*}{KF}} & \Sigma_{\overline{\overset{*}{KF}}} \end{bmatrix} \end{aligned}$$

In order to derive the covariance matrix of the state allocation, we first need to derive the covariance of the survey results with the estimated state $\Sigma_{\beta_{SV}^{*}x_{n|n}} = cov(\beta_{SV}^{*}, x_{n|n})$.

Derivation of $\Sigma_{\overset{*}{SV}x_{n|n}}$

$$\begin{aligned} \Sigma_{\beta_{SV}x_{n|n}} &= E\left[(\beta_{SV}^{*} - E[\beta_{SV}^{*}])(x_{n|n} - E[x_{n|n}])'\right] \\ x_{n|n} &= x_{n|n-1} - K_n g(x_{n|n-1}) + K_nY_n \\ E[x_{n|n}] &= E[x_{n|n-1} - K_n g(x_{n|n-1})] + K_nE[Y_n] \\ x_{n|n} - E[x_{n|n}] &= x_{n|n-1} - K_n g(x_{n|n-1}) - E[x_{n|n-1} - K_n g(x_{n|n-1})] + K_n(Y_n - E[Y_n]) \\ \Sigma_{\overset{*}{SV}x_{n|n}} &= \Sigma_{\overset{*}{SV}\ (x_{n|n-1})} + \Sigma_{\overset{*}{SV}Y_n}K_n' \\ &= \Sigma_{\overset{*}{SV}Y_n}K_n' \end{aligned}$$

The final result is because $\Sigma_{SV\ (x_{n|n-1})} = 0$ as the survey results at time *n* are independent and therefore not correlated with the prediction of the *state* at time *n;* nor any function thereof. All terms with $x_{n|n-1}$ are collapsed into the function $\gamma(x_{n|n-1})$. The covariance matrix Σ_{SVY_n} is nonzero for the U.S. survey result observations (sum and litter rate). Otherwise it is zero.

Derivation of $\Sigma_{\ ^{*}_{SV}q^{*}_{KF}}$

$$
\begin{aligned}
\Sigma_{\ ^{*}_{SV}q^{*}_{KF}} &= E[(\beta^{*}_{SV} - E[\beta^{*}_{SV}])(q^{*}_{KF} - E[q^{*}_{KF}])'] \\
q^{*}_{KF} &= F^{*}\left(x_{n|n}\right) \\
q^{*}_{KF} &= F^{*}\left(E\left[x_{n|n}\right]\right) + F^{*\nabla}\left(E\left[x_{n|n}\right]\right)\left(x_{n|n} - E\left[x_{n|n}\right]\right) \\
E[q^{*}_{KF}] &= F^{*}\left(E\left[x_{n|n}\right]\right) \\
q^{*}_{KF} - E[q^{*}_{KF}] &= F^{*\nabla}\left(E\left[x_{n|n}\right]\right)\left(x_{n|n} - E\left[x_{n|n}\right]\right) \\
\Sigma_{\ ^{*}_{SV}q^{*}_{KF}} &= \Sigma_{\ ^{*}_{SV}x_{n|n}} F^{*\nabla}\left(x_{n|n}\right)' \\
&= \Sigma_{\ ^{*}_{SV}Y_n} K'_n J^{*\prime}_n
\end{aligned}
$$

Derivation of $\Sigma_{\ ^{*}_{KF}}$

$$
\begin{aligned}
\Sigma_{\ ^{*}_{KF}} &= E[(\beta^{*}_{KF} - E[\beta^{*}_{KF}])(\beta^{*}_{KF} - E[\beta^{*}_{KF}])'] \\
\beta^{*}_{KF} &= (I - ZU)\beta^{*}_{SV} + Zq^{*}_{KF} \\
E[\beta^{*}_{KF}] &= (I - ZU)E[\beta^{*}_{SV}] + ZE[q^{*}_{KF}] \\
\beta^{*}_{KF} - E[\beta^{*}_{KF}] &= (I - ZU)(\beta^{*}_{SV} - E[\beta^{*}_{SV}]) + Z(q^{*}_{KF} - E[q^{*}_{KF}]) \\
\Sigma_{\ ^{*}_{KF}} &= (I - ZU)\Sigma_{\ ^{*}_{SV}}(I - ZU)' + Z\Sigma_{q^{*}_{KF}}Z' + (I - ZU)\Sigma_{\ ^{*}_{SV}q^{*}_{KF}}Z' + Z\Sigma_{\ ^{*}_{SV}q^{*}_{KF}}(I - ZU)' \\
&= (I - ZU)\Sigma_{\ ^{*}_{SV}}(I - ZU)' + ZJ^{*}_n P_n J^{*\prime}_n Z' + (I - ZU)\Sigma_{\ ^{*}_{SV}Y_n} K'_n J^{*\prime}_n Z' + ZJ^{*}_n K_n \Sigma_{Y_n\ ^{*}_{SV}}(I - ZU)'
\end{aligned}
$$

Derivation of $\Sigma_{\ ^{*}_{SV}\ ^{*}_{KF}}$

$$
\begin{aligned}
\Sigma_{\ ^{*}_{SV}\ ^{*}_{KF}} &= E[(\beta^{*}_{SV} - E[\beta^{*}_{SV}])(\beta^{*}_{KF} - E[\beta^{*}_{KF}])'] \\
(\beta^{*}_{KF} - E[\beta^{*}_{KF}])' &= (\beta^{*}_{SV} - E[\beta^{*}_{SV}])'(I - ZU)' + (q^{*}_{KF} - E[q^{*}_{KF}])'Z' \\
\Sigma_{\ ^{*}_{SV}\ ^{*}_{KF}} &= (\beta^{*}_{SV} - E[\beta^{*}_{SV}])(\beta^{*}_{SV} - E[\beta^{*}_{SV}])'(I - ZU)' + (\beta^{*}_{SV} - E[\beta^{*}_{SV}])(q^{*}_{KF} - E[q^{*}_{KF}])'Z' \\
&= \Sigma_{\ ^{*}_{SV}}(I - ZU)' + \Sigma_{\ ^{*}_{SV}q^{*}_{KF}}Z' \\
&= \Sigma_{\ ^{*}_{SV}}(I - ZU)' + \Sigma_{\ ^{*}_{SV}Y_n} K'_n J^{*\prime}_n Z'
\end{aligned}
$$

Derivation of $\Sigma_{q^{*}_{KF}\ ^{*}_{KF}}$

$$
\begin{aligned}
q^{*}_{KF} - E[q^{*}_{KF}] &= J^{*}_n\left(x_{n|n} - E\left[x_{n|n}\right]\right) \\
(\beta^{*}_{KF} - E[\beta^{*}_{KF}])' &= (\beta^{*}_{SV} - E[\beta^{*}_{SV}])'(I - ZU)' + (q^{*}_{KF} - E[q^{*}_{KF}])'Z' \\
\Sigma_{q^{*}_{KF}\ ^{*}_{KF}} &= J^{*}_n \Sigma_{x_{n|n}\ ^{*}_{SV}}(I - ZU)' + J^{*}_n \Sigma_{x_{n|n}q^{*}_{KF}}Z' \\
&= J^{*}_n K_n \Sigma_{Y_n\ ^{*}_{SV}}(I - ZU)' + J^{*}_n P_n J^{*\prime}_n Z'
\end{aligned}
$$

Derivation of $\Sigma_{\ ^{*}_{KF}\overline{\ ^{*}_{KF}}}$

$$
\begin{aligned}
\Sigma_{\ ^{*}_{KF}\overline{\ ^{*}_{KF}}} &= E\left[(\beta^{*}_{KF} - E[\beta^{*}_{KF}])\left(\overline{\beta^{*}_{KF}} - E\left[\overline{\beta^{*}_{KF}}\right]\right)'\right] \\
\beta^{*}_{KF} - E[\beta^{*}_{KF}] &= (I - ZU)(\beta^{*}_{SV} - E[\beta^{*}_{SV}]) + Z(q^{*}_{KF} - E[q^{*}_{KF}]) \\
\left(\overline{\beta^{*}_{KF}} - E\left[\overline{\beta^{*}_{KF}}\right]\right)' &= (\beta^{*}_{KF} - E[\beta^{*}_{KF}])'\delta^{\nabla}(\beta^{*}_{KF})' \\
\Sigma_{\ ^{*}_{KF}\overline{\ ^{*}_{KF}}} &= (I - ZU)\Sigma_{\ ^{*}_{SV}\ ^{*}_{KF}}\delta^{\nabla}(\beta^{*}_{KF})' + Z\Sigma_{q^{*}_{KF}\ ^{*}_{KF}}\delta^{\nabla}(\beta^{*}_{KF})'
\end{aligned}
$$

$$= (I - ZU)\left[\Sigma_{\underset{SV}{*}}(I - ZU)' + \Sigma_{\underset{SV}{*}Y_n} K_n' J_n^{*\prime} Z'\right]\delta^{\nabla}(\beta_{KF}^{*})'$$
$$+ Z\left[J_n^{*} K_n \Sigma_{Y_n \underset{SV}{*}}(I - ZU)' + J_n^{*} P_n J_n^{*\prime} Z'\right]\delta^{\nabla}(\beta_{KF}^{*})'$$

Derivation of Elements of $\Sigma_{\underset{SV}{*}Y_n}$

The observations that have a nonzero covariance with the survey results are the U.S.-level survey results for pig crop (P), sows farrowed (S), and the litter rate. Table 6 shows the covariance matrix for pig crop, sows farrowed, and the litter rate index by state *j* with the U.S. aggregated survey results.

Table 6

State ADXX Survey Results	**Observations**		
	$\sum_j p$	$\sum_j s$	$\ln\left(\frac{\sum_j p}{\sum_j s}\right)$
p_j	$\sigma_{p_j}^2$	$\sigma_{p_j s_j}$	$\frac{1}{\sum_j p}\sigma_{p_j}^2 - \frac{1}{\sum_j s}\sigma_{s_j p_j}$
s_j	$\sigma_{s_j p_j}$	$\sigma_{s_j}^2$	$\frac{1}{\sum_j p}\sigma_{p_j s_j} - \frac{1}{\sum_j s}\sigma_{s_j}^2$

p_j	Pig crop survey result for state *j*
s_j	Sows farrowed survey result for state *j*
$\sigma_{p_j}^2$	Pig crop survey result variance for state *j*
$\sigma_{s_j}^2$	Sows farrowed survey result variance for state *j*
$\sigma_{p_j s_j} = \sigma_{s_j p_j}$	Covariance of survey results for pig crop and sows farrowed

Table 6 can be derived by using a two-state example and generalizing it to more than two states.
We can then estimate $\Sigma_{F(X)X} = E\{(F[X] - E[F[X]])(X - E[X])'\}$ using the Taylor Series linearization of $\Sigma_{F(X)X} = F^{\nabla}(\mathrm{E}[\mathrm{X}])\Sigma_{\mathrm{X}}$. We define $F(X)$ and X as

$$F(X) = \begin{bmatrix} \sum_j p \\ \sum_j s \\ \ln\left(\frac{\sum_j p}{\sum_j s}\right) \end{bmatrix}, X = \begin{bmatrix} p_1 \\ p_2 \\ s_1 \\ s_2 \end{bmatrix}$$

Using the two-state example, we have

$$F(X) = \begin{bmatrix} \sum_j p \\ \sum_j s \\ \ln\left(\frac{\sum_j p}{\sum_j s}\right) \end{bmatrix} = \begin{bmatrix} 1p_1 + 1p_2 + 0s_1 + 0s_2 \\ 0p_1 + 0p_2 + 1s_1 + 1s_2 \\ \ln\left(\frac{1p_1 + 1p_2 + 0s_1 + 0s_2}{0p_1 + 0p_2 + 1s_1 + 1s_2}\right) \end{bmatrix}$$

Therefore $\Sigma_{F(X)X} = F^{\nabla}(\mathrm{E}[\mathrm{X}])\Sigma_{\mathrm{X}}$

$$F^{\nabla}(\mathrm{E}[\mathrm{X}])\Sigma_{\mathrm{X}} = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ \frac{1}{\sum_j p} & \frac{1}{\sum_j p} & -\frac{1}{\sum_j s} & -\frac{1}{\sum_j s} \end{bmatrix} \begin{bmatrix} \sigma_{p_1}^2 & 0 & \sigma_{p_1 s_1} & 0 \\ 0 & \sigma_{p_2}^2 & 0 & \sigma_{p_2 s_2} \\ \sigma_{s_1 p_1} & 0 & \sigma_{s_1}^2 & 0 \\ 0 & \sigma_{s_2 p_2} & 0 & \sigma_{s_2}^2 \end{bmatrix} =$$

$$\begin{bmatrix} \sigma_{p_1}^2 & \sigma_{p_2}^2 & \sigma_{p_1 s_1} & \sigma_{p_2 s_2} \\ \sigma_{s_1 p_1} & \sigma_{s_2 p_2} & \sigma_{s_1}^2 & \sigma_{s_2}^2 \\ \frac{1}{\sum_j p}\sigma_{p_1}^2 - \frac{1}{\sum_j s}\sigma_{s_1 p_1} & \frac{1}{\sum_j p}\sigma_{p_2}^2 - \frac{1}{\sum_j s}\sigma_{s_2 p_2} & \frac{1}{\sum_j p}\sigma_{p_1 s_1} - \frac{1}{\sum_j s}\sigma_{s_1}^2 & \frac{1}{\sum_j p}\sigma_{p_2 s_2} - \frac{1}{\sum_j s}\sigma_{s_2}^2 \end{bmatrix}$$

These results can be expanded to any number of states.

13 Filter Results

This section provides results for three scenarios of Kalman Filter results. The results are from three different treatments or parameterizations of the ASB estimates in the Filter. For the first, we omit an ASB measurement. For the second treatment, we assume the ASB is biased. For the third treatment, we assume the ASB is unbiased. Details are provided on specific parameterizations of the observations so that it is clear how the treatments differ. Decomposition of the estimates into relative absolute net contributions is explained.

In this paper, we have defined the hog inventory system equations. Their derivations have been presented without any evidence of the performance of Filter inventory estimates by the various parameterizations. Performance can be evaluated more easily when there exist some unbiased measures of the true signal to which we can compare the filter results. Signal Filtering is used in situations where one or more measurements of an unobservable signal are collected, and by the very nature of the problem, the true signal is not available, so a comparison to truth cannot be made. This is the case with hog inventory estimation. As true inventories are not available for comparison, we will compare the Filter estimates to the ASB published, and to each other across treatments; and examine the inventory constraints to judge whether the Filter estimates follow the rules and "make sense". For each of the ten published inventory items; namely total hogs and pigs (H), pig crop (P), sows farrowed (S), market hogs less than 50 lbs (G_1), market hogs between 50 and 119 lbs (G_2), market hogs between 120 and 179 lbs (G_3), market hogs greater than 180 lbs (G_4), total market hogs (M), breeding herd (B), and litter rate (T); we will present graphically the results of a fixed interval Kalman Smoother estimate of inventory for three different parameterizations or treatments of the observations. We will compare the estimates of the variances of the Kalman Smoother estimates between the three treatments. We will also decompose the Smoother at the last point in time $E[x_t|y_n]|t = n$ into what will be defined as absolute relative net contributions from categories of observations. This will provide understanding as to which data items are influential in each treatment of the measurements. Additionally, we will include the estimates of the variances of the process noise and observation noise obtained by the Expectation Maximization algorithm for each of the three treatments. These are the diagonals of the Q and R matrices from sections 8.1 and 8.2, respectively.

13.1 Treatment 1 – No ASB Measurements

The first treatment is the estimation of hog inventories without an ASB measurement. For this scenario, we give the fixed interval Kalman Smoother results based on all of the relationships that the ASB uses to obtain its inventory measurements; however, we omit any expert opinion measurements in the observation vector. Table 7 lists the observation notation and descriptions used in the treatment 1 filter. The third column "Parameterization of Observation Noise" indicates whether observation noise variances are fixed (a hard constraint) or estimated. Fixing the noise variance parameter is the methodology by which a constraint can be strictly enforced. The three, six, and twelve month balance sheet constraints are strictly enforced by the ASB and therefore this behavior is reflected in the filter by fixing associated noise variance parameters so that the solutions' three, six, and twelve month balance sheet residuals are bounded by ± 500 thousand hogs. It is also essential to note that the ASB gives heavy weight to the survey litter rate. Omitting an ASB measurement and estimating the State-Space model parameters without a fixed constraint on the litter rate results in an observation noise estimate for the survey litter rate that is not consistent with ASB behavior. ASB behavior can be reflected in the Filter without ASB measurements by fixing the variance parameter associated with the survey litter rate observation equations. Fixing the variance in this way puts strict bounds on how far the filter estimate for the litter rate will deviate from the survey litter rate. For example, if the variance of the observation noise associated with the survey litter rate were fixed at zero, the filter estimate for the litter rate would be exactly the survey litter rate, and the filter estimates for pig crop and sows farrowed would reflect this. The farther that variance is fixed from zero, the more the filter estimate for litter rate can deviate from the survey litter rate. The breeding herd smoother is an imposed constraint and therefore also fixed. We treat the ratio between survey sows farrowed and previous quarter's breeding herd as unbiased. Although the sows farrowed/breeding herd constraint introduced in section 4.7 equation (9) defines sows farrowed as one half of the previous quarter's breeding herd, the

Figure **25** graph demonstrates that the historical ASB estimates do not agree. As the ASB treats the survey ratio of pig crop to sows farrowed as unbiased, we assume the survey ratio of sows farrowed to previous quarter's breeding herd is also unbiased. It is understood that the breeding herd in the denominator is from a different survey quarter and hence survey result than the numerator since it is lagged one quarter; however, the survey results are similar for the same survey quarter as for the lagged quarter as shown in Figure 35.

Figure 35

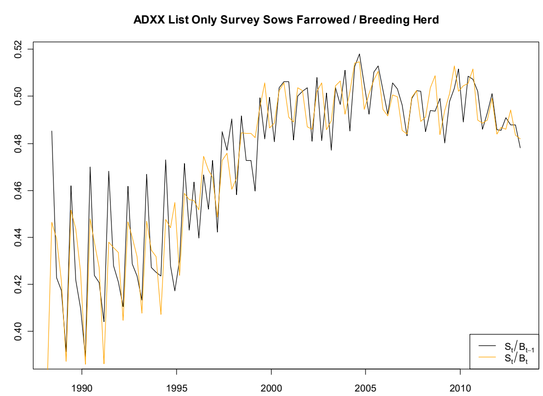


Table 7 below lists the hog inventory measurement notation, description, and how it is parameterized in the treatment. For these three treatment scenarios, we use only the ADXX list frame survey result with the exception of the litter rate. The ADMW multiframe survey result is not computed quarterly for all inventory items and it is sufficient to use the list frame survey result in the treatment scenarios.

Table 7

Notation	Description	Parameterization Of Observation Noise
ADXX.H	List frame survey result for total hogs and pigs	Estimated
ADXX.P	List frame survey result for pig crop	Estimated
ADXX.S	List frame survey result for sows farrowed	Estimated
ADXX.F1	List frame survey result for f_1	Estimated
ADXX.F2	List frame survey result for f_2	Estimated
ADXX.F3	List frame survey result for f_3	Estimated

Notation	Description	Parameterization Of Observation Noise
ADXX.F4	List frame survey result for f_4	Estimated
BSN3	3 Month Balance Sheet Net	Fixed
BSN6	6 Month Balance Sheet Net	Fixed
BSN12	12 Month Balance Sheet Net	Fixed
RATIO.P	Slaughter Ratio – Pig Crop (section 4.4)	Estimated
RATIO.M	Slaughter Ratio – Market Hogs (section 4.5)	Estimated
SL5WKS	5 Week Slaughter Ratio (section 4.6)	Estimated
ADMW.SL	Multiframe Survey result for litter rate	Fixed
ADXX.SL	List frame survey result for litter rate	Fixed
.5	List frame survey result for S_t/B_{t-1}	Fixed
1	Breeding Herd Smoother (section 10.3.2)	Fixed

13.2 Treatment 2 – ASB Measurements as Biased Estimates

For the second scenario, Treatment 2, we add the ASB measurements to the observations and use the parameterization introduced in 10.1.2 which defines the ASB measurements as biased. The other items remain the same.

Table 8

Notation	Description	Parameterization Of Observation Noise
HP	ASB estimate for total hogs and pigs	Estimated
PP	ASB estimate for pig crop	Estimated
SP	ASB estimate for sows farrowed	Estimated
F1.P	ASB estimate for f_1	Estimated
F2.P	ASB estimate for f_2	Estimated
F3.P	ASB estimate for f_3	Estimated
F4.P	ASB estimate for f_4	Estimated
ADXX.H	List frame survey result for total hogs and pigs	Estimated
ADXX.P	List frame survey result for pig crop	Estimated
ADXX.S	List frame survey result for sows farrowed	Estimated
ADXX.F1	List frame survey result for f_1	Estimated
ADXX.F2	List frame survey result for f_2	Estimated
ADXX.F3	List frame survey result for f_3	Estimated
ADXX.F4	List frame survey result for f_4	Estimated
BSN3	3 Month Balance Sheet Net	Fixed
BSN6	6 Month Balance Sheet Net	Fixed
BSN12	12 Month Balance Sheet Net	Fixed
RATIO.P	Slaughter Ratio – Pig Crop (section 4.4)	Estimated
RATIO.M	Slaughter Ratio – Market Hogs (section 0)	Estimated
SL5WKS	5 Week Slaughter Ratio (section 4.6)	Estimated
ADMW.SL	Multiframe Survey result for litter rate	Fixed
ADXX.SL	List frame survey result for litter rate	Fixed
.5	List frame survey result for S_t/B_{t-1}	Fixed
1	Breeding Herd Smoother (section 10.3.2)	Fixed

13.3 Treatment 3 – ASB Measurements as Unbiased Estimates

For Treatment 3, we remove the ASB bias component from the system equations. The filter treats the ASB measurements as unbiased estimates of true inventory. As the ASB estimates are parameterized as unbiased and they give heavy weight to the survey litter rate, there is no longer a need to fix the variances associated with the litter rates noise processes and they are therefore estimated. Lastly, the ratio observation of survey sows farrowed to breeding herd is replaced by the ASB values and the variances is estimated instead of fixed. These changes are bolded in Table 9. All other measurements remain the same.

Table 9

Notation	Description	Parameterization Of Observation Noise
HP	ASB estimate for total hogs and pigs	Estimated
PP	ASB estimate for pig crop	Estimated
SP	ASB estimate for sows farrowed	Estimated
F1.P	ASB estimate for f_1	Estimated
F2.P	ASB estimate for f_2	Estimated
F3.P	ASB estimate for f_3	Estimated
F4.P	ASB estimate for f_4	Estimated
ADXX.H	List frame survey result for total hogs and pigs	Estimated
ADXX.P	List frame survey result for pig crop	Estimated
ADXX.S	List frame survey result for sows farrowed	Estimated
ADXX.F1	List frame survey result for f_1	Estimated
ADXX.F2	List frame survey result for f_2	Estimated
ADXX.F3	List frame survey result for f_3	Estimated
ADXX.F4	List frame survey result for f_4	Estimated
BSN3	3 Month Balance Sheet Net	Fixed
BSN6	6 Month Balance Sheet Net	Fixed
BSN12	12 Month Balance Sheet Net	Fixed
RATIO.P	Slaughter Ratio – Pig Crop (section 4.4)	Estimated
RATIO.M	Slaughter Ratio – Market Hogs (section 0)	Estimated
SL5WKS	5 Week Slaughter Ratio (section 4.6)	Estimated
ADMW.SL	**Multiframe Survey result for litter rate**	**Estimated**
ADXX.SL	**List frame survey result for litter rate**	**Estimated**
.5	**ASB estimate for S_t/B_{t-1}**	**Estimated**
1	Breeding Herd Smoother (section 10.3.2)	Fixed

13.4 Decomposition of $E[x_n|y_n]$ into Absolute Relative Net Contributions

In addition to comparing the fixed interval Kalman Smoother estimates of the *state* and their associated variances, we also examine the decomposition of the estimates. This is a way of comparing between the treatments which observations are most influential. For the sake of simplicity and relevance, we will look at the decomposition of the measurement contributions for the most recent measurement vector in time ($t = n$) for all three treatments and inventory items which are linear functions of the *state*. Specifically these are total hogs and pigs, pig crop, sows farrowed, and the weight group functions (the weight groups themselves are nonlinear functions of the *state*). As a measurement of inventory can have a positive or negative contribution, we will compare the absolute relative net contributions. We categorize the measurements according to measurement type. The six categories are ASB measurements, SURVEY measurements, BALANCE sheet measurements, SLAUGHTER ratio measurements, the cumulative historical contribution which will be explained in this section and which we will call "MODEL", and OTHER measurements.

Table **10** shows the breakdown of observations into categories.

Table 10

Observation	Category
HP	ASB
PP	
SP	
F1.P	
F2.P	
F3.P	
F4.P	
ADXX.H	SURVEY
ADXX.P	
ADXX.S	
ADXX.F1	
ADXX.F2	
ADXX.F3	
ADXX.F4	
ADXX.SL	
ADMW.SL	
BSN3	BALANCE
BSN6	
BSN12	
RATIO.P	SLAUGHTER
RATIO.M	
SL5WKS	
.5	OTHER
1	
	MODEL

The "other" category consists of the sows farrowed/breeding herd ratio and the breeding herd constraint. We define a matrix M where the columns are the six categories and the rows are the observations. The values of M are 1 if the observation belongs to the category and zero otherwise. Define a matrix C where the columns are the seven inventory items H, P, S, F_1, F_2, F_3, and F_4; and the rows are the observations. The values of C contain the contribution of the observations such that the column sums equal the fixed interval Kalman Smoother estimates. Let **1** be a vector of ones with dimensions 6×1 . The absolute relative net contribution by category (ARNC) is then calculated as

$$ARNC = \frac{|M'C|}{\mathbf{11}'|M'C|} \tag{48}$$

The $ARNC$ matrix contains the absolute relative net contributions by inventory item (columns) and category (rows). Note that the brackets in this case stand for the absolute value and not the matrix determinate.

We now derive the matrix C containing the net contribution by inventory item (columns) and observation (rows). For a linear system of transition and observation equations, the Kalman Filter and Kalman smoother at $t = n$ provided in Shumway & Stoffer (2006) is

$$x_{n|n} = x_{n|n-1} + K_n\left(y_n - A_n x_{n|n-1}\right) \tag{49}$$

where $K_n = P_{n|n-1}A'_n\left(A_nP_{n|n-1}A'_n + R\right)^{-1}$ is the Kalman Gain and $P_{n|n-1} = E\left[\left(x_n - x_{n|n-1}\right)\left(x_n - x_{n|n-1}\right)' | y_{n-1}\right]$ is the variance of the *state* prediction $x_{n|n-1}$. We can rewrite equation (49) as

$$x_{n|n} = (I - K_nA_n)x_{n|n-1} + K_ny_n \tag{50}$$

From the State-Space transition equation $x_{n|n-1} = \Phi x_{n-1|n-1}$, we can write equation (50) which is the Kalman Filter and Smoother at $t = n$ as the recursive relationship

$$x_{n|n} = (I - K_nA_n)\Phi x_{n-1|n-1} + K_ny_n \tag{51}$$

The contribution $(I - K_nA_n)\Phi$ in the first term of equation (51) weights the previous quarter's state $x_{n-1|n-1}$, and the contribution K_n from the second term weights the most recent measurements of inventory y_n. As this is a recursive equation, we will show that we can write this equation in terms of all measurements and the initial *state* $x_{0|0}$. We start with the recursive equation (51) and calculate $x_{n-1|n-1}$ as

$$x_{n-1|n-1} = (I - K_{n-1}A_{n-1})\Phi x_{n-2|n-2} + K_{n-1}y_{n-1} \tag{52}$$

Substitution of (52) into (51) yields

$$x_{n|n} = (I - K_nA_n)\Phi(I - K_{n-1}A_{n-1})\Phi x_{n-2|n-2} + (I - K_nA_n)\Phi K_{n-1}y_{n-1} + K_ny_n \tag{53}$$

With an additional third recursion, the pattern is recognizable

$$\begin{aligned} x_{n|n} = {} & (I - K_nA_n)\Phi(I - K_{n-1}A_{n-1})\Phi(I - K_{n-2}A_{n-2})\Phi x_{n-3|n-3} \\ & + (I - K_nA_n)\Phi(I - K_{n-1}A_{n-1})\Phi K_{n-2}y_{n-2} + (I - K_nA_n)\Phi K_{n-1}y_{n-1} + K_ny_n \end{aligned} \tag{54}$$

and it becomes evident that $x_{n|n}$ can be written

$$x_{n|n} = \left[\prod_{k=0}^{n-1}(I - K_{n-k}A_{n-k})\Phi\right]x_{0|0} + \sum_{m=0}^{n-1}\left[\prod_{j=1}^{m}\left(I - K_{n-j+1}A_{n-j+1}\right)\Phi\right]K_{n-m}y_{n-m} \tag{55}$$

For the initial *state* $x_{0|0}$ in equation (55) we are using published data with absolute certainty (initial variance of zero). We will call this $y_0 = x_{0|0}$. The result is that we can write the final Kalman Filter/Fixed interval Smoother estimate at $t = n$ as a "weighted average" of the initial *state* and all measurements.

$$x_{n|n} = \sum_{m=0}^{n}\lambda_m y_{n-m} \tag{56}$$

$$\lambda_m = \begin{cases} K_{n-m} & m = 0 \\ \left[\prod_{j=1}^{m}\left(I - K_{n-j+1}A_{n-j+1}\right)\Phi\right]K_{n-m} & 0 < m < n \\ \prod_{k=0}^{n-1}(I - K_{n-k}A_{n-k})\Phi & m = n \end{cases} \tag{57}$$

The interpretation is that the estimate $x_{n|n}$ is a composite of the initial *state* and all measurements in time weighted by the state-space model parameters. For an analysis of the decomposition, we will partition out from the summation in equation (56) the most recent data vector at $m = 0$

$$x_{n|n} = K_n y_n + \sum_{m=1}^{n} \lambda_m y_{n-m} \tag{58}$$

The first term of equation (58) is the contribution of the most recent measurement vector y_n; the second term is the composite contribution from the initial *state* and historical measurement vectors. This aggregate contribution of the historical observations is the "Model" category for the absolute relative net contributions. Each term's contribution in the summation could be calculated using the appropriate λ_m. For the nonlinear version of the decomposition, we have the Filter equations

$$\begin{aligned} x_{n|n} &= x_{n|n-1} + K_n\left[y_n - H\left(x_{n|n-1}\right)\right] \\ x_{n|n-1} &= G\left(x_{n-1|n-1}\right) \end{aligned} \tag{59}$$

The result is the recursion equation

$$\begin{aligned} x_{n|n} &= G\left(x_{n-1|n-1}\right) + K_n\left\{y_n - H\left[G\left(x_{n-1|n-1}\right)\right]\right\} \\ &= G\left(x_{n-1|n-1}\right) - K_n H\left[G\left(x_{n-1|n-1}\right)\right] + K_n y_n \\ &= J\left(x_{n-1|n-1}\right) + K_n y_n \end{aligned} \tag{60}$$

where $K_n y_n$ contains the contribution of the most recent data and $J\left(x_{n-1|n-1}\right)$ contains the contributions of cumulative past measurements analogous with the linear weighted average component $\sum_{m=1}^{n} \lambda_m y_{n-m}$. The contribution matrix is calculated as

$$C = \left[(K_n \times 1y_n')||(I - K_n A^*)x_{n|n-1}\right]' A^{*\prime} \tag{61}$$

where $\times$ is the elementwise multiplication operator, $||$ appends matrix columns, 1 is an $m \times 1$ vector of ones in which m is the dimension of the *state*, and A^* represents the linear transformation for which $A^* x_{n|n} = \left[H_n\; P_n\; S_n\; f_{1_n}\; f_{2_n}\; f_{3_n}\; f_{4_n}\right]'$. Substitution of (**61**) into (**48**) gives the Absolute Relative Net Contribution matrix.

$$ARNC = \frac{\left|M'\left[(K_n \times 1y_n')||(I - K_n A^*)x_{n|n-1}\right]' A^{*\prime}\right|}{\mathbf{11}'\left|M'\left[(K_n \times 1y_n')||(I - K_n A^*)x_{n|n-1}\right]' A^{*\prime}\right|} \tag{62}$$

13.5 Contribution Tables

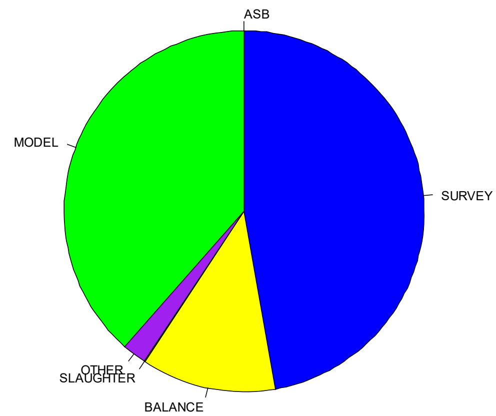
The remainder of this paper contains the results of hog inventory estimation through Signal Filtering based on the three treatments defined in sections 13.1 - 13.3. Table 11 contains the relative absolute net contribution tables for each of the three treatments by categorized measurements; ASB, survey, balance sheet data, slaughter data, other (composed of sows to breeding herd ratio and breeding herd smoother), and historical observations (called "Model") . Following these tables are graphs of the estimates and charts of the contribution allocations organized by inventory item, as well as graphs of the constraints. It should be noted that because the natural log of 1 is zero, the contribution of the breeding herd smoother is incalculable.

Table 11

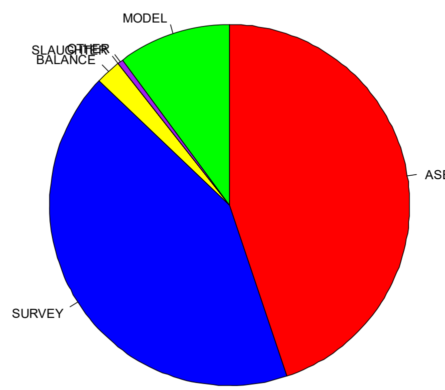
No ASB							
	H	P	S	F1	F2	F3	F4
ASB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SURVEY	29.75	36.89	41.09	20.54	47.36	95.09	59.95
BALANCE	30.55	14.91	11.00	20.09	5.12	1.16	1.41
SLAUGHTER	0.38	0.06	0.05	0.18	0.01	0.06	0.10
OTHER	4.82	2.76	2.09	4.56	0.03	0.50	0.27
MODEL	34.49	45.38	45.77	54.64	47.49	3.19	38.27
ASB Biased							
	H	P	S	F1	F2	F3	F4
ASB	47.28	38.18	37.14	42.94	45.50	67.33	35.50
SURVEY	42.56	43.53	45.40	43.38	49.62	10.35	61.10
BALANCE	0.86	3.22	2.35	1.30	1.48	3.24	3.16
SLAUGHTER	0.03	0.02	0.02	0.03	0.01	0.02	0.05
OTHER	0.38	0.74	0.62	0.61	0.28	0.59	0.02
MODEL	8.88	14.30	14.47	11.74	3.11	18.48	0.16
Unbiased ASB							
	H	P	S	F1	F2	F3	F4
ASB	32.11	9.87	34.43	17.45	42.57	72.76	44.75
SURVEY	31.20	62.25	32.61	74.13	49.89	8.03	11.65
BALANCE	7.58	4.90	3.17	2.03	1.28	1.92	0.83
SLAUGHTER	0.25	0.20	0.17	0.16	0.00	0.04	0.09
OTHER	0.01	0.00	0.00	0.00	0.00	0.00	0.00
MODEL	28.85	22.78	29.61	6.24	6.25	17.25	42.68

Table 12: Summary Contribution Equally Weighted over all Inventory Intentory Items

#1: No ASB	***Min***	***Mean***	***Max***
ASB	0.00	0.00	0.00
SURVEY	20.54	47.24	95.09
BALANCE	1.16	12.03	30.55
SLAUGHTER	0.01	0.12	0.38
OTHER	0.03	2.15	4.82
MODEL	3.19	38.46	54.64



#2: ASB Biased	***Min***	***Mean***	***Max***
ASB	35.50	44.84	67.33
SURVEY	10.35	42.28	61.10
BALANCE	0.86	2.23	3.24
SLAUGHTER	0.01	0.03	0.05
OTHER	0.02	0.46	0.74
MODEL	0.16	10.16	18.48



#3: ASB Unbiased	***Min***	***Mean***	***Max***
ASB	9.87	36.28	72.76
SURVEY	8.03	38.54	74.13
BALANCE	0.83	3.10	7.58
SLAUGHTER	0.00	0.13	0.25
OTHER	0.00	0.00	0.01
MODEL	6.24	21.95	42.68

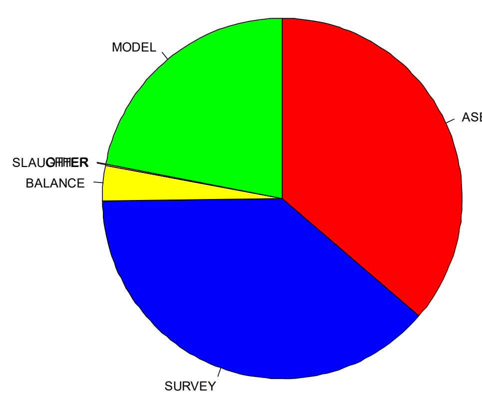


Figure 36: Total Hogs and Pigs

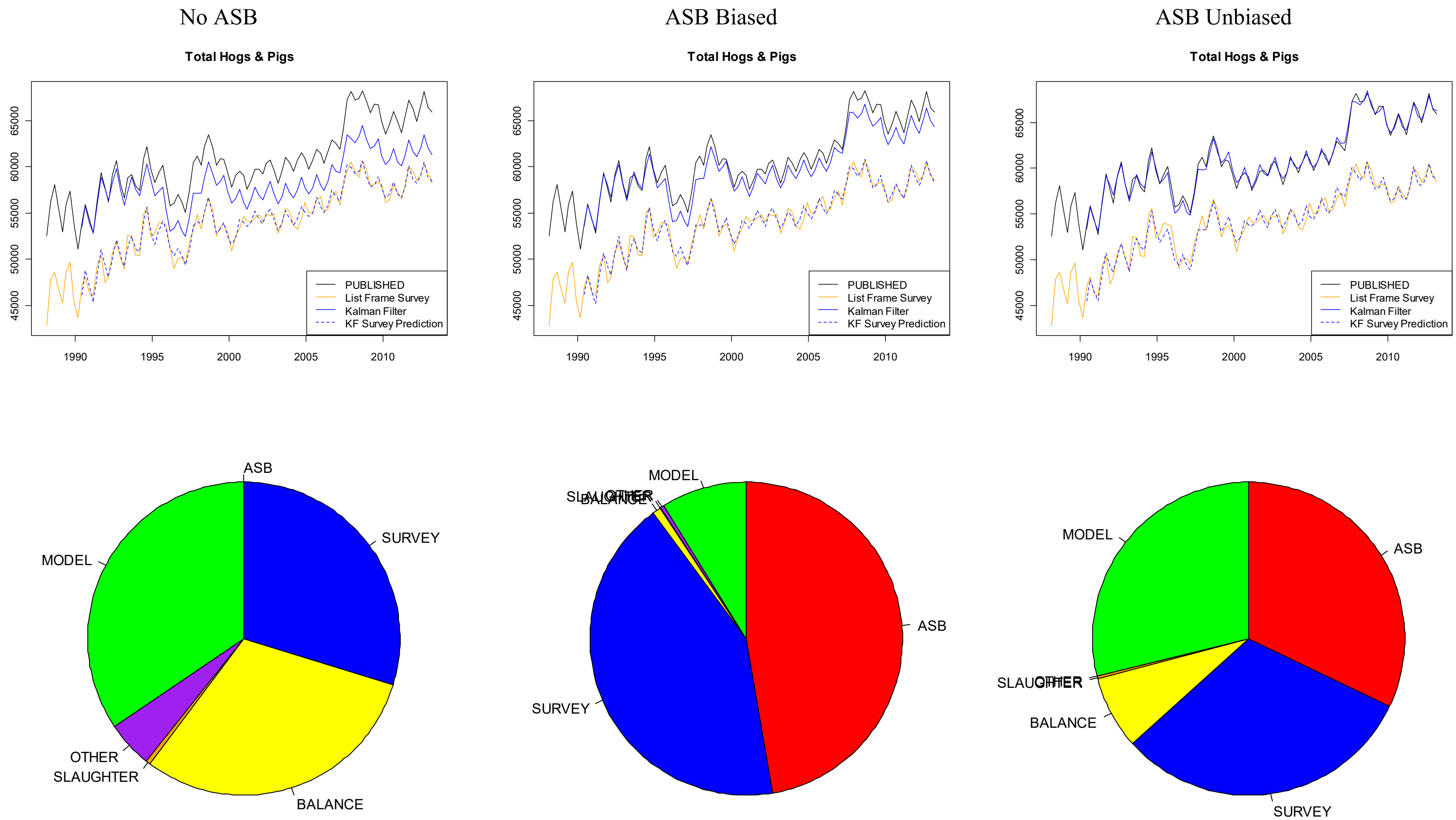


Figure 37: Pig Crop

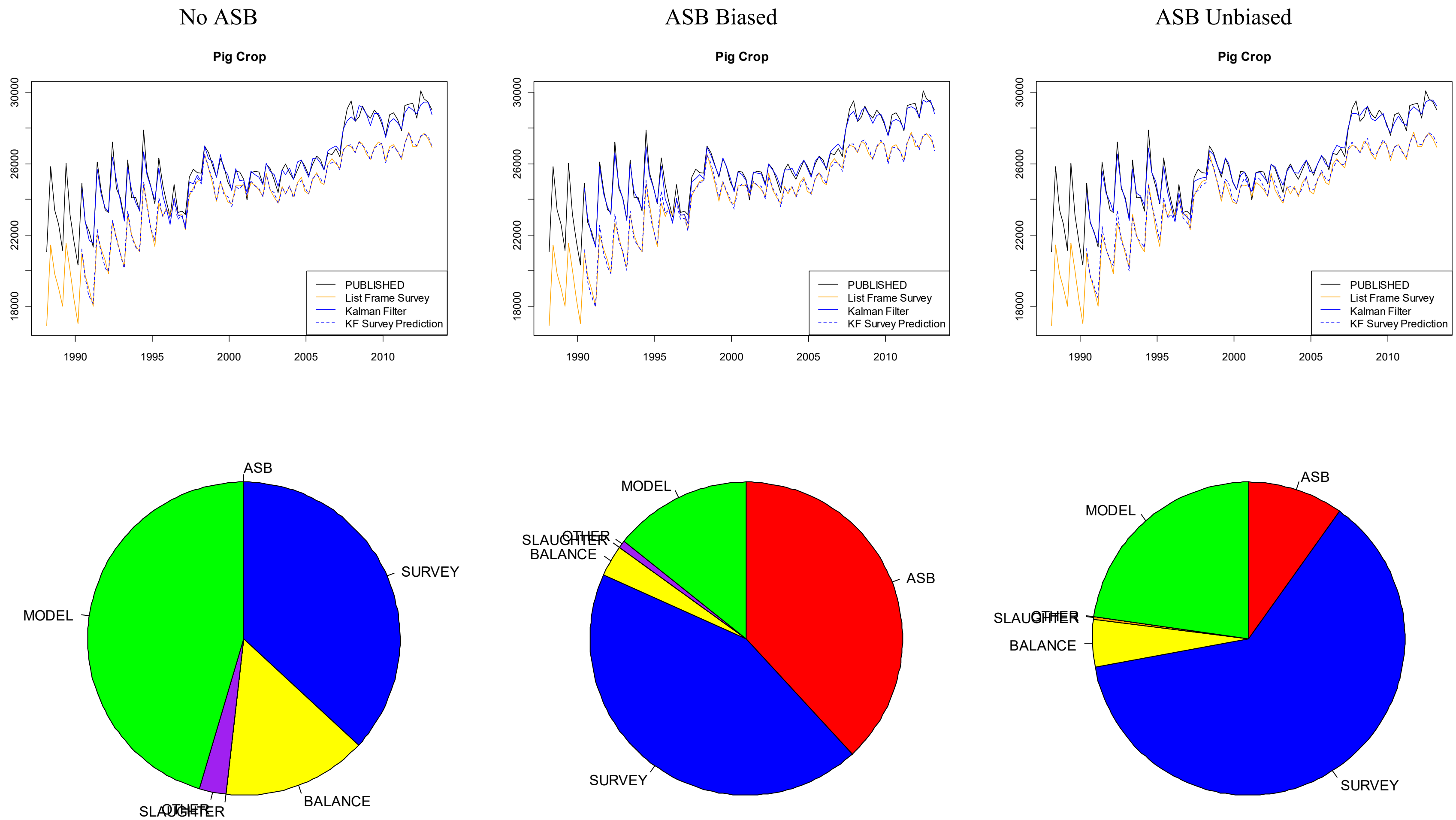
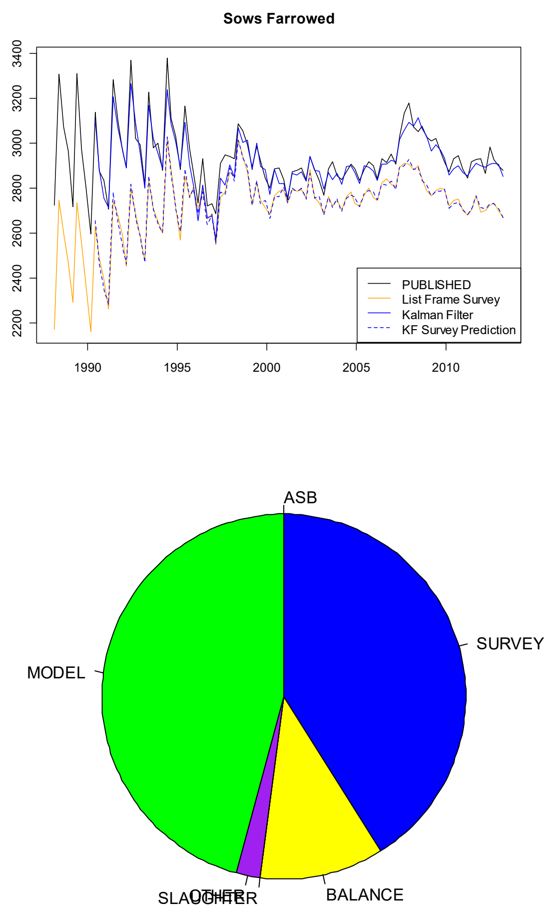
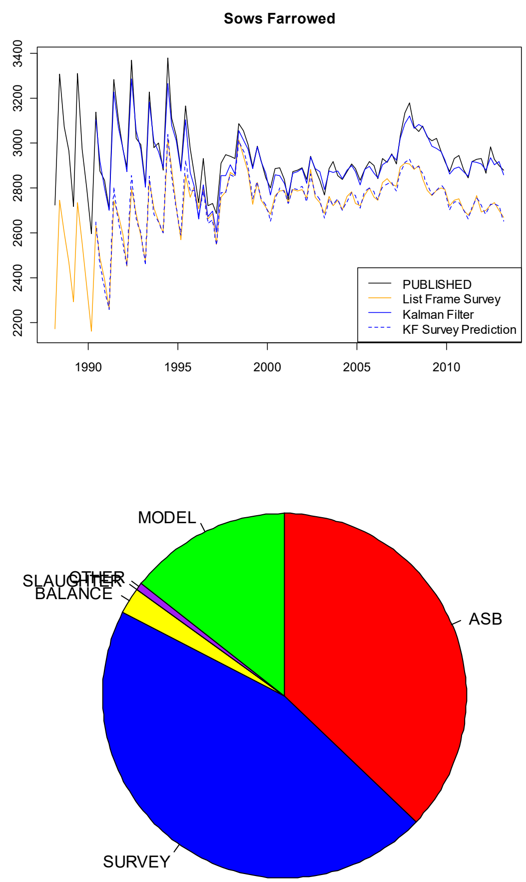


Figure 38: Sows Farrowed

No ASB



ASB Biased



ASB Unbiased

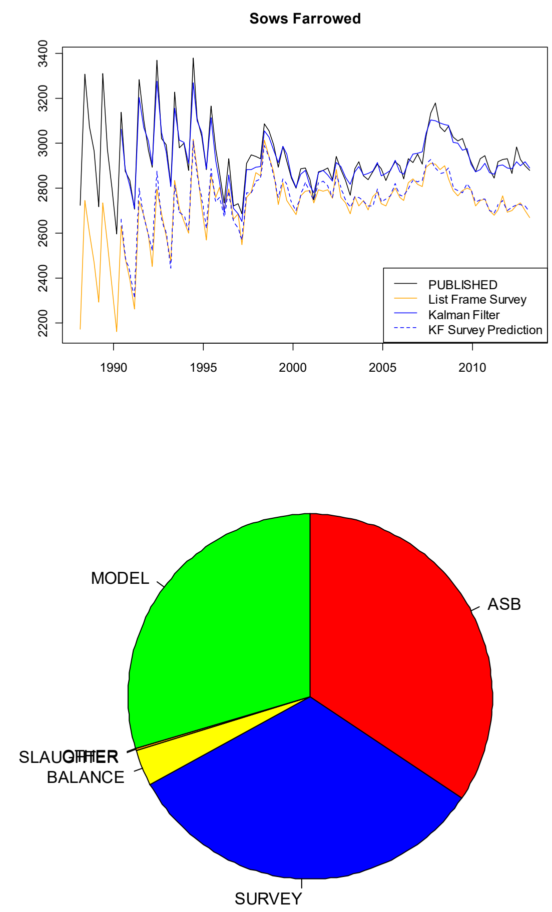


Figure 39: Weight Group Function 1

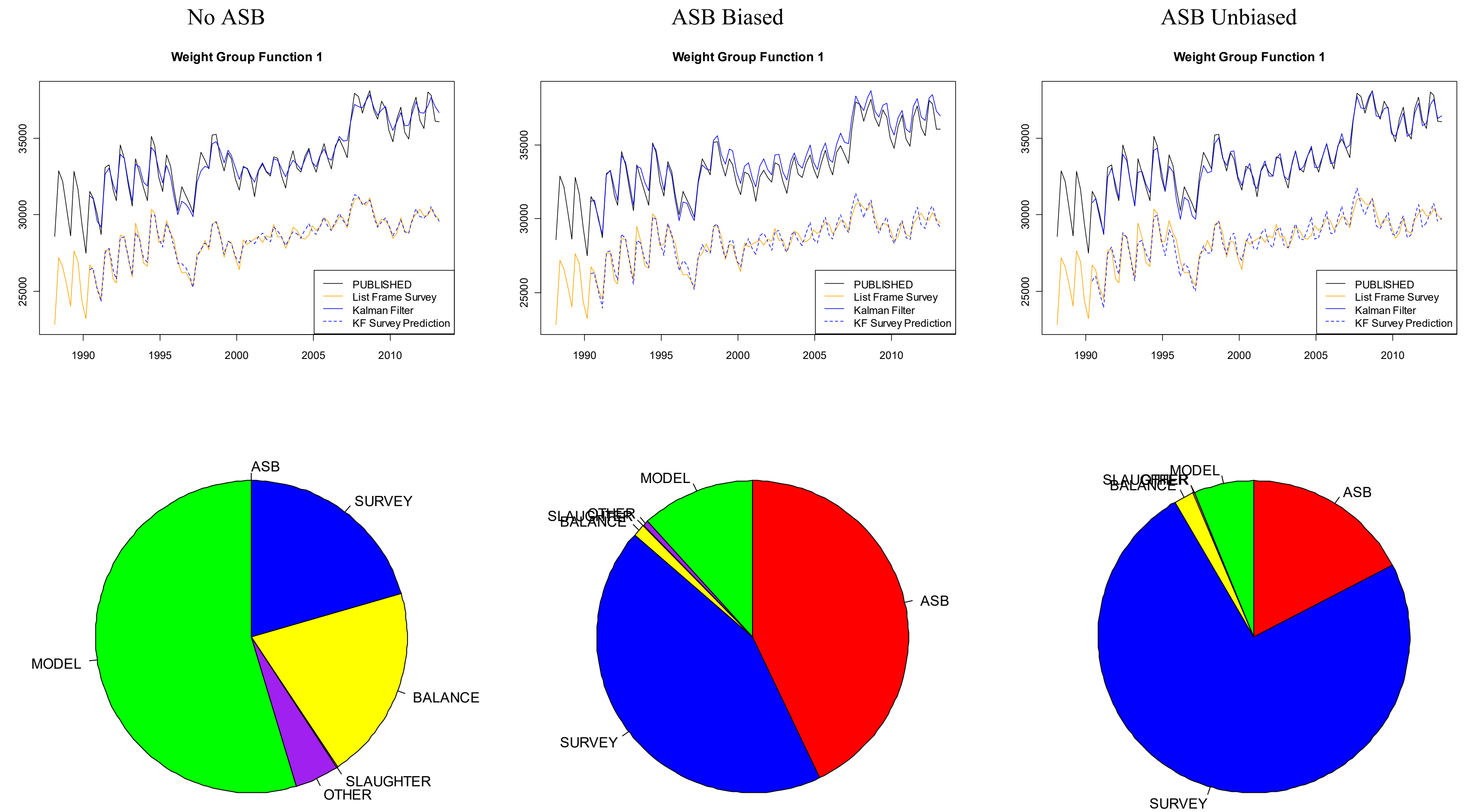


Figure 40: Weight Group Function 2

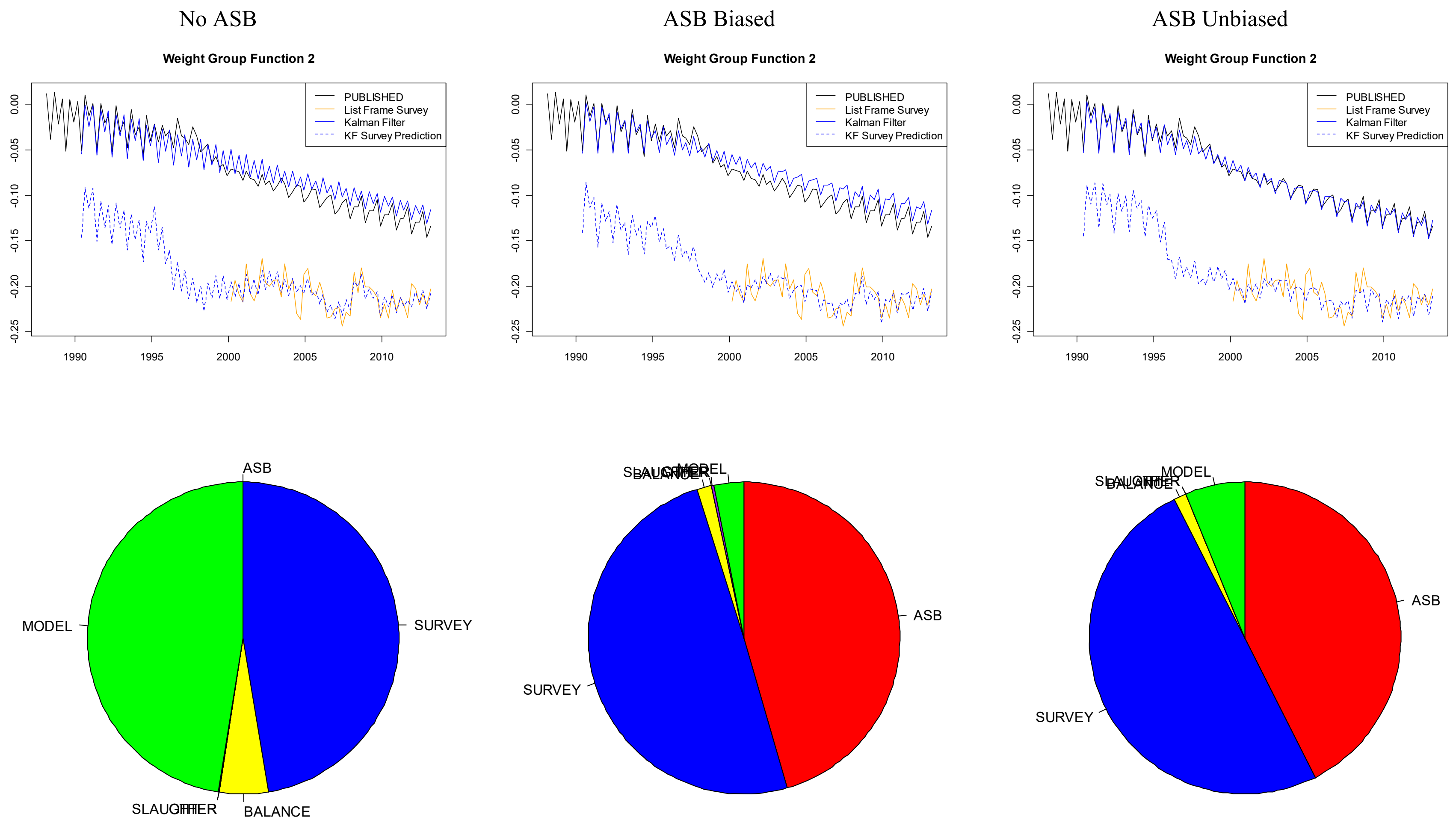


Figure 41: Weight Group Function 3

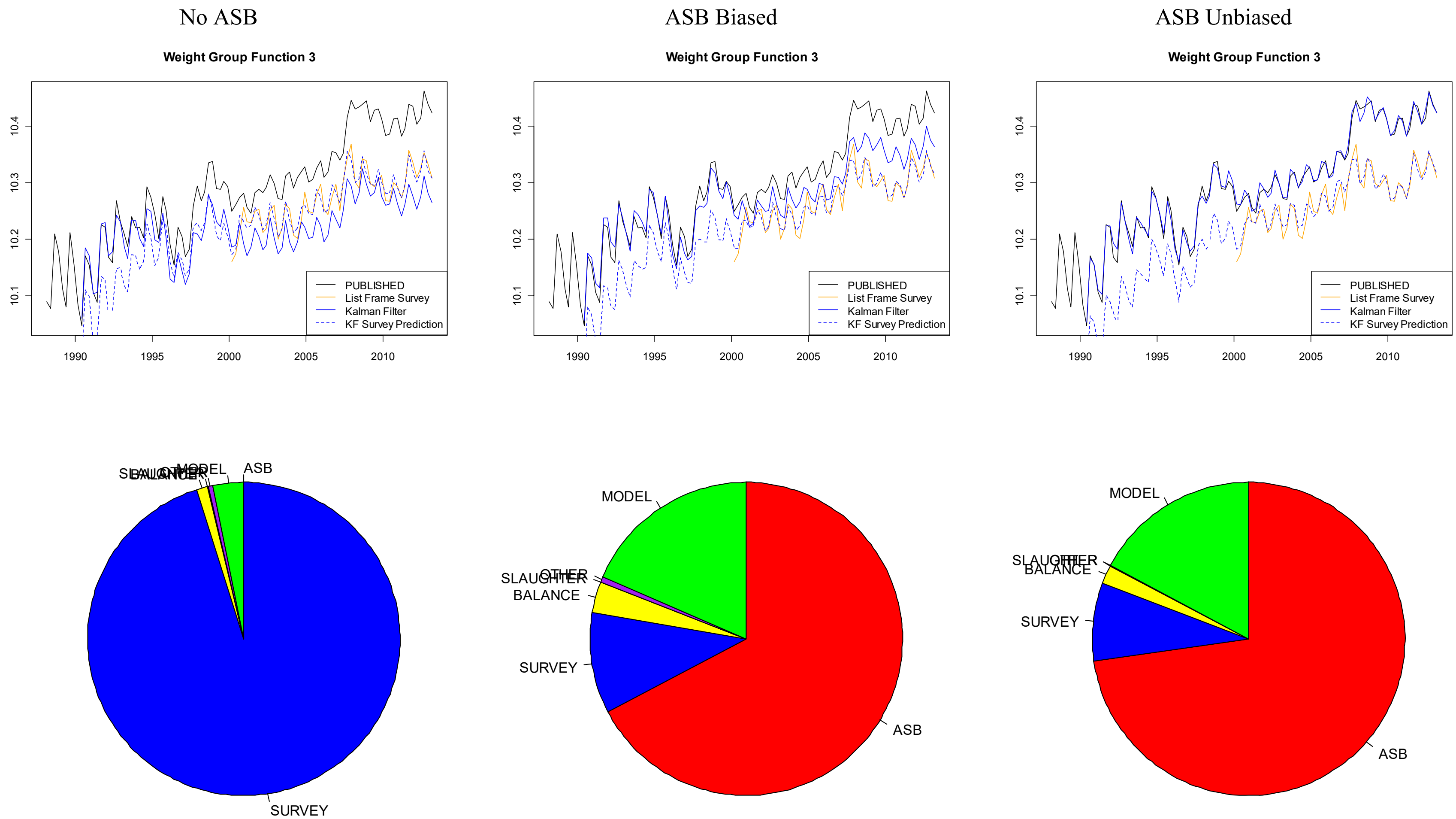


Figure 42: Weight Group Function 4

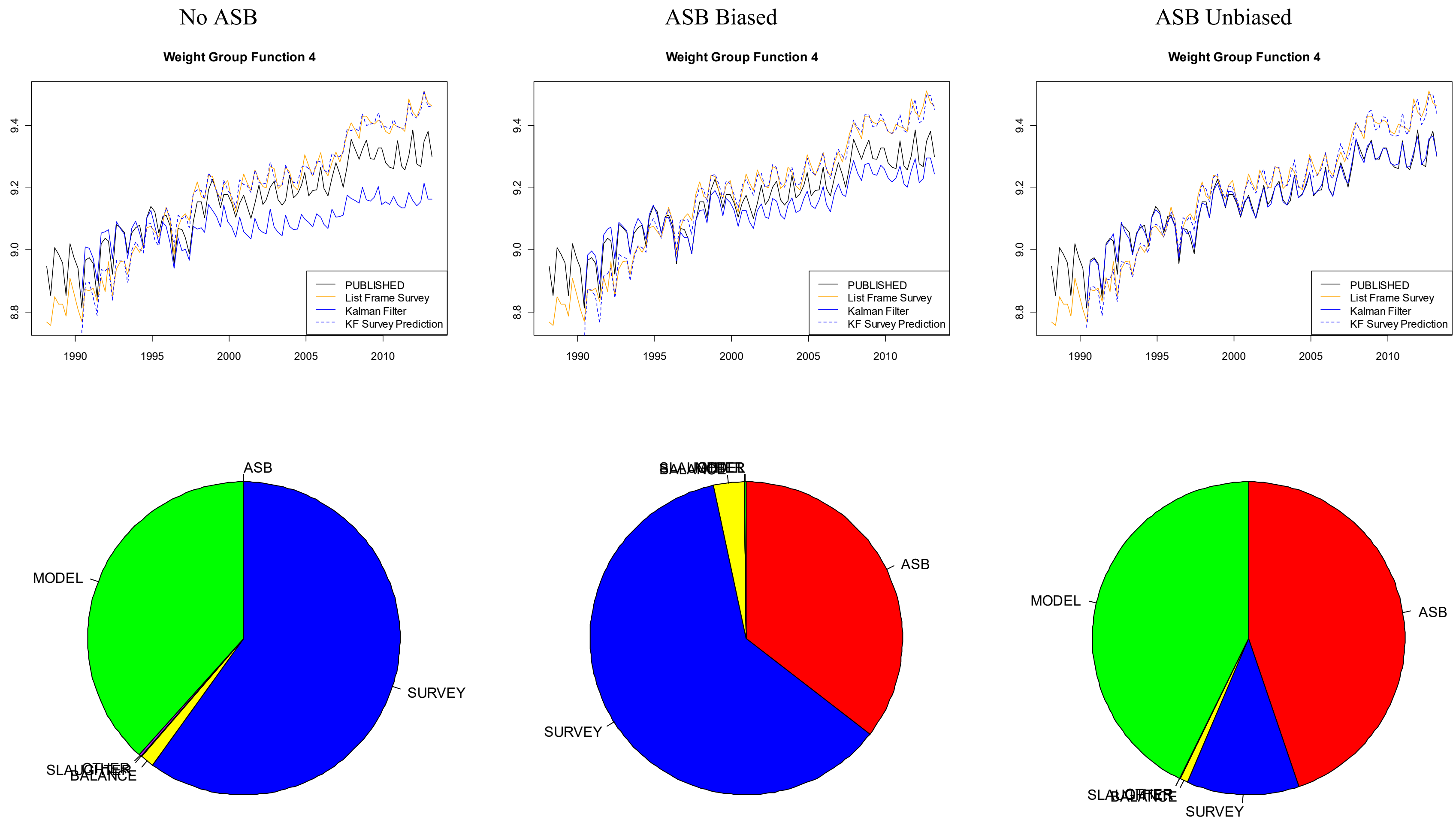
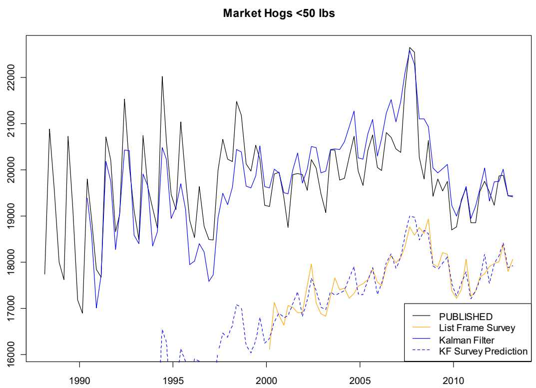
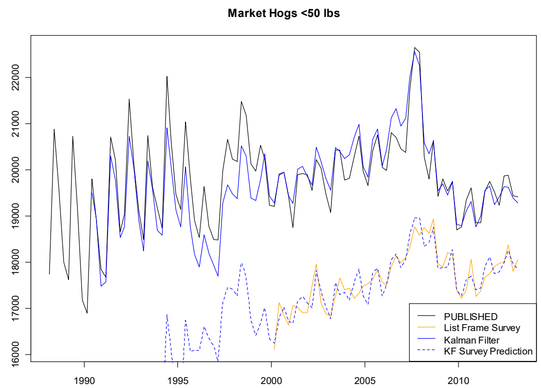


Figure 43: Market Hogs Less <50 lbs

No ASB



ASB Biased



ASB Unbiased

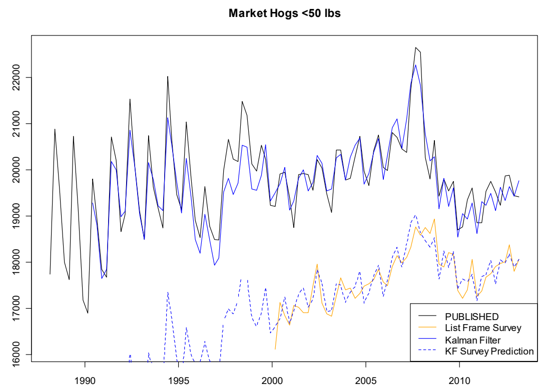
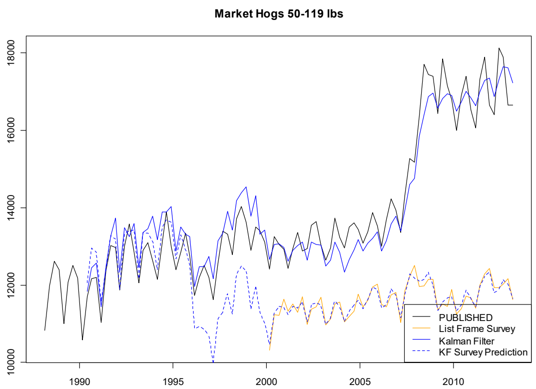
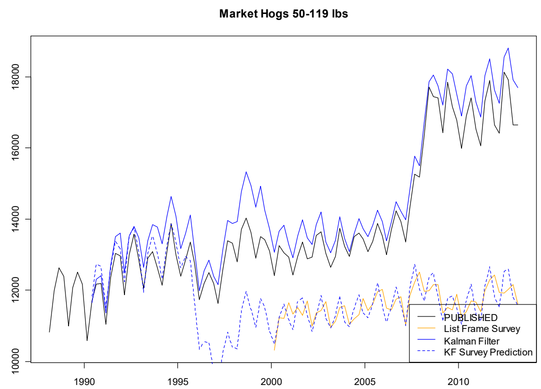


Figure 44: Market Hogs 50-119 lbs

No ASB



ASB Biased



ASB Unbiased

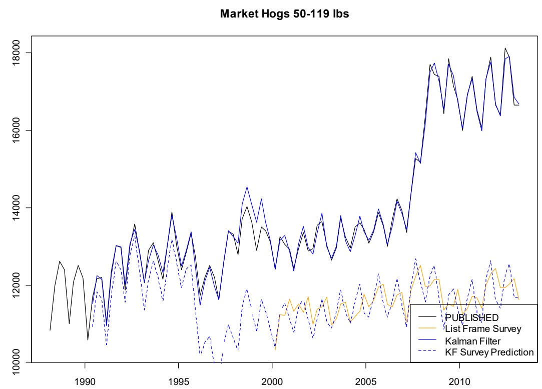


Figure 45: Market Hogs 120-179 lbs

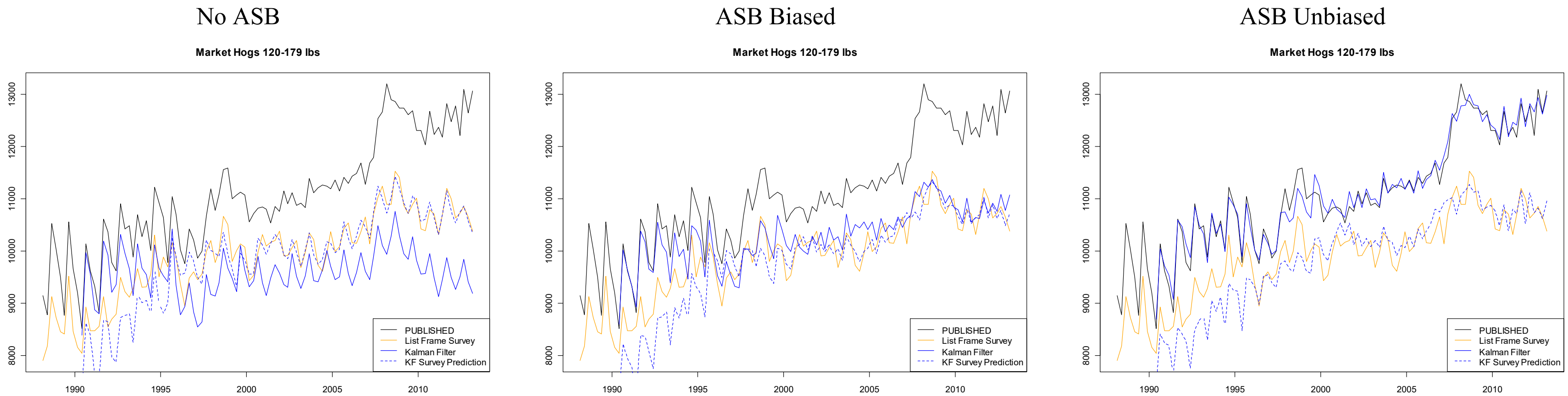


Figure 46: Market Hogs 180+ lbs

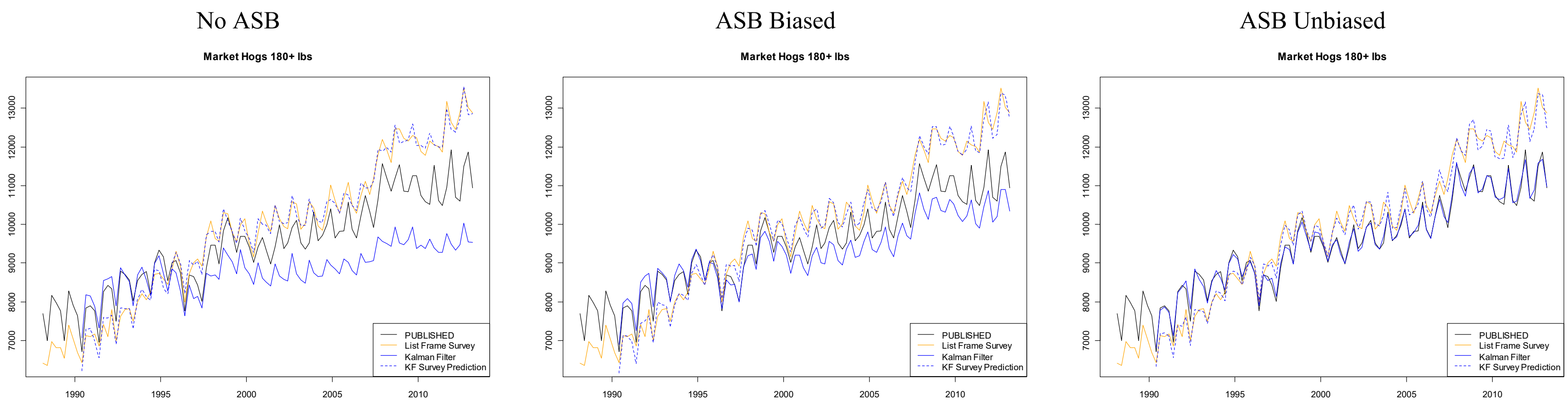
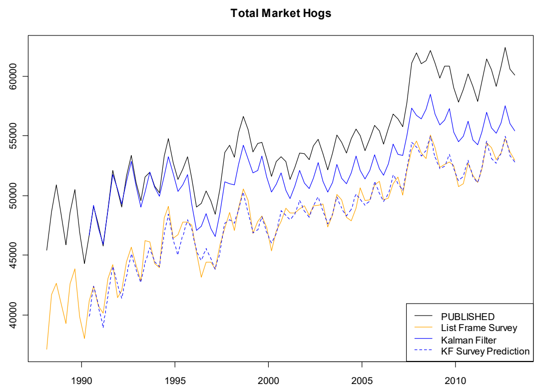
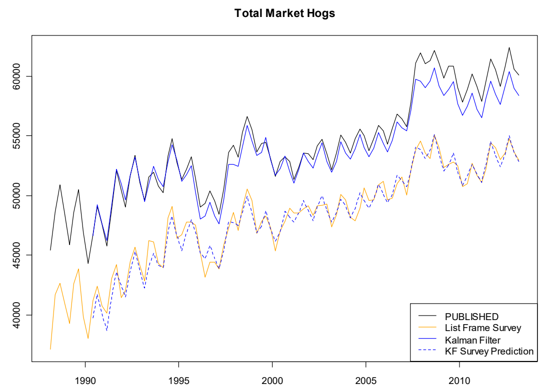


Figure 47: Total Market Hogs

No ASB



ASB Biased



ASB Unbiased

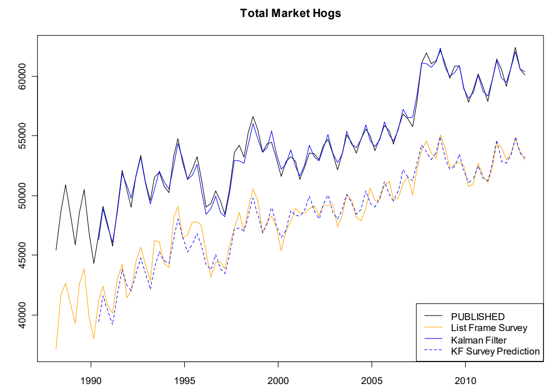
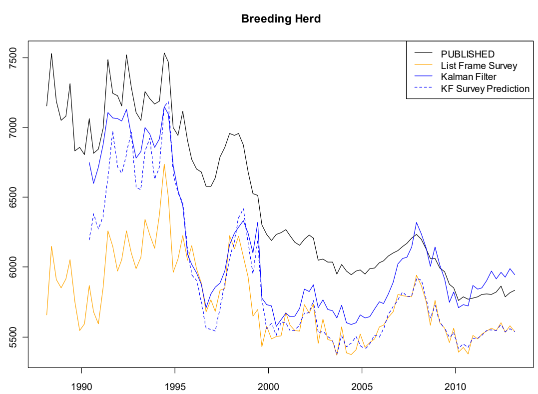
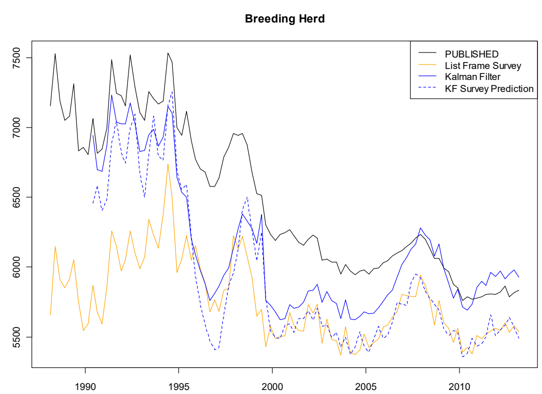


Figure 48: Breeding Herd

No ASB



ASB Biased



ASB Unbiased

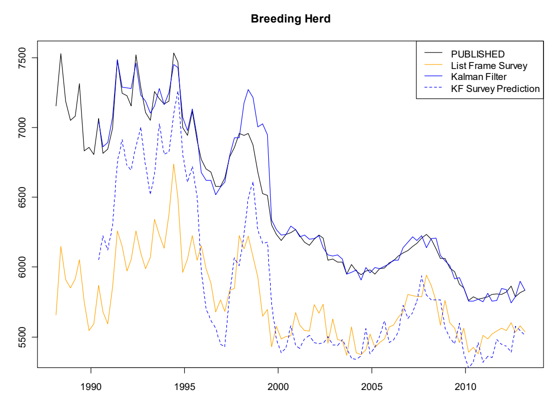


Figure 49: Litter Rate

No ASB | ASB Biased | ASB Unbiased

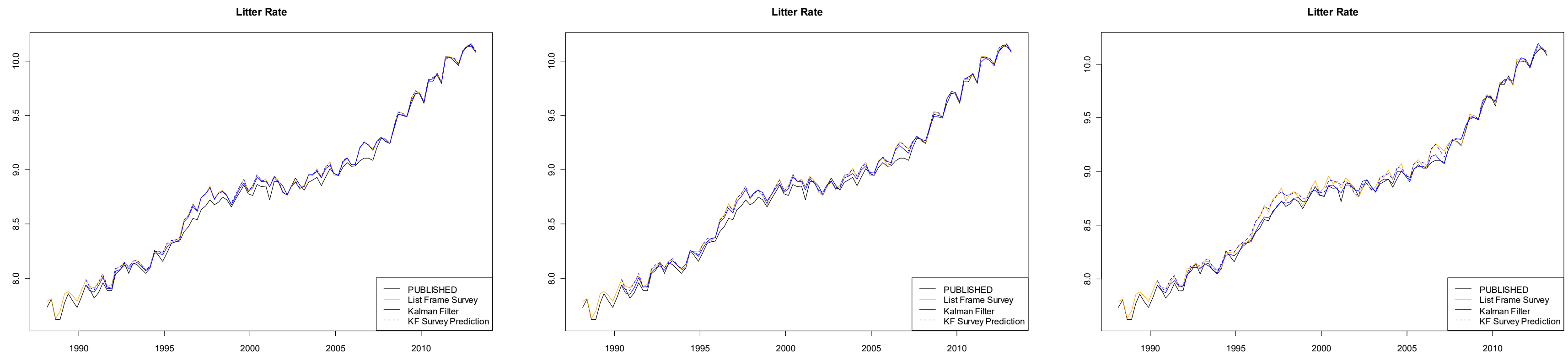


Figure 50: Death Loss Ratio

No ASB | ASB Biased | ASB Unbiased

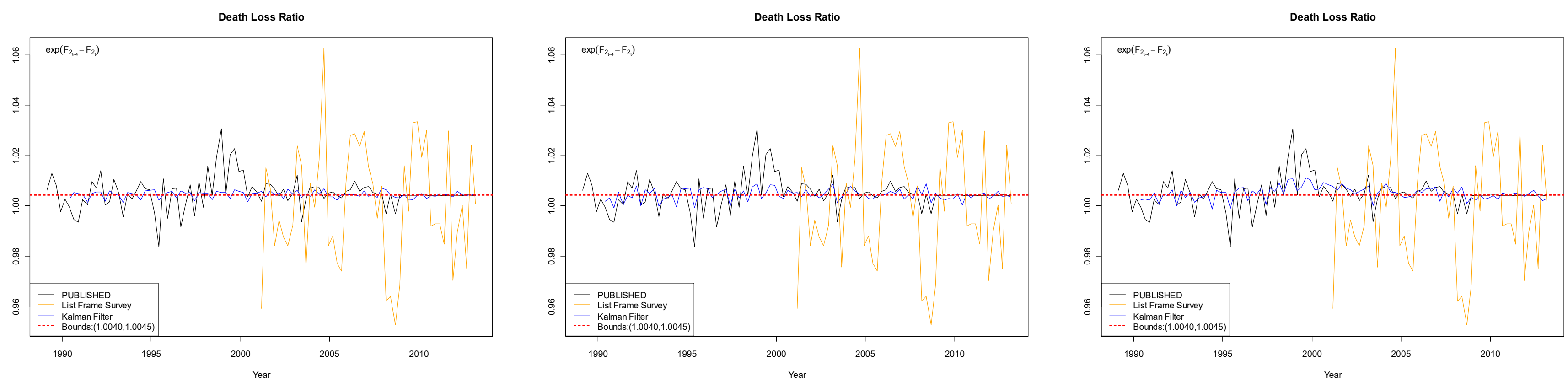


Figure 51: Weight Group Ratio Transition

No ASB | ASB Biased | ASB Unbiased

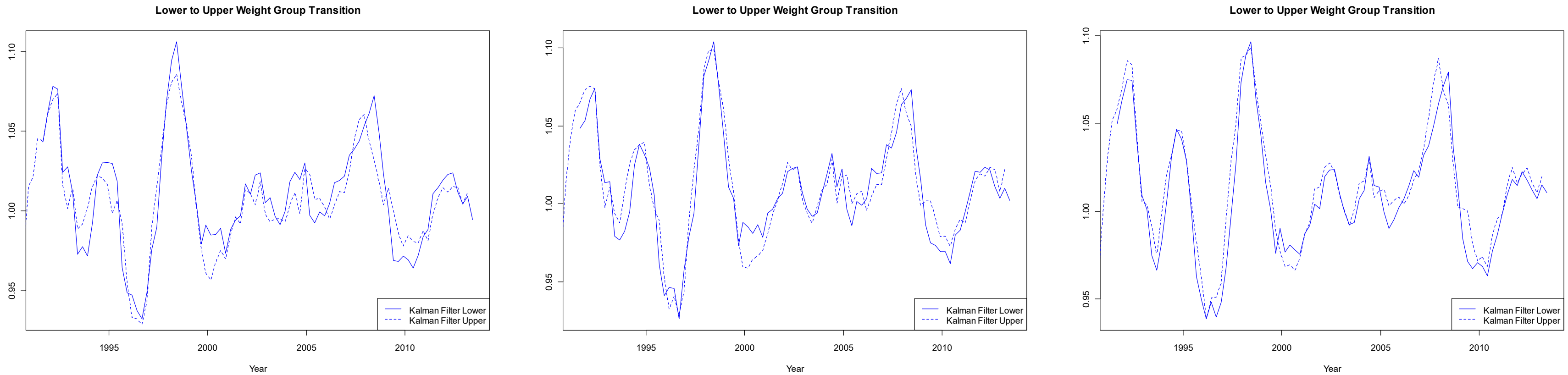


Figure 52: Pig Crop and Slaughter Ratio

No ASB | ASB Biased | ASB Unbiased

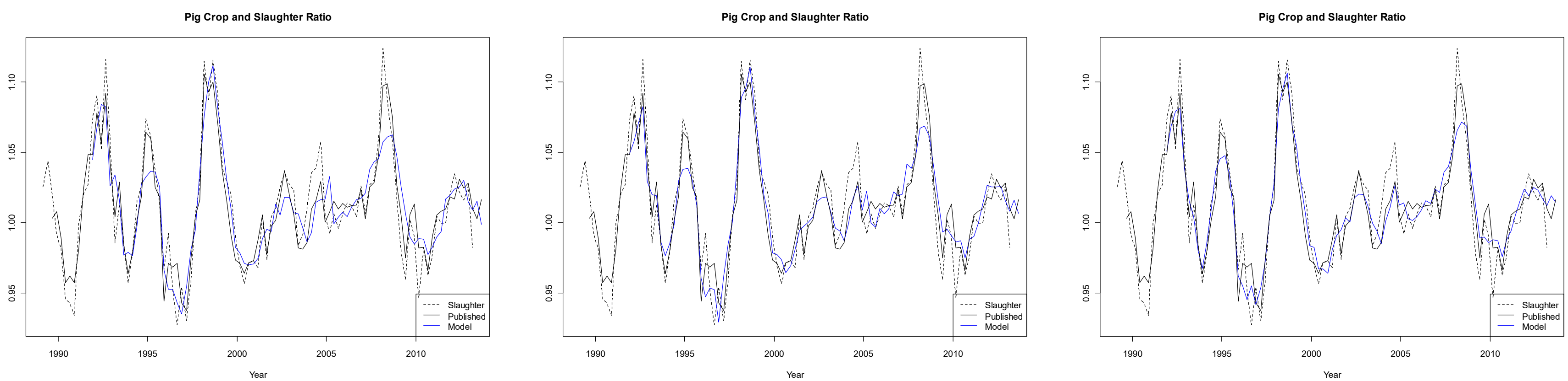
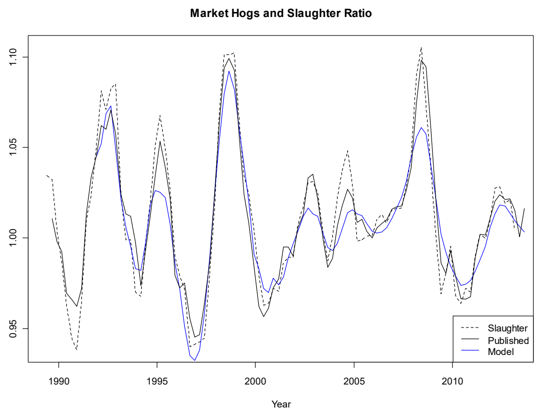
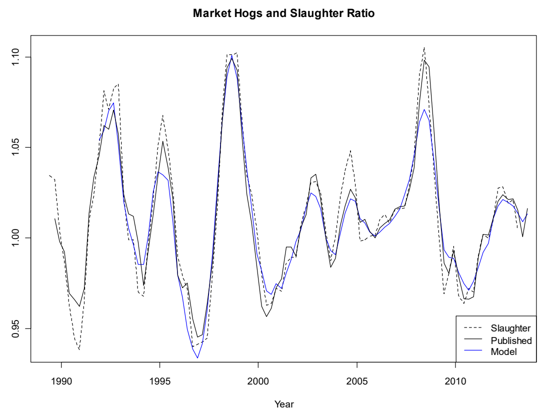


Figure 53: Market Hogs and Slaughter Ratio

No ASB



ASB Biased



ASB Unbiased

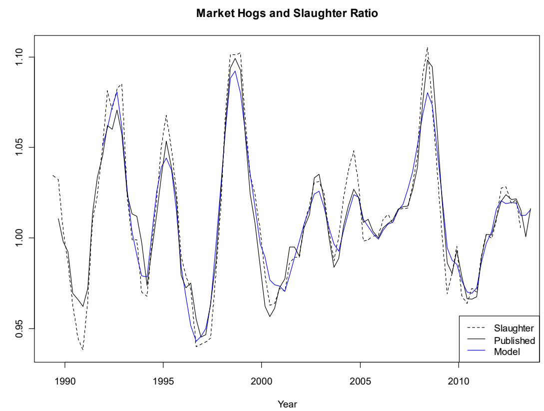
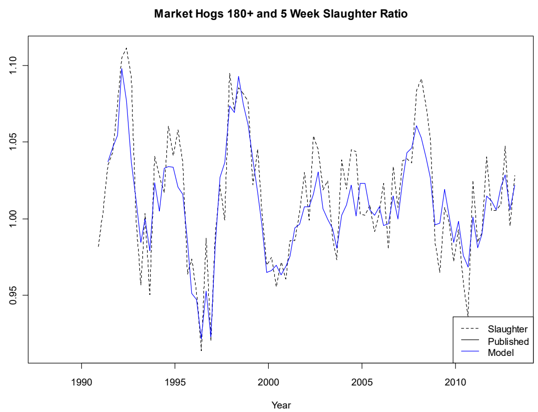
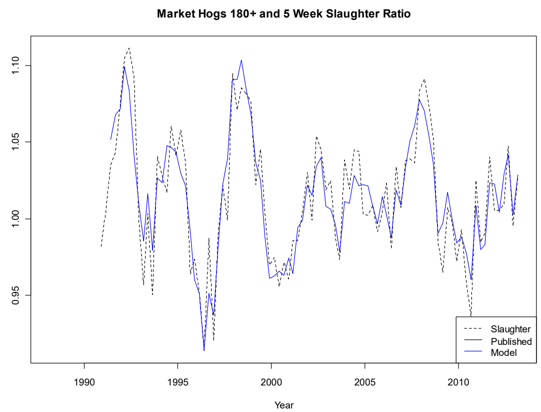


Figure 54: Market Hogs 180+ and Slaughter Ratio

No ASB



ASB Biased



ASB Unbiased

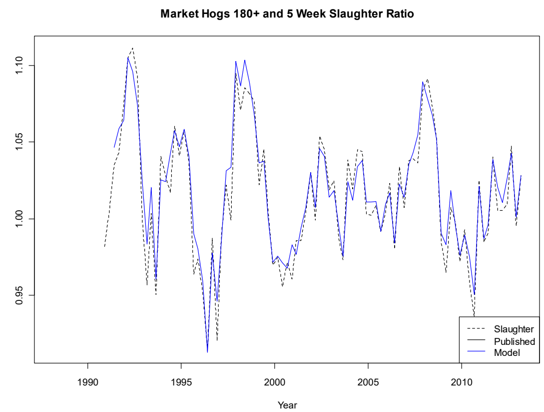


Figure 55: Three Month Balance Sheet Residual

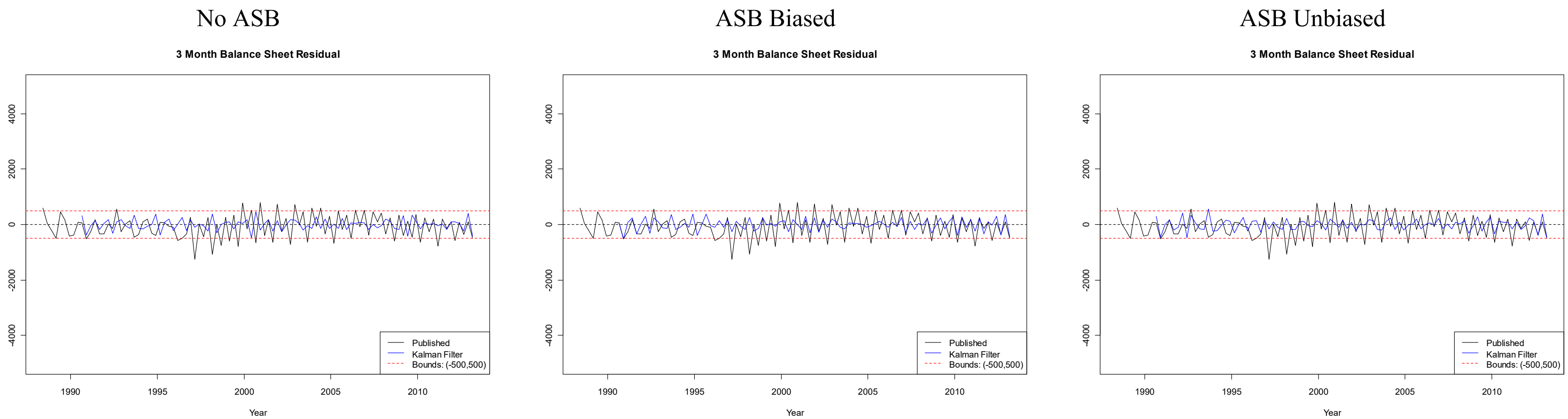


Figure 56: Six Month Balance Sheet Residual

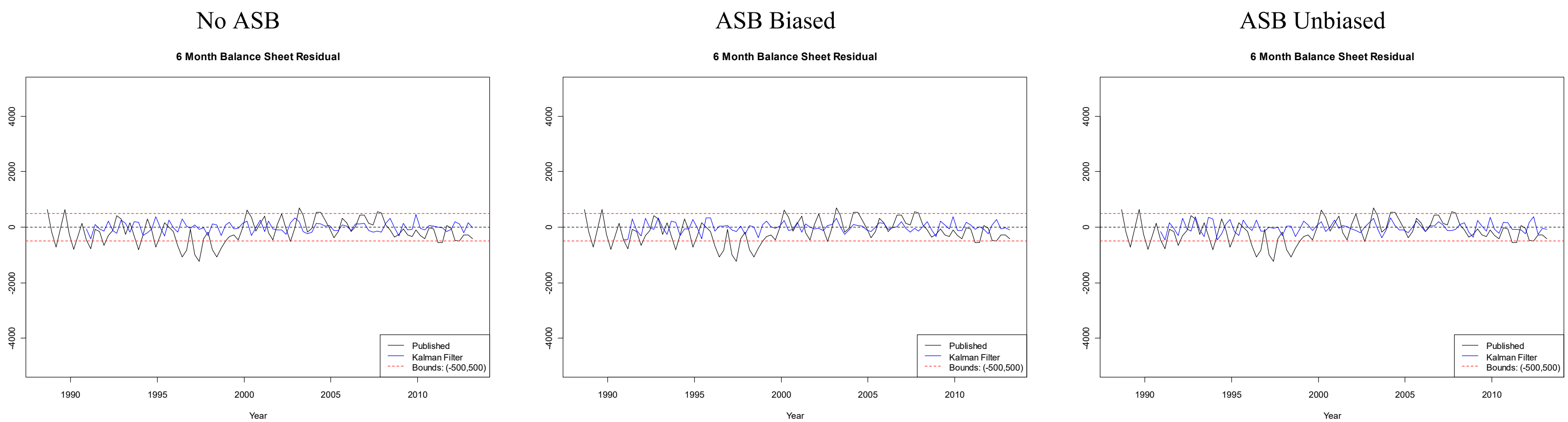
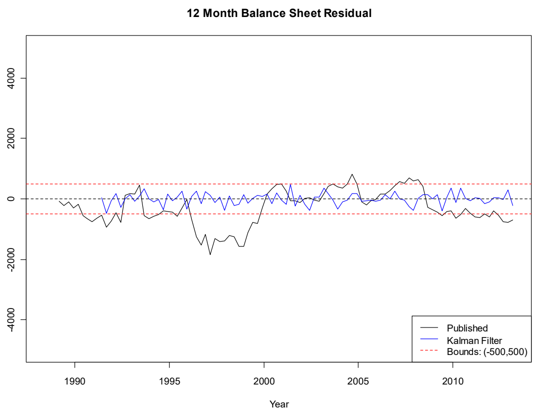
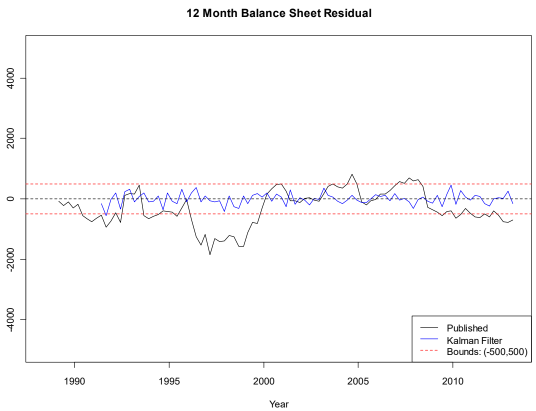


Figure 57**:** Twelve Month Balance Sheet Residual

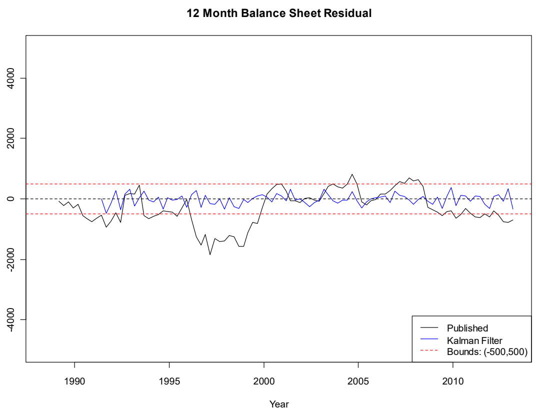
No ASB



ASB Biased



ASB Unbiased



13.6 Summary of Results

Treatments 1, 2, and 3 demonstrate that it is possible to start at the same level of inventory at a particular point in time and generate many different solutions, given the same constraints that the ASB uses to set its published numbers. The variance parameters Q and R were estimated to maximize the likelihood of the realization of the observation vectors, given the constraints and assumptions discussed in this paper. If a particular constraint - for example, a slaughter ratio - is not deemed adequate, the corresponding noise process in these covariance matrices could be fixed, as was done with the survey litter rates in order to enforce ASB behavior in the treatments in which there were no ASB measurements, or in which the ASB measurements were parameterized to contain possible bias. Strictly enforcing too many constraints can have computational complications, as a solution may not in fact exist that satisfies all constraints.

13.6.1 Treatment 1 – No Expert Measurements

The plots of the fixed interval Kalman Smoother estimates in Figure 36 through Figure 49 show that the results for pig crop, sows farrowed, weight groups 1 and 2, and the litter rate appear to agree for the most part with the ASB published inventories. Total hog inventory, total market hogs, and consequently breeding herd appear significantly different. Further inspection shows that these differences are attributed to weight groups 3 and 4 (Figure 45 and Figure 46). These weight groups are encapsulated in weight group function 3 (Figure 41), which also deviates considerably from the ASB published. Both the survey results and ASB measurements for f_3 and f_4 will prove to be highly influential observations in treatments 2 and 3 relative to the other measurements.

One notable result is the slaughter ratios' lack of contribution to the estimates in all three treatments. We are examining the influence of the measurements of inventory at the last point in time on the estimates of inventory at that time. In section 4.4 it was established that slaughter has a lagged effect on inventory by two quarters. One would expect that the slaughter ratios at time $t = n$ would have some influence on the inventory estimates at some point $n - 2 \leq t \leq n$. However this is not the case. The maximum relative absolute net contribution of the slaughter ratios in treatment 1 is 0.38% in the Kalman Smoother for total hogs and pigs at time $t = n$. In treatment 2 the maximum relative absolute net contribution of the slaughter ratios is 0.05% for f_4 at time $t = n$. In treatment 3 the maximum relative absolute net contribution of the slaughter ratios is 0.25% for the total hogs and pigs estimate at $t = n$.

13.6.2 Treatment 2 – Biased Expert Measurements

The initial *state* of the Filter at $x_{0|0} = E[x_0|y_0]$ for all three treatments is set at the published ASB values and is parameterized with zero uncertainty i.e. $var(x_{0|0}) = P_{0|0} = 0$. This means that for the initial starting position of each filter scenario, the ASB values are treated as absolute truth. The initial values of the bias parameters corresponding to each ASB measurement in treatment 2 are initialized at zero. The visually apparent biases in weight group 3 and weight group 4 seen in treatment 1 are also observable in the filter results of treatment 2. As treatment 2 estimates the ASB bias as part of the *state* and we estimate the variance of the *state* within the filter, we can test the null hypothesis that the bias is equal to zero versus the alternative that there exists a nonzero bias in the ASB estimates. Graphs of the p-values of this hypothesis test for each point in time are given in Figure 58 through Figure 64. P-values that fall below the dashed red line in the graphs indicate there is enough evidence to reject the null hypothesis that the bias is zero at that particular point in time at a significance level of $\alpha = 0.05$. This analysis does not take into account simultaneous inference across time and inventory items. Independent hypothesis testing of the Treatment 2 bias parameters for pig crop, Figure 59, and sows farrowed, Figure 60, shows greatest lack of evidence of bias for those two inventory items. There is sufficient evidence to support the existence of bias in the ASB measurements as time progresses for total hogs and pigs and the four weight group functions.

Figure 58

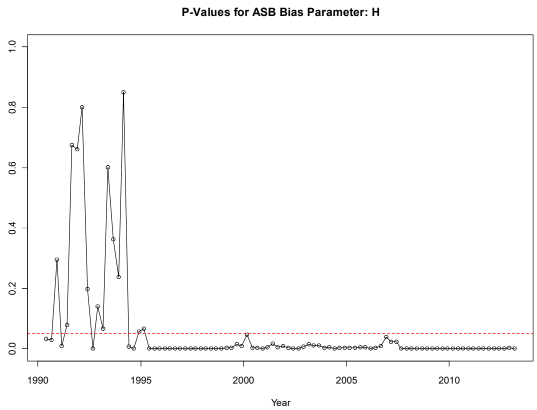


Figure 59

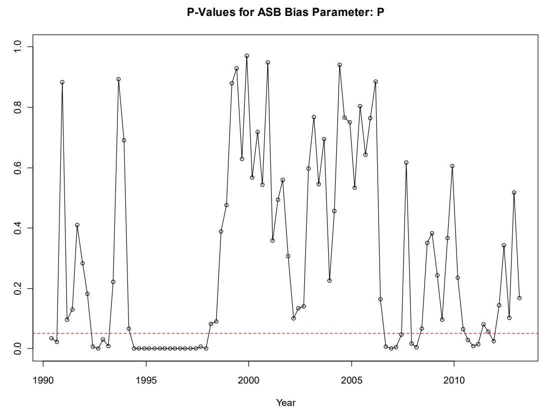


Figure 60

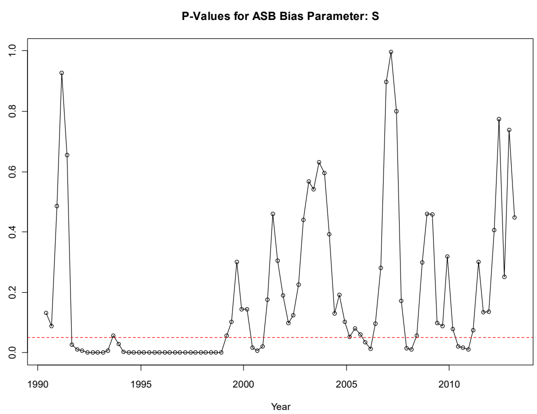


Figure 61

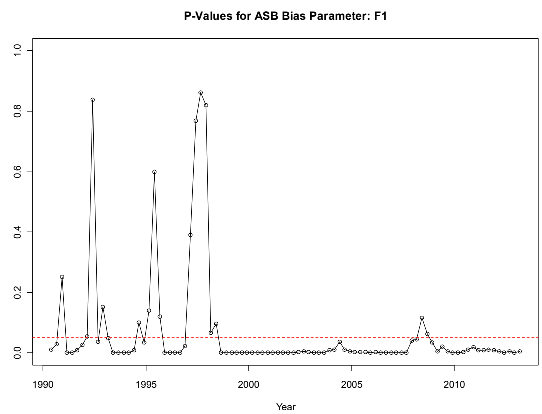


Figure 62

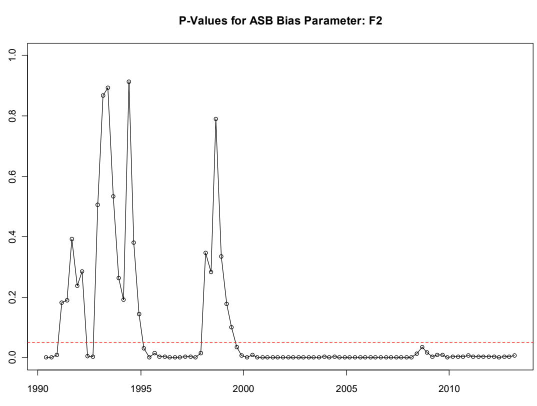


Figure 63

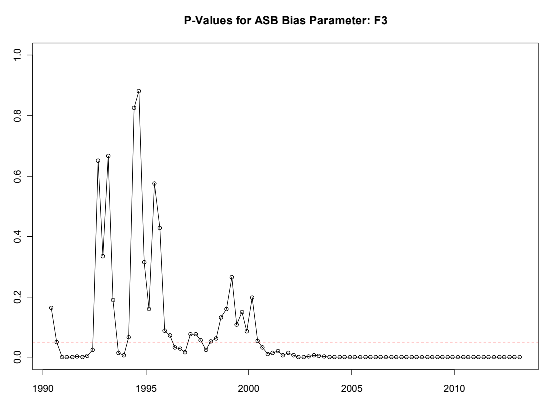
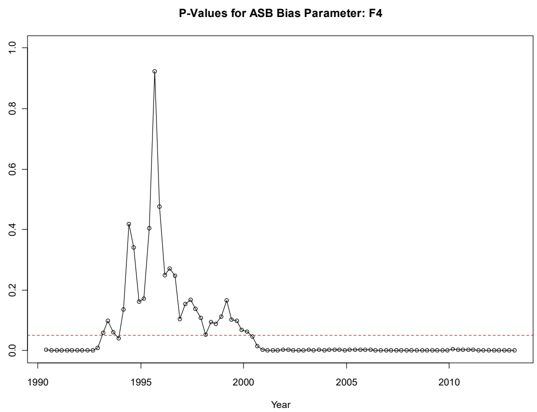


Figure 64



The mean relative absolute net contribution by category for Treatment 2 in Table **12** on page 40 shows that both the survey results and the ASB measurements are highly influential measurements in the inventory estimates. The survey results contribute on average 42.28% of the estimates and the ASB measurements contribute 44.84% of the estimates. Of these percentages, the survey results and ASB estimates for weight group functions 3 and 4 make up over 75% of the survey and ASB relative absolute net contributions to the inventory item estimates on average (see Figure 65 and Figure 66). These functions contain weight groups 3 and 4 which by visual inspection contain the most relative bias. Intuitively it could be hypothesized that weight group 3 is not restricted by as many constraints as the other inventory items, and therefore the filter relies heavily on observations containing information on weight group 3. It is also worth noting the presence of bias in the ASB measurement for weight group 4 and weight group function 4 (Figure 46, middle) despite the “good behavior” of the five week slaughter ratio relative to the annual ratio of weight group 4 (Figure 54, middle).

Figure 65

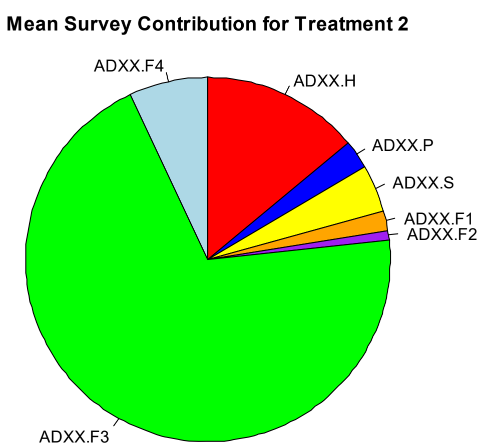
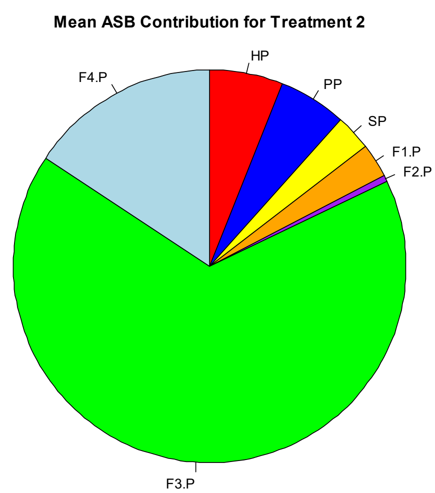


Figure 66



13.6.3 Treatment 3 – Unbiased Expert Measurements

The results for the final parameterization of ASB measurements as unbiased estimates of true inventory demonstrate that congruency can be achieved with external data and the inventory estimates, in addition to a smooth transition from the publishing of ASB measurements to Kalman Smoother measurements. Treatment 3 in Table 12 on page 40 shows the categorized mean relative absolute net contribution of each measurement type to hog inventories. In comparing Treatment 3 to Treatment 2 with regard to the measurement contributions, it appears that treating the ASB measurements as unbiased resulted in a more uniform overall contribution of measurements on the final inventory estimates than in the case of the biased ASB measurements (Treatment 2, Table 12). The absolute relative contribution of the historical estimates (labeled "model") on the last inventory measurements increased from the Treatment 2 level. In Figure 67 and Figure 68 we see that the most influential survey results and ASB measurements are weight group functions 3 and 4, similar to the contribution profile of Treatment 2. When the ASB measurements are treated as unbiased, the ASB measurement for weight group function 4 shows comparable influence to that of weight group function 3 (Figure 68).

Figure 67

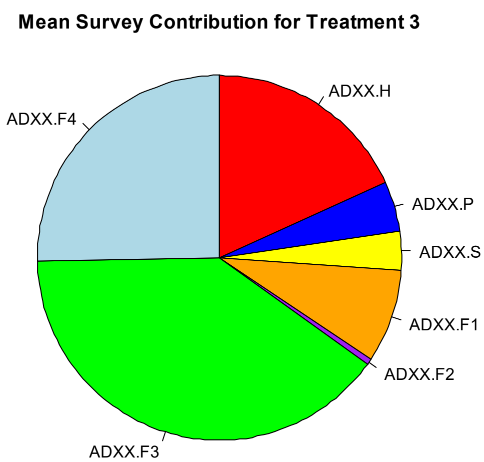
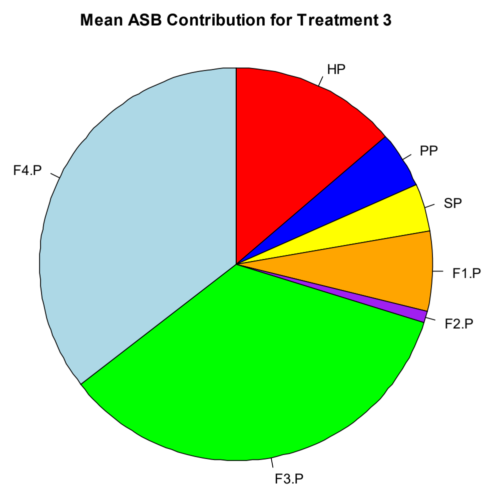


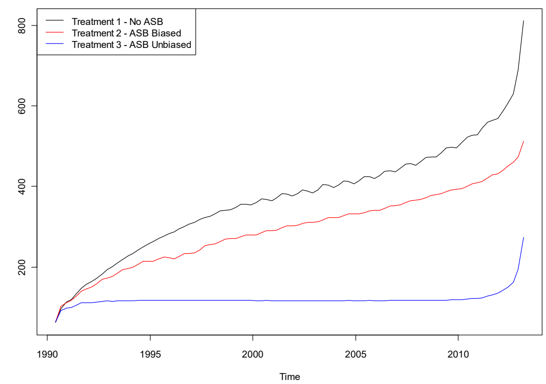
Figure 68



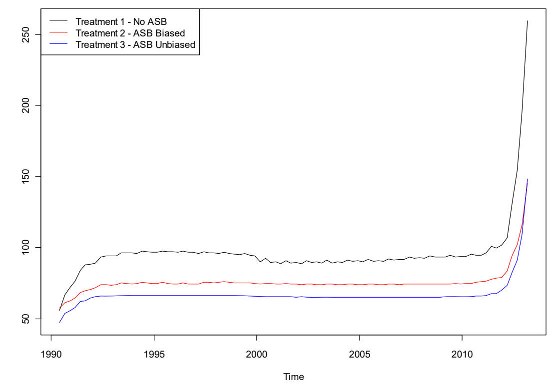
13.7 Standard Errors

Graphs of the standard errors that follow demonstrate that when the ASB measurement is included and treated as an unbiased estimate, the fixed interval Kalman Smoother variance estimates are minimized between all three treatments. For Sows Farrowed, the standard errors are very close between Treatments 2 and 3. For all other inventory items, Treatment 3 resulted in the smallest standard errors. Excluding expert opinion resulted in the highest standard errors of the fixed interval Kalman Smoother estimates.

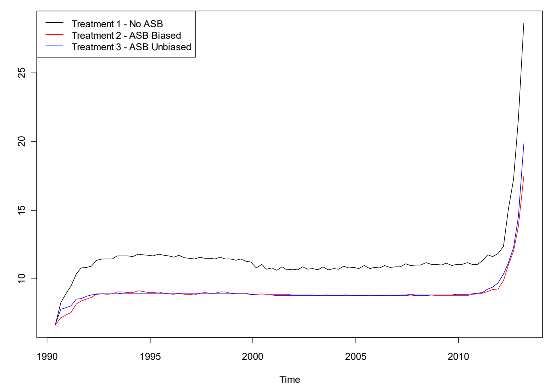
Kalman Filter Standard Errors: Total Hogs



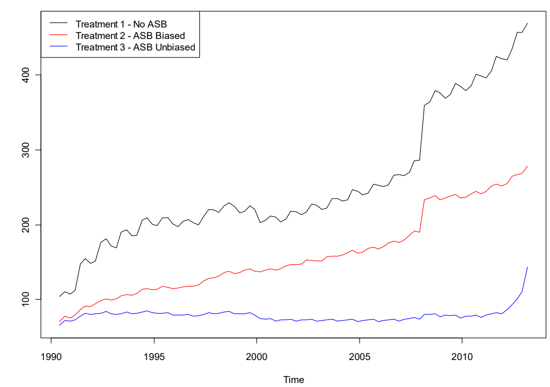
Kalman Filter Standard Errors: Pig Crop



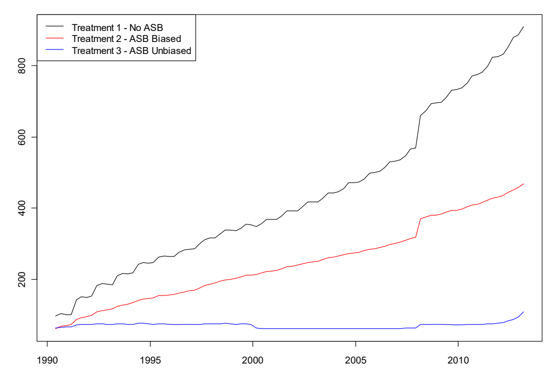
Kalman Filter Standard Errors: Sows Farrowed



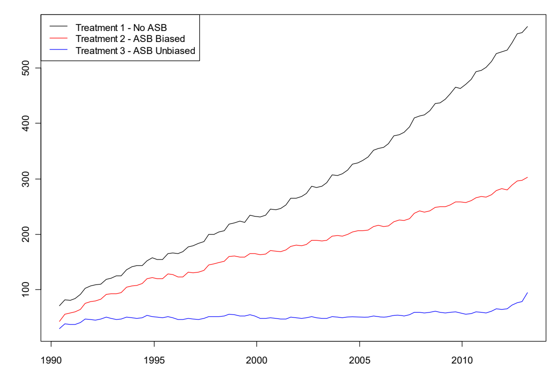
Kalman Filter Standard Errors: Mkt <50 lbs



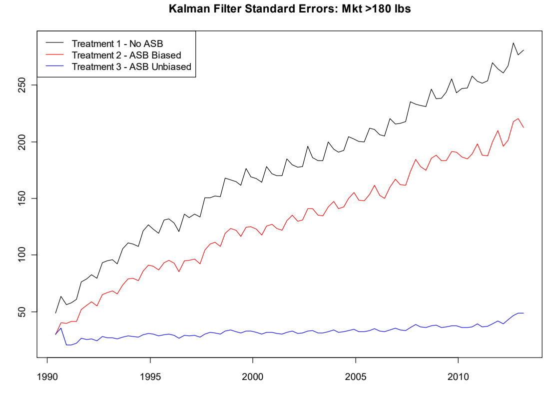
Kalman Filter Standard Errors: Mkt 50-119 lbs



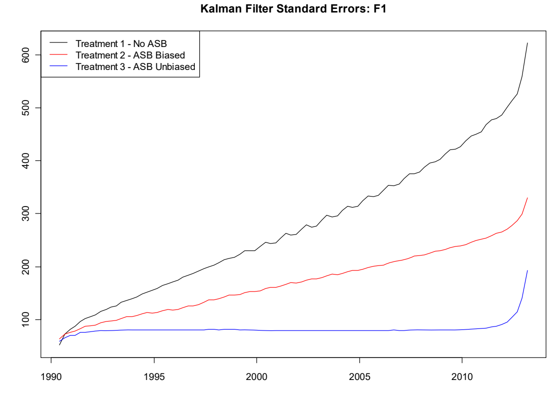
Kalman Filter Standard Errors: Mkt 120-179 lbs

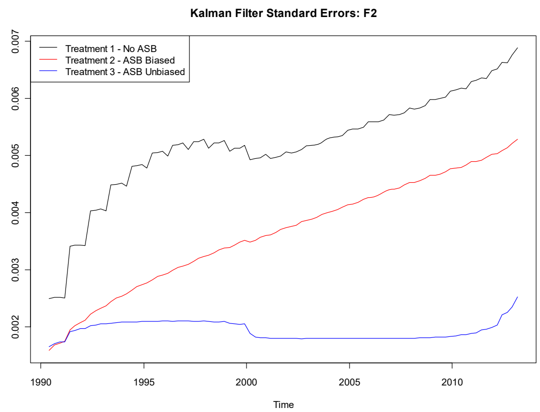


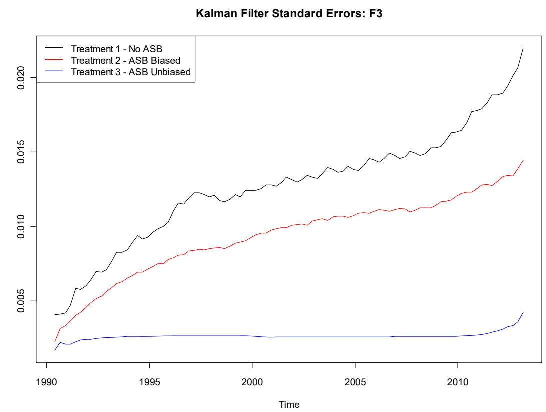
Kalman Filter Standard Errors: Mkt >180 lbs

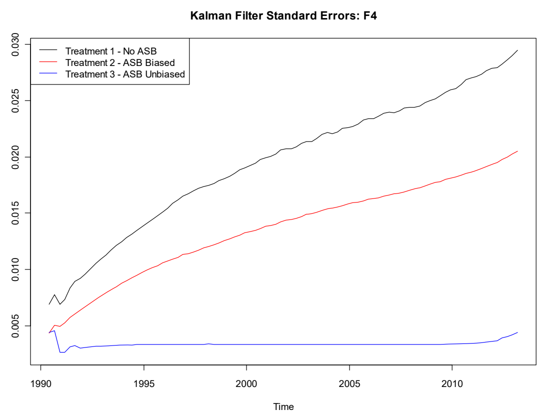


Kalman Filter Standard Errors: F1




Kalman Filter Standard Errors: F2
Treatment 1 - No ASB
Treatment 2 - ASB Biased
Treatment 3 - ASB Unbiased
0.002
0.003
0.004
0.005
0.006
0.007
1990
1995
2000
2005
2010
Time


Kalman Filter Standard Errors: F3
Treatment 1 - No ASB
Treatment 2 - ASB Biased
Treatment 3 - ASB Unbiased
0.005
0.010
0.015
0.020
1990
1995
2000
2005
2010
Time


Kalman Filter Standard Errors: F4
Treatment 1 - No ASB
Treatment 2 - ASB Biased
Treatment 3 - ASB Unbiased
0.005
0.010
0.015
0.020
0.025
0.030
1990
1995
2000
2005
2010
Time

References

Anderson, D.O. and Moore, John B. *Optimal Filtering.* Englewood Cliffs, NJ: Prentice-Hall Inc., 1979.

Casella, George and Berger, Roger L. Statistical Inference. Pacific Grove, CA: the Wadsworth Group, 2002.

Durbin, J. and Koopman, S.J. *Time Series Analysis by State Space Methods.* Oxford: Oxford University Press, 2012.

Green, W. H. *Econometric Analysis (4th Edition)*. New Jersey: Prentice-Hall, 2000.

Shumway, R.H. and Stoffer, D.S. *Time Series Analysis and its Applications*. New York: Springer Science+Business Media, LLC., 2006.

Biometrics 000, 1–25 DOI: 000
000 0000

Bayesian Hidden Markov Models for Dependent Large-Scale Multiple Testing

Xia Wang[1,*], Ali Shojaie[2], and Jian Zou[3]

[1] Department of Mathematical Sciences, University of Cincinnati, Cincinnati, Ohio 45221, U.S.A.

[2] Department of Biostatistics, University of Washington, Seattle, Washington 98195, U.S.A.

[3] Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, Massachusetts 01609, U.S.A.

**email:* xia.wang@uc.edu

Summary: We construct an optimal and flexible multiple hypotheses testing procedure for dependent data based on Bayesian techniques. Our procedure aims at handling two challenges, namely dependence structure and non-null distribution specification. Ignoring dependence among hypotheses tests may lead to loss of efficiency and bias in decision. Misspecification in the non-null distribution, on the other hand, can result in both false positive and negative errors. To address these challenges we use hidden Markov models to accommodate the dependence structure among the tests. Furthermore, we apply Dirichlet mixture process prior on the alternative distribution to overcome the potential pitfalls in distribution misspecification. The testing algorithm based on Bayesian techniques optimizes the false negative rate (FNR) while controlling the false discovery rate (FDR). The proposed method is compared with existing approaches using both simulated and real data examples.

Key words: Bayesian hierarchical model; Dirichlet mixture process prior; False discovery rate; Hidden Markov model; Multiple hypotheses testing.

This paper has been submitted for consideration for publication in *Biometrics*

1. Introduction

Large-scale hypotheses testing with dependence is common in many application areas, from disease monitoring to genomics and brain imaging. Early research in multiple hypothesis testing and false discovery rate (FDR) control largely ignored the dependence structure among hypotheses. The efforts were instead focused on establishing the control of FDR in correlated settings (Benjamini and Yekutieli, 2001) using existing agnostic procedures, such as the step-down procedure of Benjamini and Hochberg (1995). Recent research, however, has showed that ignoring correlation often degrades statistical accuracy and can lead to high variability of testing results and hence irreproducibility of scientific findings (Efron, 2007; Sun and Cai, 2009; Scharwartzman and Lin, 2011). Recent attention has shifted to developing multiple comparison procedures for dependent hypotheses; see, e.g., Owen (2005); Benjamini and Heller (2007); Finner et al. (2007); Heller (2010); Guo et al. (2014); Sun et al. (2015).

Sun and Cai (2009) recently studied the large-scale hypothesis testing problem in settings where the dependence is governed through a hidden Markov process. They showed that adaptively exploiting the dependence structure among hypotheses lowers the false non-discovery rate, while controlling the FDR at a given level of α. Their approach has been further extended to deal with heterogeneous chromosome groups (Wei et al., 2009), two-dimensional graphical correlation studies (Li et al., 2010; Liu et al., 2012), and three-dimensional neuroimaging data (Shu et al., 2015). More recently, Xiao et al. (2013) developed region-specific hidden Markov models in genome-wide association studies, where they decided the optimal number of the normal mixture components for the disease-associated observations by a data-driven penalized criterion.

In this paper, we develop optimal and flexible hypotheses testing procedures for large-scale, dependent data. Our proposals are well-suited for multiple hypotheses testing problems in settings where the hypotheses are temporally dependent or their correlation structure can be captured by a one-dimensional structure, such as a line graph. This includes, among others, applications in disease monitoring and genomics studies, which are explored in Section 4. However, the proposed models have broad applications in many other settings, including finance, marketing and neurosciences.

Our contributions to the existing research in the area of large-scale, dependent testing are twofold. First, we develop Bayesian computational algorithm in both parametric and semi-parametric models as an alternative to the expectation-maximization (EM) algorithm of Sun and Cai (2009). The proposed Bayesian algorithm is particularly advantageous when the non-null distribution is a mixture of normal distributions, instead of single normal distribution: our simulation experiments confirm the previous findings that the results from the EM algorithm, such as the one used in Sun and Cai (2009), depend on the starting values, while the results from the Bayesian method are relatively robust to initialization.

The Bayesian modeling framework also facilitates extensions that allow for greater flexibility in specification of distributions and parameters. This is in contrast to maximum likelihood methods, which may have difficulty when the model is overfitted with a larger number of mixture components than the actual number of components. Titterington et al. (1985) presented empirical studies with convergence to singularities and spurious local modes in estimation by the EM algorithm, even using the true parameters as the starting value. To alleviate this problem, Hathaway (1985) introduced an inequality constraint on the variance components for univariate mixtures of normals. Bayesian approaches, with appropriate choices of proper priors on the variance components, are in fact related to the constraint introduced in Hathaway (1985).

Our second contribution is the development of a flexible Bayesian nonparametric framework that alleviates the need to pre-specify the number of mixture components in the non-null distribution. Sun and Cai (2009) considered the setting where the number of mixture components in the non-null distribution is either known, or is estimated using a model comparison criteria, such as BIC. As an alternative, we consider mixture modeling with an unknown number of mixtures. Our approach is related to the use of nonparametric mixtures by Efron et al. (2001) and the hierarchical mixture model in Newton et al. (2004), but we instead use a Dirichlet process mixture (DPM) priors (Do et al., 2005) on the non-null distribution to model the mixture structure. The DPM prior provides great flexibility in the estimation of the density of non-null distribution and avoids the misspecification. Here, we aim to estimate the density of the non-null test statistics as discussed in Escobar and West (1995). Our application of DPM priors is thus similar to Shahbaba and Johnson (2013). However, in contrast to our hypothesis testing framework, they applied a latent random partition model based on the DPM to achieve variable or model selection.

The rest of the paper is organized as follows. In Section 2, we describe our Bayesian hidden Markov model (HMM) methods for multiple hypotheses testing. We discusses three cases of the non-null distribution: a single distribution, a mixture distribution with a known number of components, and a mixture distribution with an unknown number of components. In Section 2.4, we establish the posterior consistency of the Bayesian HMM with a known number of components. Extensive simulation studies are presented in Section 3, where the proposed methods are compared with existing multiple hypotheses testing procedures. Applications of the proposed methods to two real data applications are presented in Section 4. Section 5 concludes the paper with discussions and ongoing research. Due to space limitation, additional details on the proposed Bayesian computation and posterior consistency are relegated to the Online Supplementary Material.

2. Bayesian Hidden Markov Model

Let $\mathbf{X} = \{x_1, x_2, \ldots, x_m\}$ be observations corresponding to m dependent hypotheses. Denote by S_t the true state of x_t, with $S_t = 0$ corresponding to the null state and $S_t = 1$ the non-null state. Our goal is to estimate $\mathbf{S} = \{S_t\}_{t=0}^{m}$ based on the observed $\mathbf{X}$.

In Section 2.1, we introduce validity and optimality concepts in multiple hypothesis testing and their extension under the Bayesian approach. We then describe the hidden Markov model (HMM) and its application to hypothesis testing in Section 2.2. The proposed Bayesian models are presented in Section 2.3, where we present a Bayesian hierarchical model for the case where the number of mixture components is known and construct a nested nonparameteric Bayesian model for the setting where the number of mixture components is unknown. Posterior consistency of the proposed Bayesian model is established in Section 2.4.

2.1 *Valid and Optimal Procedures in Multiple Hypothesis Testing*

Suppose the m hypotheses consist of m_0 tests from the null state and m_1 tests from the non-null state; $m = m_0 + m_1$. Consider a testing procedure that claims non-significance in U tests and significance in R tests. Denote the number of tests correctly declared non-significant as N_{00} and those correctly declared significant as N_{11}. Let N_{10} and N_{01} be the number of the false positives and false negatives. The false discovery rate (FDR) is then $E(N_{10}/R \mid R > 0)Pr(R > 0)$ and the marginal false discovery rate (mFDR) is calculated as mFDR $= E(N_{10})/E(R)$. The false non-discovery rate (FNR) and the marginal false non-discovery rate (mFNR) are similarly defined as $E(N_{01}/U|U > 0)Pr(U > 0)$ and mFNR $=$ $E(N_{01})/E(U)$, respectively. Sun and Cai (2009) defined a valid procedure as the one that controls FDR at a pre-specified level α. Among all the available procedures, the one with the smallest FNR is consider optimal.

Genovese and Wasserman (2003) introduced a Bayesian multiple testing procedure and established the asymptotic equivalence of Bayesian and frequentist approaches for controlling the FDR. In the Bayesian setting, FDR is often defined in terms of the posterior probabilities, where the posterior probability $P_\vartheta(S_t = 0 \mid \mathbf{X})$ of the model with parameters ϑ is considered green the test statistic. To control the FDR at a given level, a threshold is then calculated based on the increments in the ordered posterior probabilities instead of the ordered p-values (Newton et al., 2004; Müller et al., 2004). Specifically, the posterior probabilities are ranked from the smallest to the largest as $P_\vartheta(S_{(1)} = 0|\mathbf{X}), \ldots, P_\vartheta(S_{(m)} = 0|\mathbf{X})$. Let

$$k = \max\left\{ i : \frac{1}{i}\sum_{t=1}^{i} P_\vartheta(S_{(t)} = 0|\mathbf{X}) \leqslant \alpha \right\}.$$

The FDR is controlled at the level α when rejecting all $H_{0(t)}, t = 1, \ldots, k$. It has been observed that the Bayesian approach may be anti-conservative for data with high correlation and a high proportion of true null hypotheses (Dudoit et al., 2008; Kim et al., 2009).

Sun and Cai (2009) recently proposed the local index of significance (LIS), $\text{LIS}_t = P_\vartheta(S_t = 0|\mathbf{X})$, as a test statistic for hypothesis t. They showed that an optimal α-level FDR controlling procedure can be obtained by rejecting hypotheses $H_{(1)}, \ldots H_{(k)}$, where

$$k = \max\left\{ i : \frac{1}{i}\sum_{t=1}^{i} \text{LIS}_{(t)} \leqslant \alpha \right\}.$$

Clearly, the posterior probability is conceptually the same as LIS measure used in Sun and Cai (2009), which suggests a close connection between LIS procedure and the Bayesian multiple hypotheses testing procedure. The flexibility provided by hierarchical Bayesian modeling, however, makes it straightforward to accommodate more complex data structures considered in this paper.

2.2 *Hidden Markov Model*

In this section we describe our hidden Markov model (HMM) for large-scale dependent multiple hypothesis testing. Our framework is based on the doubly stochastic time series models introduced by Tjøstheim (1986); however, this framework is applicable in a variety of other settings with serial correlation.

Suppose the observable times series $x_t, t = 0, 1, \ldots, m$, depends on the realization of an unobservable, latent random process $S_t, t = 0, 1, \ldots, m$. The sequence of observations $\mathbf{X} = (x_1, x_2, \ldots, x_m)'$ takes values from a sampling space $\mathcal{X}$ and can be discrete or continuous. The hidden process $\mathbf{S} = \{S_t\}_{t=0}^m$ is often assumed to be a discrete-time process with finite state space $\{1, \ldots, K\}$.

Following Sun and Cai (2009), we use a two-state HMM ($K = 2$) for the setting of large-scale dependent hypothesis testing. ~~In~~ In this framework, $S_t = 0$ corresponds to the null state and $S_t = 1$ to the non-null state. We assume the latent state space variables $\mathbf{S}$'s are identically distributed Bernoulli random variables. The states $S_0, S_1, \ldots, S_m$ are assumed to be correlated through a stationary, irreducible and aperiodic Markov chain starting from its ergodic distribution with $\boldsymbol{\pi} = (\pi_0, \pi_1)$, where $\Pr(S_t = 0) = \pi_0$ and $\Pr(S_t = 1) = \pi_1$, and a 2×2 transition matrix $\mathcal{A}$. The element a_{jk} of $\mathcal{A}$ encodes the probability of transition from state j at at time $t-1$ to state k at time t. Formally, $a_{jk} = \Pr(S_t = k | S_{t-1} = j), j, k \in \{0, 1\}$, $a_{jk} \geqslant 0$ and $\sum_{k=0}^{1} a_{jk} = 1$ for $j = 0, 1$. The diagonal element a_{jj} is called the persistence probability as it indicates the expected duration of state j, which is longer with a_{jj} closer to 1. The two eigenvalues of $\mathcal{A}$ are 1 and $a_{00} + a_{11} - 1$. The larger the second eigenvalue $a_{00} + a_{11} - 1$, the more persistent the latent process S_t (Frühwirth-Schnatter, 2006).

Conditional on the unobserved state $\mathbf{S} = \{S_t\}_{t=0}^m$, the observations $\mathbf{X} = (x_1, x_2, \ldots, x_m)'$ are then assumed to be independent and identically distributed with distribution $\mathcal{F}$. We consider parametric distributions with the conditional probability density functions $f_{S_t}(x_t | S_t, \boldsymbol{\theta}_{S_t})$, where $\boldsymbol{\theta}_{S_t}$ are the vector of state specific parameters. Specifically, $[x_t | S_t] \sim (1 - S_t) f_0 + S_t f_1$. In Summary, the proposed HMM can be depicted as

$$\begin{array}{ccccccccc} S_0 & \xrightarrow{\mathcal{A}} & S_1 & \xrightarrow{\mathcal{A}} & S_2 & \xrightarrow{\mathcal{A}} & \cdots & \xrightarrow{\mathcal{A}} & S_m \\ \downarrow{\scriptstyle \mathcal{F}} & & \downarrow{\scriptstyle \mathcal{F}} & & \downarrow{\scriptstyle \mathcal{F}} & & & & \downarrow{\scriptstyle \mathcal{F}} \\ x_0 & & x_1 & & x_2 & & \cdots & & x_m \end{array}$$

The HMM parameters include $\vartheta = (\mathcal{A}, \boldsymbol{\pi}, \mathcal{F})$, where $\mathcal{A} = \{a_{jk}\}, j, k = 0, 1$ is the transition matrix, $\boldsymbol{\pi} = (\pi_0, \pi_1)$ is the stationary distribution and $\mathcal{F} = \{f_0, f_1\}$ is the observation distribution with state specific parameters $\boldsymbol{\theta}_k, k = 0, 1$.

In the above setting, the large-scale hypothesis testing task amounts to estimating the hidden states $\mathbf{S} = \{S_t\}_{t=0}^m$ based on the observations $\mathbf{X} = (x_1, x_2, \ldots, x_m)'$. Sun and Cai (2009) used this framework in a disease monitoring setting, where $\mathbf{X}$ corresponds to the observed daily emergency room visits by patients with influenza-like illness (ILI) and the hidden Markov chain $\mathbf{S}$ was considered to be the indicator for start of a new outbreak. In the Bayesian setting, inference on the state indicator S_t is expressed as the probability $\Pr(S_t = k|\mathbf{x}^\tau, \vartheta)$ for $k = 1, \ldots, K$, which is the predictive state probability if $t > \tau$, the filtered state probability if $t = \tau$, and the smoothed state probability if $t < \tau$ (Frühwirth-Schnatter, 2006). The full-sample smoothed probabilities $\Pr(S_t = 0|\mathbf{X}, \vartheta)$ (i.e., when $\tau = m$) is thus the key quantity in large-scale hypothesis testing.

2.3 *Bayesian Modeling and Computation*

To parameterize the observation distribution $\mathcal{F} = \{f_0, f_1\}$, we assume the null observations are from a normal distribution with mean μ_0 and variance σ_0^2, i.e., $f_0 \sim N(\mu_0, \sigma_0^2)$. We assume the non-null distribution is either a single normal distribution, $f_1 \sim N(\mu_1, \sigma_1^2)$, or a mixture of normal distributions, $f_1 = \sum_{\ell=1}^{L} p_\ell N(\mu_{1\ell}, \sigma_{1\ell}^2)$ with L components. Here, p_ℓ is the mixture proportion for component ℓ. In Section 2.3.1 we develop a Bayesian hierarchical model for the setting where f_1 is either a single distribution or a mixture distribution with a known number of components. For the case where L is unknown, a nested nonparametric Bayesian framework is proposed in Section 2.3.2.

We employ Markov chain Monte Carlo (MCMC) sampling to obtain posterior inference in both settings, i.e., when L is known or unknown. In addition to its flexibility in the setting where L is unknown, a main advantage of the proposed Bayesian computation framework over the EM algorithm used in the LIS method of Sun and Cai (2009) is its robustness to the initial values. In fact, our numerical evaluations in Section 3.2 indicated that if the EM algorithms starts from a point far away from the true value or too close to another mixture mode, it sometimes converges to a value far away from the true values. Even worse, the EM algorithm may end at spurious local modes with a single observation. In such settings, the instability of the EM algorithm leads to estimation and inference errors that negatively impacts the hypothesis testing outcome of LIS.

2.3.1 *Bayesian hierarchical model with a known number of mixture components.* To perform posterior inference for the HMM model with the complete-data likelihood

$$L(\mathbf{X}, \mathbf{S}|\vartheta) = p(\mathbf{X}|\mathbf{S}, \vartheta)p(\mathbf{S}|\vartheta) = p(S_0|\vartheta)\prod_{t=1}^{m} f_{S_t}(x_t; \mu_{S_t}, \sigma^2_{S_t})a_{S_{t-1},S_t},$$

we specify the prior distributions of parameters $\vartheta = (\mathcal{A}, \boldsymbol{\pi}, \mathcal{F})$ as follows.

First, note that the other entries of the transition matrix $\mathcal{A}$ can be calculated from a_{00}. We assume $a_{00} \sim \text{Beta}(a_0^{\mathcal{A}}, b_0^{\mathcal{A}})$, where $\text{Beta}(a, b)$ is the beta distribution with parameters a and b. For the means of the observation distributions, we set $\mu_0 \sim N(0, \sigma^2_\mu)$ and $\mu_{1\ell} \sim N(0, \sigma^2_\mu)$ for $\ell = 1, \ldots L$. For the variance parameters of the observation distribution, we set $\sigma_0^2 \sim \text{IG}(a_0^{\sigma^2}, b_0^{\sigma^2})$ and $\sigma^2_{1\ell} \sim \text{IG}(a_0^{\sigma^2}, b_0^{\sigma^2})$, where $\text{IG}(a, b)$ is the inverse gamma distribution with mean $b/(a-1)$. Let $\boldsymbol{\mu}_1 = \{\mu_{11}, \ldots, \mu_{lL}\}$ and $\boldsymbol{\sigma}^2_1 = \{\sigma^2_{11}, \ldots, \sigma^2_{1L}\}$. When $L = 1$, both of these vectors degenerate to scalars. When $L > 1$, let $\mathbf{p} = \{p_1, \ldots, p_L\}$ be the proportions of the L mixture components in $f_1(x_t; \boldsymbol{\mu}_1, \boldsymbol{\sigma}^2_1) \sim \sum_{\ell=1}^{L} p_\ell N(x_t; \mu_{1\ell}, \sigma^2_{1\ell})$. For known L, we impose a Dirichlet prior on $\mathbf{p}$, $\text{Dirichlet}(\mathbf{p}; \mathbf{c})$. The hyperparameters include $a_0^{\mathcal{A}}, b_0^{\mathcal{A}}, \sigma^2_\mu, a_0^{\sigma^2}, b_0^{\sigma^2}$, and $\mathbf{c}$. In the simulation studies and the real data applications, we set $\sigma^2_\mu = 100$, $a_0^{\sigma^2} = 2$, $b_0^{\sigma^2} = 1$, $a_0^{\mathcal{A}} = 3$, $b_0^{\mathcal{A}}$=3, and $\mathbf{c} = 3$. The hyperparameters on $a_0^{\mathcal{A}}$, $b_0^{\mathcal{A}}$, and $\mathbf{c}$ are chosen following the suggestions of Gassiat and Rousseau (2014). All other hyperparameters are chosen to lead to large variances in the priors.

The most involved component of the proposed Bayesian computation framework is the sampling of the hidden states $\{S_t\}_{t=1}^{m}$. We use a data augmentation strategy and treat the hidden Markov chain $\mathbf{S}$ as missing data (Robert and Celeux, 1993; Albert and Chib, 1993; McCulloch and Tsay, 1994). The full posterior conditional distribution of $(\mathbf{S}, \vartheta)$ is then

$$
\begin{aligned}
f(\mathcal{A}, \boldsymbol{\pi}, \mathcal{F}, \mathbf{S}|\{x_t\}_{t=1}^m) &\propto f(\mathbf{x}|\mathbf{S}, \vartheta) f(\mathbf{S}|\vartheta) f(\vartheta) \qquad (1)\\
&\propto \prod_{t=1}^m f_{S_t}(x_t; \mu_{S_t}, \sigma^2_{S_t}) \cdot \pi_{S_0} \prod_{t=1}^m a_{S_{t-1}, S_t} \qquad (2)\\
&\quad \times \prod_{j=0}^1 \mathrm{Beta}(a_{jj}; a_0^{\mathcal{A}}, b_0^{\mathcal{A}}) N(\mu_0; 0, \sigma^2_\mu) \mathrm{IG}(\sigma^2_0; a_0^{\sigma^2}, b_0^{\sigma^2})\\
&\quad \times \prod_{\ell=1}^L N(\mu_{1\ell}; 0, \sigma^2_\mu) \prod_{\ell=1}^L \mathrm{IG}(\sigma^2_{1\ell}; a_0^{\sigma^2}, b_0^{\sigma^2}) \mathrm{Dirichlet}(\mathbf{p}; \mathbf{c}).
\end{aligned}
$$

The data augmentation strategy conveniently divides the MCMC estimation into two iterative steps, sampling ϑ conditional on the hidden state indicator $\mathbf{S}$ and sampling $\mathbf{S}$ conditional on ϑ. The estimation of null and non-null state specific parameters conditional on the hidden Markov chain is the same as the usually independent and identical data case. Sampling of the hidden state indicator $\mathbf{S}$ is carried out by forward filtering, backward smooth algorithm (Frühwirth-Schnatter, 2006). The inference on $\mathbf{S}$ depends on the observed data $\mathbf{X}$ through their densities f_0 and f_1 under null and non-null states, which make it straightforward to deal with complex mixture structure in the non-null distribution by Bayesian techniques. Details of the algorithm are given in Web Appendices A and B.

2.3.2 *Nested non-parametric Bayesian model for an unknown number of mixture components.* In practice, the number of components L is often unknown. Previous attempts to address this problem have used (ad-hoc) model comparison approaches, such as the BIC. The hierarchical Bayesian framework allows us to use a Dirichlet process mixture (DPM) model to address this problem. The DPM is naturally nested within the HMM model for estimating the non-null density f_1 (Escobar and West, 1995).

The computational framework of Section 2.3.1 for known L can be easily extended to the nested DPM model. Specifically, conditioning on ϑ, the sampling scheme for the latent state indicator $\mathbf{S}$ is identical to that in Section 2.3.1. When L is unknown, additional constraints are needed to distinguish the null and non-null states. With unknown L, we thus further assume that the null distribution is known. Conditioning on $\mathbf{S}$, the parameters of f_1, i.e., μ_ℓ, σ_ℓ^2 for $\ell = 1, \dots, L$ and the number of mixture component L, are jointly estimated using the DPM model from the observations with $S_t = 1$. This component of the model is specified as an infinite mixture of normals. More specifically, let $\boldsymbol{\theta}_1$ be the collection of all $\boldsymbol{\theta}_{1\ell} = \{\mu_{1\ell}, \sigma_{1\ell}^2\}$ and denote by $S_{1t} = \ell$ the "latent component" associated with observation x_t. We then consider the following model

$$
\begin{aligned}
& x_t|(S_{1t} = \ell, S_t = 1, \boldsymbol{\theta}_1) \sim N(\mu_{1\ell}, \sigma_{1\ell}^2), \\
& S_{1t} = \ell|\mathbf{p} \sim \text{Multinomial}(\mathbf{p}), \\
& \boldsymbol{\theta}_1|G \sim G, \text{ where } G = \sum_{\ell=1}^{\infty} p_\ell \delta_{\theta_{1\ell}}|\alpha, \boldsymbol{\theta}_1, H \sim DP(\alpha, H), \\
& \mathbf{p} \sim \text{GEM}(\alpha), \text{ and } \boldsymbol{\theta}_{1\ell} = \{\mu_{1\ell}, \sigma_{1\ell}^2\} \sim H = \text{NIG}(\xi_0, \kappa_0, \nu_0, \lambda_0).
\end{aligned}
$$

In the above, the infinite set of mixture weights $\mathbf{p}$ is sampled from the sequential stick-breaking process GEM(α) — named after Griffiths, Engen and McCloskey (Ishwaran and Zarepour, 2002) — where $\alpha > 0$ is the concentration parameter in the Dirichlet process (Sethuraman, 1994). We use $\alpha = 1$. The base distribution H, which specifies the mean of DP(α, H), is specified as a normal-inverse-gamma distribution with $\mu_{1\ell}|\sigma_{1\ell}^2 \sim N(\xi_0, \kappa_0\sigma_{1\ell}^2)$ and $\sigma_{1\ell}^2 \sim \text{IG}(\nu_0/2, 2/\nu_0\lambda_0)$, where the hyperparameters are set to $\xi_0 = 0, \kappa_0 = 1/9, v_0 = 5$, and $\lambda_0 = 5$ as in the demonstration examples by Teh (2009). Finally, the collapsed Gibbs sampling Algorithm of Neal (2000) is applied to estimate the non-null densities f_1 based on the sampled values of $\mathbf{p}$ and $\boldsymbol{\theta}_1$.

2.4 *Asymptotic Properties*

In this section we establish posterior consistency of the proposed Bayesian approach by specializing recent results of Gassiat and Rousseau (2014) to our problem. We focus here on the Bayesian hierarchical model of Section 2.3.1 for an HMM with a known number of mixture components under the non-null distribution and leave the discussion of infinite mixtures to future research. We first state the requirements on the prior distributions.

(C0) Let $g_v, v = 1, \ldots, |\vartheta|$ denote the prior distribution for the vth element of the vector of parameters $\vartheta = (\mathcal{A}, \boldsymbol{\pi}, \mathcal{F})$ of the hierarchical Bayesian model of Section 2.3.1. Let ϑ_v^* be the vth parameter of the true underlying HMM and $\mathcal{B}_\varepsilon(\vartheta_v^*)$ be an ε-ball around it (for an arbitrary norm). Then, for all $v = 1, \ldots, |\vartheta|$ and all $\varepsilon > 0$, $g_v\left(\mathcal{B}_\varepsilon(\vartheta_v^*)\right) > 0$.

Proposition 1: Consider the HMM model of Section 2.2 with $K = 2$, $f_0 \sim N(\mu_0, \sigma_0^2)$ and $f_1 \sim \sum_{l=1}^{L} p_l N(\mu_{1l}, \sigma_{1l}^2)$ for a known L. Let $\theta = (\mu_0, \mu_{11}, \ldots, \mu_{1L}, \sigma_0, \sigma_{11}, \ldots, \sigma_{1L})$ be the set of parameters of the normal densities for null and non-null hypotheses. Assume the following assumptions are satisfied.

(C1) For $i, j = 0, 1$, $a_{ij} > 0$. Moreover, for $l = 1, \ldots, L$, $p_l > 0$.

(C2) The Dirichlet prior for $\mathbf{p}$ is continuous and positive on the set of positive probability mass functions $\Delta_L = (u_1, \ldots, u_{L-1}) : u_1 \geqslant 0, \ldots, u_{L-1} \geqslant 0, \sum_{i=1}^{L-1} u_i \leqslant 1$. Moreover, there exists constants $C > 0, \alpha_1 > 0, \ldots, \alpha_L > 0$ such that

$$\forall (u_1, \ldots, u_{L-1}) \in \Delta_L, u_L = 1 - \sum_{i=1}^{L-1} u_i, \quad 0 < \pi(u_1, \ldots, u_{L-1}) \leqslant C\, u_1^{\alpha_1 - 1} u_L^{\alpha_L - 1}.$$

(C3) Let $\Theta^* = (\theta_0^*, \theta_1^*, \ldots, \theta_L^*)$ be the vector of true parameters of the observation distributions $\mathcal{F} = \{f_0, f_1, \ldots, f_L\}$. Denote by $D^1 f_i$ the vector of first derivatives of f_i and by $D^2 f_i$ the matrix of its second derivatives, with respect to the parameters. Let $T = \{\mathbf{t} = (t_0, \ldots, t_L) \in (0, \ldots, L)^{L+1} : t_i < t_{i+1}, i = -1, \ldots, L-1\}$ (with $t_{-1} = 0$). For any $\mathbf{t} = (t_0, \ldots, t_L) \in T$, any $(h_i)_{i=0}^{L+1-t_L} \in (\mathbb{R}^+)^{L+1}$ any $(a_i)_{i=0}^{L} \in \mathbb{R}^{L+1}, (b_i)_{i=0}^{L} \in \mathbb{R}^{L+1}, (c_i)_{i=0}^{L} \in (\mathbb{R}^d)^{L+1}$, any $z_{i,j} \in \mathbb{R}^d, \alpha_{i,j} \in \mathbb{R}$, $i = 0, \ldots, L$, $j = 1, \ldots, t_i - t_{i-1}$, such that $\|z_{i,j}\| = 1, \alpha_{i,j} \geqslant 0$ and $\sum_{j=1}^{t_i - t_{i-1}} \alpha_{i,j} = 1$, for any $(\theta_i)_{i=0}^{L-t_L} \notin \{\theta_i^*, i = 0, \ldots, L\}$,

$$\sum_{i=0}^{L} h_i f_{\theta_i} + \sum_{i=0}^{L} (a_i f_{\theta_i^*} + c_i^\top D^1 f_{\theta_i^*}) + \sum_{i=0}^{L} b_i^2 \sum_{j=1}^{t_i - t_{i-1}} \alpha_{i,j} z_{i,j}^\top D^2 f_{\theta_i^*} z_{i,j} = 0,$$

if and only if

$$a_i = 0, \quad b_i = 0, \quad c_i = 0 \quad \forall i = 0, \ldots, L.$$

Then, there exists M large enough such that

$$\mathbb{P}\left(|\hat{a}_{kk} - a_{kk}| \leqslant M\sqrt{\frac{\log m}{m}}, k = 0, 1; \quad \|\hat{\Theta} - \Theta^*\|_1 \leqslant M\sqrt{\frac{\log m}{m}} \;\middle|\; X_{1:m} \right) = 1 - o_{\mathbb{P}}(1). \quad (3)$$

If, in addition, the prior distributions for the parameters $\vartheta = (\mathcal{A}, \boldsymbol{\pi}, \mathcal{F})$ of the Bayesian HMM of Section 2.3.1 satisfy Condition (C0), then the full posterior conditional distribution (1) is also consistent.

Proof. First recall that in our two-state HMM of Section 2.3.1, f_0 represents the density under the null state, which is assumed to follow a univariate normal distribution and f_1 represent the density under the non-null state. The density f_1 is assumed to be a mixture of normal distributions with a known number of components L, that is $f_1 = \sum_{\ell=1}^{L} p_\ell f_\ell^* = \sum_{\ell=1}^{L} p_\ell N(\mu_{1\ell}, \sigma_{1\ell}^2)$. The transition matrix is

$$\begin{bmatrix} a_{00} & a_{01} \\ a_{10} & a_{11} \end{bmatrix}.$$

Our 2-state HMM with the mixture non-null distribution can be equivalently written as a $(L+1)$-state HMM, with univariate normal distributions $f_0, f_1^*, \ldots, f_L^*$ for each state. The transition matrix for this $(L+1)$-state HMM is given by

$$\begin{bmatrix} a_{00} & p_1 a_{01} & p_2 a_{01} & \cdots & p_L a_{01} \\ a_{10} & p_1 a_{11} & p_2 a_{11} & \cdots & p_L a_{11} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{10} & p_1 a_{11} & p_2 a_{11} & \cdots & p_L a_{11} \end{bmatrix}.$$

Thus, to establish (3) it suffices to show that the assumptions (A1)-(A4) in Gassiat and Rousseau (2014) — which are needed for their Theorem 2 — are satisfied.

First note that Condition (C2) is identical to condition (A1) in Gassiat and Rousseau

(2014). Condition (C1) also guarantees that condition (A0) of Gassiat and Rousseau (2014), for the $(L+1)$-state HMM is satisfied.

Next, given that the conditional distributions of our HMM are all normal, it is also easy to show that Condition (A2) and (A3) of Gassiat and Rousseau (2014) are satisfied. Finally, note that by Lemma 2 in Appendix 6.5 of Gassiat and Rousseau (2014), Condition (C3) implies that Condition (A4) of Gassiat and Rousseau (2014) holds. Thus, all necessary conditions for Corollary 1 of Gassiat and Rousseau (2014), ensuring the conclusion in (3).

Given (3), the consistency of the full posterior distribution 2 follows from Schwartz's Theorem and the fact that for the parametric HMM model of Section 2.3.1, Condition (C0) guarantees that the true distributions is in the Kullback-Leibler support of the specified priors (see, e.g., Theorem 1 of Ghosal et al, 1999).

Proposition 1 shows the consistency of full posterior distribution of the Bayesian hierarchical model in (1). It then follows that the marginal posterior probabilities of the hidden states $\{S_t\}_{t=1}^m$, i.e., the quantities $\Pr(S_t = 0|\mathbf{X}, \vartheta)$ used in large-scale Bayesian inference, consistently classify the hidden state into null or non-null.

Conditions (C0)-(C2) are rather standard assumptions about Bayesian HMMs; (C3) is a general identifiability condition for parameters of finite state space HMMs, and guarantees that the set of observation distributions $\mathcal{F}$ are distinguishable. Gassiat and Rousseau (2014) point out that (C3) holds for a mixture of normals with distinct means and variances.

3. Simulation Studies

In this section, we compare the proposed Bayesian methods with L known (FB) or unknown (nested NPB) with the FDR controlling procedure of Benjamini and Hochberg (1995) (BH), the adaptive p-value procedure of Storey (2002) (AP), the LIS method (Sun and Cai, 2009), and the oracle procedure (OR) which assumes that the true parameters are known. The OR results serve as benchmark. All procedures are compared on average FDR, FNR, and the number of true positives (ATP) values from $N = 50$ simulated datasets.

In all simulations, $m = 3000$ observations are used and the target FDR is set at $\alpha = 0.10$. The initial state distribution is assumed as $\boldsymbol{\pi}^0 = (\pi_0^0, \pi_1^0) = (0, 1)$. The elements in the transition matrix $\mathcal{A}$ is specified as $a_{00} = 0.95, a_{01} = 0.05$, and $a_{10} = 1 - a_{11}$, with a_{11} varying for different scenarios. In all simulations, null observations are generated from the standard normal distribution, $\{X_t|S_t = 0\} \sim N(0, 1)$. The non-null observations, on the other hand, are either generated from a single normal distribution, $\{X_t|S_t = 1\} \sim N(\mu, 1)$ or a multi-component normal mixture $\{X_t|S_t = 1\} \sim \sum_{\ell=1}^{L} p_\ell N(\mu_{1\ell}, 1)$. The values of a_{11} and μ or μ_ℓ are varied to investigate how the HMM parameters affect the performance of testing procedures. We refer the interested reader to Chi (2011) for theoretical evaluation of the effects of HMM parameters on multiple testing procedures.

3.1 *Simple non-null distribution ($L = 1$)*

Figure 1 summarizes the results for a simple non-null distribution with known $L = 1$. The upper panel of the figure corresponds to the setting where the mean is fixed at $\mu = 2$, and a_{11} varies from 0.2 to 0.8 by 0.1 increments. Varying a_{11} changes the stationary distribution of the HMM $\boldsymbol{\pi} = (\pi_0, \pi_1)$ as $\pi_0 = a_{10}/(a_{01} + a_{10})$, $\pi_1 = a_{01}/(a_{01} + a_{10})$. When a_{11} increases with a_{00} fixed, the HMM is more persistent and the proportion of non-null observations increases. All methods reasonably controls the FDR. In most cases, BH has lower FDR compared to other methods, especially when a_{11} is large. The procedures are, however, clearly divided into two groups in terms of FNR and ATP: procedures that ignore the dependence among hypotheses, i.e., BH and AP, have higher FNR and lower ATP than those that take the dependence into account, i.e., OR, LIS, and FB. The difference rapidly grows with a_{11} increasing.

The simulations used in the lower panels of Figure 1 fix a_{11} at 0.8 with the mean μ varying from 1 to 4 by 0.5. Under all scenarios, the stationary distribution is $\boldsymbol{\pi} = (0.8, 0.2)$ and there are approximately the same number of non-null observations, which is around 600. The results show how the strength of the non-null signals affects the performance of testing procedures under the same magnitude of dependence. When μ varies, all methods have FDR under control while the μ is larger. The performance of FB and LIS differs when the μ is low (between 1 to 2), where FB leads to results closer to those obtained by OR (benchmark). In terms of FNR and ATP, FB and LIS have almost identical performance as the OR. BH and AP have much higher FNR and lower ATP, especially when the non-null signal is weak. Although FDR is under control by all procedures, BH and AP are less efficient compared to FB and LIS methods. BH is the most conservative one with higher FNR and lower ATP.

[Figure 1 about here.]

3.2 *Mixture non-null distribution with known L*

In this setting, we consider a normal mixture with $L = 3$ known components, defined as $f_1 = 0.4N(\mu, 1) + 0.3N(1, 1) + 0.3N(3, 1)$ and vary μ -4 to -1 by 0.5 increments. Figure 2 compares the performances of BH, AP, LIS, FB, NPB, and OR. The number of mixture components L is an unknown parameter in NPB, but is taken to be known in all the other procedures. It can be seen that BH is the most conservative procedure with the lowest FDR. LIS and AP do not properly control the FDR when the non-null mean of the first component μ is between -1 and -2, but correctly control at 0.10 it in other cases. On the other hand, both Bayesian methods always control the FDR at around 0.10. Similar to the simple non-null setting of Section 3.1, the methods can be divided into two groups in terms of FNR and APT: BH and AP have higher FNR and lower ATP compared to OR, LIS, FB, and NPB. Moreover, FNR and ATP deteriorate as the non-null mean μ varies from -4 to -1. However, the magnitude of difference in both quantities is approximately constant for all values of μ. The two Bayesian methods have almost identical performance compared to OR and LIS, except for a slightly higher FNR and lower ATP between $\mu = -2$ to -1. As mentioned, LIS does not correctly control the FDR for this range of μ. On the other hand, the performance of the Bayesian methods can be improved if more informative priors — instead of the vague $N(0, 100)$ priors — can be used above on the mean parameters.

The inability of LIS to control the FDR for weak signal may be partially attributed to the sensitivity of the EM algorithm to the choice of starting values. For instance, in one of the simulation runs, we noticed that the EM algorithm did not provide good estimates of the parameters when starting values are set as 2 in a normal mixture $0.5N(-1, 1) + 0.5N(3, 1)$ and in some cases the algorithm failed to coverage.

[Figure 2 about here.]

3.3 *Mixture non-null distribution with misspecified L*

In practice, the actual number of mixture components is often unknown. There is thus a potential risk of mis-specifying the number of components L, particularly if a simple non-null model is used when the true non-null distribution is a mixture with both positive and negative means. In this simulation setting, we examine the robustness of various procedures to misspecification of L. We consider the non-null distribution $f_1 = 0.2N(\mu, 1)+0.8N(2, 1)$ with μ varying from -4 to -1 by 0.5. When applying LIS and FB, f_1 is misspecified as $f_1 = N(\mu, 1)$ with $L = 1$; L is an unknown parameter in NPB. Figure 3 summarizes the simulation results. In this case, the FDR control by FB and LIS are conservative when μ is close to -4 and anti-conservative when μ is close to -1. FB is similar to LIS when $\mu < -2.5$ but the two methods differ considerably when $\mu > -2.5$: FB has a lower FNR and higher ATP but at the price of higher FDR. Their FNR and ATP are better than BH and AP, but worse compared to nested NPB and OR. Of course, BH and AP are not affected by the misspecification of the non-null distribution. Similar to Section 2, these methods have the highest FNR and lowest ATP for all mean values. The misspecified FB and LIS methods behave similarly to BH and

AP when the negative non-null signals are strong (close to $\mu = -4$). On the other hand, they behave similarly to OR and nested NPB when the negative non-null signal is weak (close to $\mu = -1$). Under all scenarios, the nested NPB has very similar performance as OR in the terms of FDR, FNR and ATP and outperforms all other methods. This is achieved by overcoming the potential misspecification on the number of mixture components.

[Figure 3 about here.]

When L is misspecified, both FB and LIS suffer from computational instabilities that may be used to detect the misspecification. Specifically, the trace plot of μ's for FB may exhibit up-and-down segments because of the multiple local maxima. The EM algorithm used in LIS, on the other hand, depends heavily on the initial values of μ. When the initial value of μ is nonpositive, LIS performs similarly to FB. However, when the initial value is set at a value greater than 2, LIS has a much higher FNR and lower ATP while the FDR is lower than all the other procedures.

4. Case Studies

We apply the proposed methods to data on weekly incidence rates of influenza-like illness (ILI) (Sun and Cai, 2009) and a yeast expression quantitative trait loci (eQTL) data (Daye et al., 2012).

In both examples, the number of non-null components L is unknown. We follow Sun and Cai (2009) and choose the value of L for LIS by minimizing the BIC over a range of values of L. Let $\mathbb{L}(\vartheta|\mathbf{X})$ be the likelihood function for parameters ϑ of the HMM model, and denote by $\hat{\vartheta}$ as the MLE estimator under LIS model. Then $\text{BIC} = -2 \times \log[\mathbb{L}(\hat{\vartheta}|\mathbf{X})] + L\log(m)$.

We use the Bayes factor (BF) for model comparison in Bayesian models. For two models M_1 and M_2, the Bayes factor is defined as the ratio between their marginal likelihoods $\mathbb{L}(\mathbf{X}|M_1)$ and $\mathbb{L}(\mathbf{X}|M_2)$, that is $BF_{12} = \mathbb{L}(\mathbf{X}|M_1)/\mathbb{L}(\mathbf{X}|M_2)$. Newton and Raftery (1994) estimates the marginal likelihood of the data under M_i using the MCMC draws as $\hat{\mathbb{L}}(\mathbf{X}|M_i) = \left[\sum_{r=1}^{R}\{\mathbb{L}_{M_i}(\vartheta^r|\mathbf{X})\}^{-1}/R\right]^{-1}$, where $\mathbb{L}_{M_i}(\vartheta^r|\mathbf{X})$ is the likelihood values in the r^{th} MCMC draw of the parameter vector ϑ of model M_i, $i = 1, 2$. Kass and Raftery (1995) suggested the decision between the two models can be made according to the values of $\log(BF_{12})$. Specifically, the evidence against model M_2 compared with Model M_1, is considered negligible for $\log(BF_{12})$ between 0 and 0.5, is substantial for values between 0.5 and 1, is strong for values between 1 and 2, and is decisive for values greater than 2. We report the log marginal likelihood under Bayesian methods FB and nested NPB.

4.1 *Application to ILI data*

An influenza-like illness (ILI) is defined as the combination of a sudden fever of at least $39°C$ with respiratory signs and myalgia. Sun and Cai (2009) applied LIS method to the ILI data collected from the Sentinelles Network, a national computerized surveillance system in France. We obtained the data from the website (http://websenti.b3e.jussieu.fr/sentiweb). To match the analysis of Sun and Cai (2009), we only include 1216 incidence rates between January 1985 and February 2008. The incidence rates have been standardized based on the sizes of the underlying population and the representativeness of the participating physicians. Sun and Cai (2009) also applied a logarithmic transformation to reduce the skewness of the original data.

As discussed in Sun and Cai (2009), the incidence rates of ILI may be either at a low level dynamic (usual or the null state) or a high level dynamic (aberration or the non-null state). Aberration in the incidence rates may provide a valuable signal for early detection of an epidemic. Thus, it is important to detect these aberrations from the usual incidence rates at a timely and accurate manner.

We compared the results from FB with the LIS of Sun and Cai (2009). The nested NPB cannot be easily carried out here as the null distribution is unknown. BIC was used for

LIS and Bayes factor for FB to decide the number of mixture components in the non-null distribution. Table 1 shows the parameter estimates from FB with $L = 1$ to $L = 5$ and the number of aberrations detected (detected positive) under FDR=0.001. The decisive difference is between models with $L \leqslant 2$ and $L \geqslant 3$ with an approximate difference of 10 in the log marginal likelihood. With $L \geqslant 3$, the log marginal likelihood of $L = 5$ is around 1.5 larger than that of $L = 4$ or 3. The difference in the number of aberrations in incidence rates detected is marginal and the estimates of the null distribution parameters are almost identical for models with $L = 3, 4$ and 5. Thus, FB suggests that a mixture with at least 3 components provides a reasonable fit to the aberration in incidence rates with 558 to 568 time periods detected as positive. In Sun and Cai (2009), a 2-component mixture with 512 time periods considered high level dynamic was chosen as the best model. The aberration time periods identified by FB are clustered together (see Web Figure S1). Similar clusters were also identified by Sun and Cai (2009). However, FB with $L \geqslant 3$ detected the start of the cluster earlier.

[Table 1 about here.]

4.2 *Application to eQTL Data*

Daye et al. (2012) analyzed a yeast eQTL data containing 585 representative markers on $n = 112$ yeast segregants. Here we focus on the variability of genetic markers across the samples, in particular, whether the allele frequency at each locus deviates from 0.5. Under the null hypotheses that allele frequency is 50%, the test statistic has mean of 1/2 and variance $1/(4 \times 112)$ and can be approximated by a normal distribution. Since the adjacent markers tend to have similar allele frequencies, the test statistics are expected to be dependent across neighboring markers. Web Figure S2 shows the test statistics at each marker and compares the results from BH, AP, LIS ($L = 1$ and $L = 2$), FB ($L = 1$ and $L = 2$), and the nested NPB. It can be seen that taking the dependence structure into account results in detection of more clustered markers as significant. The comparison between $L = 1$ and $L = 2$ under LIS and FB methods shows the importance of correctly specifying the non-null distribution. Detailed results for LIS with $L = 1, \dots, 4$ are shown in Web Table S1. Based on the BIC results, a two-component non-null mixture distribution is the best LIS model with 86 markers identified. Table 2 shows the results for FB with $L = 1, \dots, 4$ and the nested NPB method. In this case, FB also selects $L = 2$ based on the log marginal likelihood, but only identifies 78 markers as significant. The potential misspecification is avoided by the nested NPB, which results in similar estimated parameter values to the optimal LIS model and detects the same number of markers. Out of 86 markers detected by LIS with $L = 2$ and nested NPB, 85 are common; 77 markers are common between FB and the nested NPB.

[Table 2 about here.]

5. Discussion and Conclusions

Incorporating the dependence structure can improve efficiency of multiple hypotheses testing procedures. When the number of mixture components is known in the non-null distribution, Bayesian HMM provides comparable results to those in Sun and Cai (2009). When the number of mixture components is unknown, mis-specification can be overcome using a Bayesian HMM with Dirichlet process mixture model.

In this paper, we considered a one-dimensional dependence structure, but extensions of the proposed methods to higher dimensions are also of interest. Recently Sun et al. (2015) developed large-scale hypotheses testing procedures that control false discovery rate for point-wise and cluster-wise spatial domains using data-driven procedures and Bayesian computation algorithms. Currently, a single Gaussian random field is assumed on the spatial domains and the test statistics are computed using the plug-in posterior means. Green and Richardson (2002) modeled spatial heterogeneity and clusterings using hidden Markov models, where the number of components in the spatial mixture is estimated using a reversible jump algorithm. It is interesting to further investigate a two-dimensional HMM with the latent process as null and non-null states to be estimated as an integrated part of the model. Under the Bayesian framework, the application can also be easily extended to more complex dependence structure, such as multiple hypotheses testing for data with both spatial and temporal correlation as studied in Wei and Li (2008).

Supplementary Materials

Web Appendices, tables, and figures referenced in Sections 2 and 4 are available at the Biometrics website on Wiley Online Library. Simulated datasets used in Section 3 and FORTRAN codes implementing the full Bayesian and the nested non-parametric Bayesian methods are also available at the Biometrics website on Wiley Online Library.

Acknowledgements

X. Wang was partially supported by NCI U24-CA159988, Charles Phelps Taft Center 2015 Summer Research Fellowship, Faculty Development Fund and LEAF Career Branch Award at the University of Cincinnati. A. Shojaie was partially supported by grant DMS-1161565 from the NSF. The authors would like to thank Dr. Naomi Altman for stimulating conversations at the onset of the project. The authors' collaboration was facilitated by the Massive Datasets Program at the Statistical and Applied Mathematical Sciences Institute (SAMSI).

References

Albert, J. H. and Chib, S. (1993). Bayesian analysis of binary and polychotomous response data. *Journal of the American Statistical Association* **88,** 669–679.

Benjamini, Y. and Heller, R. (2007). False discovery rates for spatial signals. *Journal of the American Statistical Association* **102 (480),** 1272–1281.

Benjamini, Y. and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B (Methodological)* **57,** 289–300.

Benjamini, Y. and Yekutieli, D. (2001). The control of the false discovery rate in multiple testing under dependency. *Annals of Statistics* **29,** 1165–1188.

Chi, Z. (2011). Effects of statistical dependence on multiple testing under a hidden Markov model. *The Annals of Statistics* **39,** 439–473.

Daye, Z. J., Chen, J., and Li, H. (2012). High dimensional heteroscedastic regression with an application to eqtl data analysis. *Biometrics* **68,** 316–326.

Do, K.-A., Müller, P., and Tang, F. (2005). A Bayesian mixture model for differential gene expression. *Journal of the Royal Statistical Society. Series C (Applied Statistics)* **54,** 627–644.

Dudoit, S., Giber, H. N., and van der Laan, M. J. (2008). Resampling-based empirical Bayes multiple testing procedures for controlling generalized tail probability and expected value error rates: focus on the false discovery rate and simulation study. *Biometrical Journal* **50,** 716–744.

Efron, B. (2007). Correlation and large-scale simultaneous significance testing. *Journal of the American Statistical Association* **102,** 93–103.

Efron, B., Tibshirani, R., Storey, J. D., and Tusher, V. (2001). Empirical Bayes analysis of a microarray experiment. *Journal of the American Statistical Association* **96,** 1151–1160.

Escobar, M. D. and West, M. (1995). Bayesian density estimation and inference using mixtures. *Journal of the American Statistical Association* **90,** 577–588.

Finner, H., Dickhaus, T., and Roters, M. (2007). Dependency and false discovery rate:

Asymptotics. *The Annals of Statistics* **35,** 1432–1455.

Frühwirth-Schnatter, S. (2006). *Finite Mixture and Markov Switching Models.* Springer.

Gassiat, E. and Rousseau, J. (2014). On the asymptotic behaviour of the posterior distribution in hidden Markov models with unknown number of states. *Bernoulli journal* **20,** 2039–2075.

Genovese, C. and Wasserman, L. (2003). Bayesian and frequentist multiple testing. In Heckerman, D., Smith, A. F. M., and West, M., editors, *Bayesian statistics 7*, pages 145–161. Oxford University Press.

Ghosal, S. and Ghosh, J. K and Ramamoorthi, R. V. (1999). Albert, J. H. and Chib, S. (1993). Posterior consistency of Dirichlet mixtures in density estimation. *Annals of Statistics* **27**(1), 143–158.

Green, P. J. and Richardson, S. (2002). Hidden Markov models and disease mapping. *Journal of the American Statistical Association* **97,** 1–16.

Guo, W., He, L., and Sarkar, S. K. (2014). Further results on controlling the false discovery proportion. *The Annals of Statistics* **42,** 1070–1101.

Hathaway, R. J. (1985). A constrained formulation of maximum-likelihood estimation for normal mixture distributions. *The Annals of Statistics* **13,** 795–800.

Heller, R. (2010). Comment: Correlated z-values and the accuracy of large-scale statistical estimates. *Journal of the American Statistical Association* **105,** 1057–1059.

Ishwaran, H. and Zarepour, M. (2002). Exact and approximate sum–representations for the Dirichlet process. *Canadian Journal of Statistics* **30,** 269–283.

Kass, R. E. and Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association* **90,** 773 – 795.

Kim, S., Dahl, D. B., and Vannucci, M. (2009). Spiked Dirichlet process prior for Bayesian multiple hypothesis testing in random effects models. *Bayesian Analysis* **4,** 707–732.

Li, H., Wei, Z., and Maris, J. (2010). A hidden Markov random field model for genome-wide association studies. *Biostatistics* **11,** 139–150.

Liu, J., Zhang, C., McCarty, C., Peissig, P., Burnside, E., and Page, D. (2012). Graphical-model based multiple testing under dependence, with applications to genome-wide association studies. *ArXiv e-prints* arXiv1210.4868L.

McCulloch, R. E. and Tsay, R. S. (1994). Statistical analysis of economic time series via Markov switching models. *Journal of Time Series Analysis* **15,** 523539.

Müller, P., Parmigiani, G., Robert, C., and Rousseau, J. (2004). Optimal sample size for multiple testing: the case of gene expression microarrays. *Journal of the American Statistical Association* **99,** 990–1001.

Neal, R. M. (2000). Markov chain sampling methods for Dirichlet process mixture models. *Journal of Computational and Graphical Statistics* **9,** 249–265.

Newton, M. and Raftery, A. (1994). Approximate Bayesian inference by the weighted likelihood bootstrap. *Journal of the Royal Statistical Society, Series B* **56,** 3–48.

Newton, M. A., Noueiry, A., Sarkar, D., and Ahlquist, P. (2004). Detecting differential gene expression with a semiparametric hierarchical mixture method. *Biostatistics* **5(2),** 155–176.

Owen, A. B. (2005). Variance of the number of false discoveries. *Journal of the Royal Statistical Society. Series B (Statistical Methodology)* **67,** 411–426.

Robert, C. P. and Celeux, G.and Diebolt, J. (1993). Bayesian estimation of hidden Markov chains: a stochastic implementation. *Statistics & Probability Letters* **16,** 77–83.

Scharwartzman, A. and Lin, X. (2011). The effect of correlation on false discovery rate estimation. *Biometrika* **98,** 199–214.

Sethuraman, J. (1994). A constructive definition of Dirichlet priors. *Statistica Sinica* **4,** 639–650.

Shahbaba, B. and Johnson, W. O. (2013). Bayesian nonparametric variable selection as an exploratory tool for discovering differentially expressed genes. *Statistics in Medicine* **32,** 2114–2126.

Shu, H., Nan, B., and Koeppe, R. (2015). Multiple testing for neuroimaging via hidden Markov random field. *Biometrics* **71(3),** 741–750.

Storey, J. D. (2002). A direct approach to false discovery rates. *Journal of Royal Statistical Society, Series B* **64(3),** 479–498.

Sun, W. and Cai, T. T. (2009). Large-scale multiple testing under dependence. *Journal of Royal Statistical Society, Series B* **91 (2),** 393–424.

Sun, W., Reich, B. J., Cai, T. T., Guindani, M., and Schwartzman, A. (2015). False discovery control in large-scale spatial multiple testing. *Journal of the Royal Statistical Society. Series B (Statistical Methodology)* **77,** 59–83.

Teh, Y. (2009). Bayesian nonparametrics (tutorial). In *MLSS*, Cambridge.

Titterington, D. M., Smith, A. F., and Makov, U. E. (1985). *Statistical analysis of finite mixture distributions (Vol. 7).* Wiley, New York.

Tjøstheim, D. (1986). Some doubly stochastic time series models. *Journal of Time Series Analysis* **7,** 51–72.

Wei, Z. and Li, H. (2008). A hidden spatial-temporal Markov random field model for network-based analysis of time course gene expression data. *The Annals of Applied Statistics* **2,** 408–429.

Wei, Z., Sun, W., Wang, K., and Hakonarson, H. (2009). Multiple testing in genome-wide association studies via hidden Markov models. *Bioinformatics* **25,** 2802–2808.

Xiao, J., Zhu, W., and Guo, J. (2013). Large-scale multiple testing in genome-wide association studies via region-specific hidden Markov models. *BMC Bioinformatics* **14,** 282.

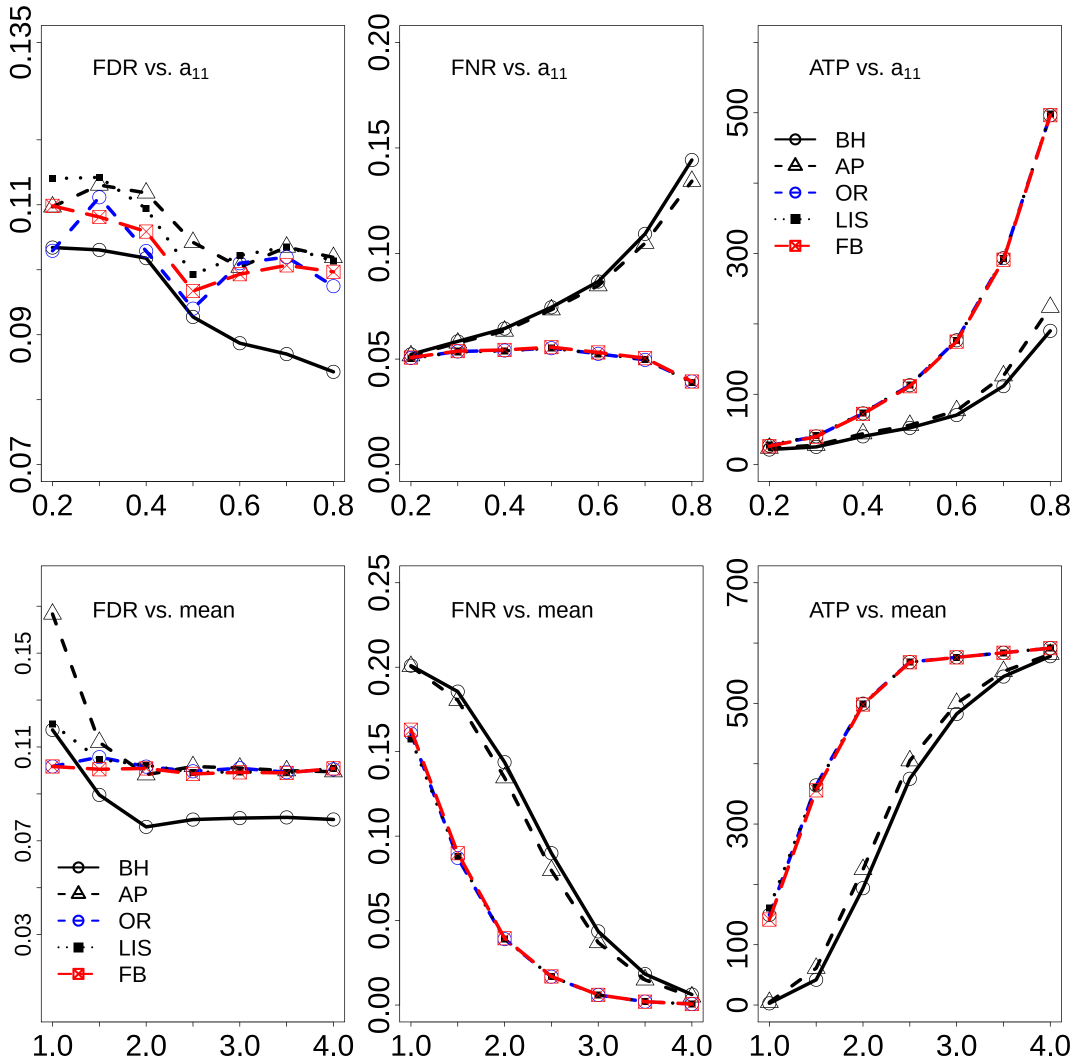


Figure 1: Comparison of FDR, FNR and ATP among BH, AP, OR, LIS, and FB. Upper panels: a_{11} varies from 0.2 to 0.8 and the non-null distribution is specified as $f_1 = N(2, 1)$; Lower panels: $a_{11} = 0.8$ and the non-null distribution is specified as $f_1 = N(\mu, 1)$ with μ varying from 1 to 4.

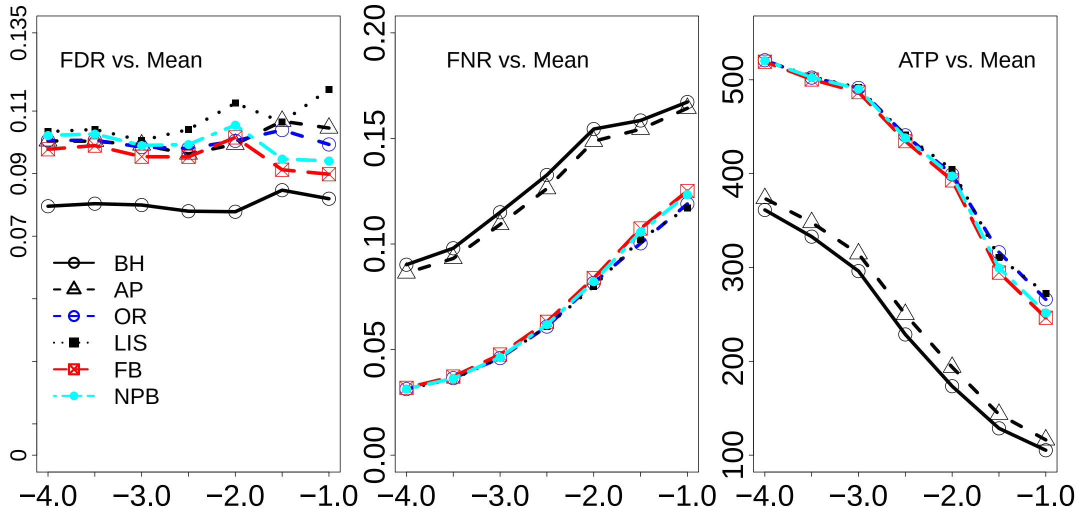


Figure 2: Comparison of BH, AP, OR, LIS, FB, and NPB procedures in setting of mixture non-null distribution with known L. Here, $a_{11} = 0.8$ and the non-null distribution is $f_1 = 0.4N(\mu, 1) + 0.3N(1, 1) + 0.3N(3, 1)$ with μ varies from -4 to -1.

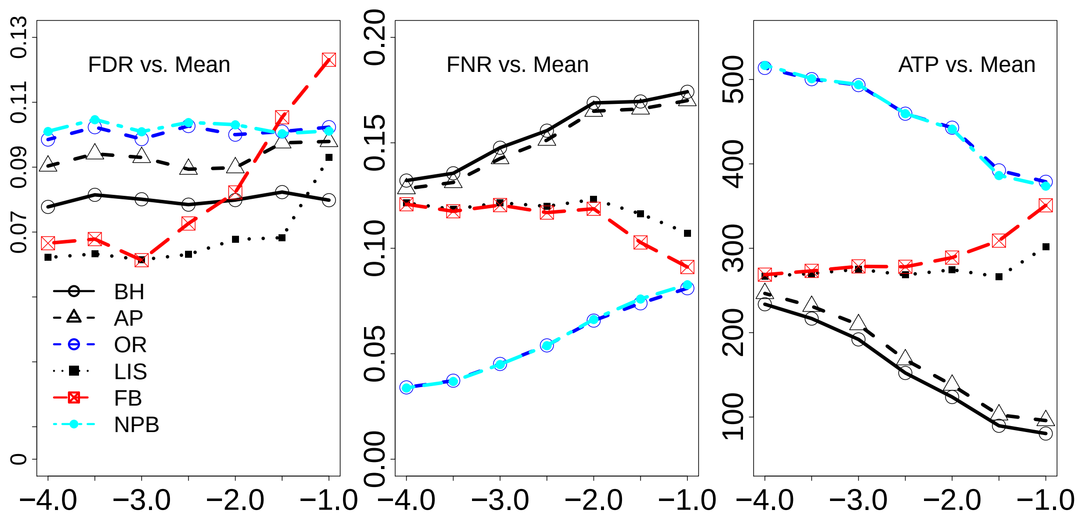


Figure 3: Results comparison among BH, AP, LIS, FB, NPB, and OR. In the simulated datasets, $a_{11} = 0.8$ and the true non-null distribution is $f_1 = 0.2N(\mu, 1) + 0.8N(2, 1)$ with μ varying from -4 to -1 but is misspecified as $f_1 = N(\mu, 1)$ in estimation with LIS and FB.

Table 1: FB Model estimation comparisons for ILI data with $L = 1$ to 5

L	Null f_0	non-null f_1	Transition matrix $\mathcal{A}$	log marginal likelihood	Detected positive
1	$N(2.47, 0.81^2)$	$N(4.89, 1.02^2)$	$\begin{bmatrix} 0.96 & 0.04 \\ 0.05 & 0.95 \end{bmatrix}$	-1803.658	405
2	$N(2.26, 0.72^2)$	$0.58N(3.91, 0.48^2)$ $+0.42N(5.65, 0.83^2)$	$\begin{bmatrix} 0.95 & 0.05 \\ 0.04 & 0.96 \end{bmatrix}$	-1721.775	518
3	$N(2.20, 0.69^2)$	$0.40N(3.66, 0.39^2)$ $+0.36N(4.56, 0.60^2)$ $+0.24N(6.12, 0.60^2)$	$\begin{bmatrix} 0.95 & 0.05 \\ 0.04 & 0.96 \end{bmatrix}$	-1711.721	558
4	$N(2.19, 0.69^2)$	$0.35N(3.62, 0.38^2)$ $+0.257N(4.32, 0.57^2)$ $+0.196N(5.03, 0.70^2)$ $+0.197N(6.20, 0.58^2)$	$\begin{bmatrix} 0.95 & 0.05 \\ 0.04 & 0.96 \end{bmatrix}$	-1711.819	562
5	$N(2.19, 0.69^2)$	$0.32N(3.61, 0.37^2)$ $+0.20N(4.17, 0.55^2)$ $+0.16N(4.63, 0.66^2)$ $+0.14N(5.36, 0.72^2)$ $+0.16N(6.26, 0.56^2)$	$\begin{bmatrix} 0.95 & 0.05 \\ 0.04 & 0.96 \end{bmatrix}$	-1710.315	568

Table 2: Model comparison under Bayesian Method for eQTL data

L	non-null f_1	Transition matrix $\mathcal{A}$	log marginal likelihood	Detected positive
1	$N(0.18, 2.64^2)$	$\begin{bmatrix} 0.96 & 0.04 \\ 0.20 & 0.80 \end{bmatrix}$	-1084.00	56
2	$0.81N(-1.77, 0.78^2)$ $+0.19N(4.54, 1.56^2)$	$\begin{bmatrix} 0.94 & 0.06 \\ 0.23 & 0.77 \end{bmatrix}$	-1008.19	78
3	$0.36N(-2.15, 0.84^2)$ $+0.49N(-1.27, 0.64^2)$ $+0.15N(4.70, 1.49^2)$	$\begin{bmatrix} 0.94 & 0.06 \\ 0.22 & 0.78 \end{bmatrix}$	-1014.60	82
4	$0.234N(-2.58, 0.84^2)$ $+0.314N(-1.70, 0.71^2)$ $+0.313N(-0.47, 0.73^2)$ $+0.139N(4.92, 1.46^2)$	$\begin{bmatrix} 0.94 & 0.06 \\ 0.22 & 0.78 \end{bmatrix}$	-1013.83	82
NPB		$\begin{bmatrix} 0.94 & 0.06 \\ 0.21 & 0.79 \end{bmatrix}$		86

United States
Department of
Agriculture

National
Agricultural
Statistics
Service

Research and
Development Division
Washington DC 20250

RDD Research Report
Number RDD-YY-NN

September 2015

Time Series Prediction of Hog Inventory

Benjamin Kedem and Lemeng Pan

Abstract

U.S. level quarterly hog time series prediction, employing a sequential regression method referred to as sequential GLM (SGLM), is considered. The method accommodates periodic changes or "shocks" by varying the length of time series sections used in 1-quarter ahead forecasting. Comparisons with a certain state-space approach, as well as with ARIMA plus a drift, point to a significant mean absolute error (MAE) reduction achieved by the sequential method. The improved U.S. level predictions are then used in future state allocation for states which produce hog inventories.

Key Words: Gaussian link, log linear, coherence, state space, shiny, mean absolute error.

1 INTRODUCTION

Hog and pig quarterly time series in the US undergo periodic changes or "shocks" possibly due to disease, tariffs, market forces, or due to rapid structural changes and new technologies, particularly in recent years. In addition, Surveys show that total hog numbers have increased from a decade ago. Indeed, typical hog time series exhibit upward trends accompanied by seasonal cycles, and at times rapid oscillation pointing to possible "shocks" in the hog industrial system [1],[2],[3]. Typical hog time series exhibiting that behavior are shown in Figures 1 to 7.

An example of a potential shock has to do with consumers' reaction to the use of a feed additive called *ractopamine*. Ractopamine which is banned in the EU, China, and Russia was approved by the FDA in 1999. From a recent NPR story on August 14, 2015 we learn that: "Most pigs in America get this drug, because it's extremely effective. It's a "beta agonist" and has effects that are similar to adrenaline. It gets a pig to put on more muscle, instead of fat, and also put on weight more quickly. That's money in the farmer's pocket: According to some experts, it adds two or three dollars of income per pig." Pork without ractopamine will soon have a **new label** approved by USDA that will say: **no ractopamine — a beta-agonist growth promotant**. See `www.npr.org/sections/thesalt/2015/08/14/432102733/a-muscle-drug-for-pigs-comes-out-of-the-shadows`.

Knowing that pork meat has been obtained from hogs medicated with ractopamine could be a deterrent, and change consumers' behavior, possibly generating a "shock" to some degree.

The problem we shall deal with here is forecasting hog time series, accommodating periodic "shocks" due to epidemics or other types of intervention, using NASS as well as public Internet data. The specific hog time series to be predicted are listed in Table 1. Referring to the table, G12,G3,G4 are called "weight groups."

Regarding market hogs less than 50 lb (referred to as G1) and market hogs 50-119 lb (referred to as G2), instead of forecasting them separately, we forecast their sum $G12 = G1 + G2$.

To avoid an undue repetition, the reader is referred to [1] for a thorough background describing the NASS hog inventory estimation/prediction problem and the role of the panel of experts, referred to as Agricultural Statistical Board (ASB), in establishing the final NASS official hog inventory estimates.

2 The Problem of Hog Prediction

Consider the total hog inventory H observed quarterly. So, time t is measured in quarters. Suppose we are at time t and wish to predict $H(t + 1)$. However, at time t we only know a preliminary

Table 1: Hog time to be predicted

Time Series	Notation
Total hog inventory	H
Pig crop	P
Sows farrowed	S
Market hogs less than 119 lb	G12
Market hogs 120-179 lb	G3
Market hogs greater than 180 lb	G4
Market hogs	M=G12+G3+G4
Breeding herd	B=H-M

estimate of H_t denoted by $H0_t$. At time $t-1$ we only know a preliminary estimate $H1_{t-1}$, but not H_{t-1} itself. At time $t-2$ we only know a preliminary estimate $H2_{t-2}$, but not H_{t-2}. At time $t-3$ we only know a preliminary estimate $H3_{t-3}$, but not H_{t-3}. It should be noted that $H1$ is more precise than $H0$, $H2$ is more precise than $H1$, and $H3$ is more precise than $H2$.

However, H **is known** at times $t-4, t-5, \ldots$. In other words, at time t we know $H_{t-4}, H_{t-5}, H_{t-6}, \ldots$. Hence, in terms of quarters, at time t we know H FOUR quarters ago (a year ago), FIVE quarters ago, SIX quarters ago, etc.

The same holds for the series $P, S, B, G3, G4$, but no preliminary estimates of $G12$ are available at time t.

Fortunately, at time t we know the results of certain surveys referred to as "indications", publicly available monthly pork price per pound, and commercial slaughter data, albeit at time $t-2$. These will prove useful predictors.

The problem is then to predict the results of a future quarter based on all the information available to an observer up to time t, while taking into consideration possible "shocks" or irregular changes.

3 Forecasting Methods

In what follows we describe several forecasting methods which will be applied in the next section to various hog time series.

3.1 Busselberg (2013) State-Space Model (RDD)

Define the shift operator

$$Bx_t \equiv x_{t-1}.$$

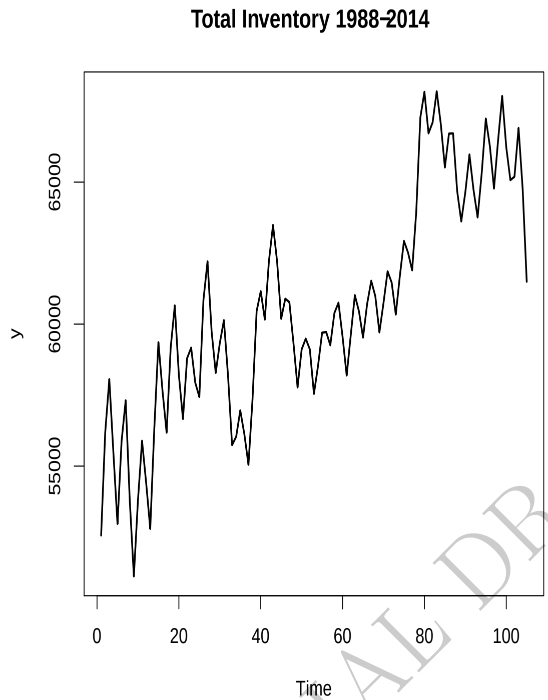
The basic idea is to estimate a linear filter operator $\Delta(x_t)$ to capture both a trend and an annual cycle in the hog data,

$$\Delta(x_t) \equiv (1-B)(1-B^4)x_t = x_t - x_{t-1} - x_{t-4} + x_{t-5}$$

and then use the following telescopic sum to get x_t:

$$x_t = \Delta(x_t) + x_{t-1} + x_{t-4} - x_{t-5}$$

Figure 1: Total inventory time series



For example:
1. If H_t = Total inventory at time t.
2. Then H_{t-4}, H_{t-5} are known.
3. Busselberg [1] estimates the **states** $\Delta(H_t), H_{t-1}$.
4. Then to estimate H_t he uses the telescopic sum:

$$\hat{H}_t = \hat{\Delta}(H_t) + \hat{H}_{t-1} + H_{t-4} - H_{t-5}$$

This approach is sensible under steady state, particularly when the various preliminary estimates H1,H2,H3 are are not far from their true counterparts.

However, problems arise when the telescopic sums "do not add up". More precisely, in the telescopic sum

$$\hat{H}_t = \hat{\Delta}(H_t) + \hat{H}_{t-1} + H_{t-4} - H_{t-5}$$

problems arise when either $\hat{\Delta}(H_t)$ or $\hat{H}_{t-1}$ or both are poorly estimated, perhaps due to **sudden changes** or **shocks** in the hog population. The resulting $\hat{H}_t$ is then far from the true H_t.

Here is a problematic scenario. Assume that the "stationary" $\Delta(H_t)$ is estimated with precision. Since at time t we **know** H_{t-4}, H_{t-5}, after cancellation we obtain the approximation

$$\begin{aligned} \hat{H}_t &= \hat{\Delta}(H_t) + \hat{H}_{t-1} + H_{t-4} - H_{t-5} \\ &\approx H_t - H_{t-1} + \hat{H}_{t-1}. \end{aligned}$$

We see that there is a problem when $\hat{H}_{t-1}$ is much larger than the true H_{t-1}. In that case there is no proper cancellation and $\hat{H}_t$ tends to be larger than the true H_t.

For example, take $t = 3/2014$. Then $t - 1 = 12/2013$ for which $H(12/2013) = 64,775$. A reasonable estimate is:

$$\hat{H}(12/2013) \approx H1(12/2013) = 66,025 >> 64,775.$$

This is a possible explanation of why Busselberg [1] RDD total inventory prediction for 3/2014 is much larger than the true $H(3/2014)$. See figure 8.

On the other hand, when $\hat{H}_{t-1} \approx H_{t-1}$ we should expect good prediction. Take $t = 12/2012$. Then $t - 1 = 9/2012$, and $H(9/2012) = 68,032$. A reasonable estimate is:

$$\hat{H}(9/2012) \approx H1(9/2012) = 67,702 \approx\approx 68,032.$$

This explains why Busserlberg total inventory prediction for 12/2013 is very good. See figure 8.

Now, prediction is only prediction. And prediction which depends on many factors may not be reliable. To counter this problem to some extent, we need realistic prediction intervals which capture truth with a high probability. Busselberg [1] RDD state space formulation provides in many cases excessively narrow prediction intervals, an example of which is seen in the Figure 8, where 5 of 8 prediction estimates are much outside the prediction intervals.

The potential problem persists throughout the Busseleberg [1] RDD state-space model as **all** the Kalman filter estimates are functions of one or more of:

- $\Delta(H_t) + H_{t-1} + H_{t-4} - H_{t-5}$

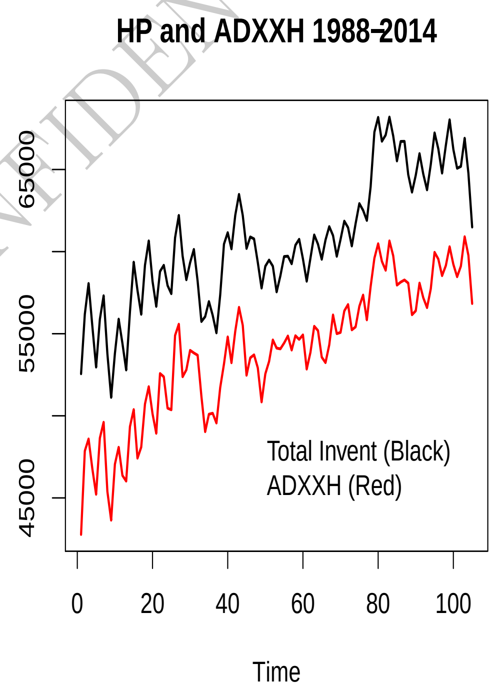


Figure 2: Total inventory and its indication time series.

- $\Delta(P_t) + P_{t-1} + P_{t-4} - P_{t-5}$
- $\Delta(S_t) + S_{t-1} + S_{t-4} - S_{t-5}$
- $\Delta(f_{1t}) + f_{1t-1} + f_{1t-4} - f_{1t-5}$

where H=Total inventory, P=Pig crop, S=Sows farrowed, $f_1 = G_1 + G_2 = G12$.

3.2 ARIMA Plus a Drift

An important way to forecast time series is by means of a class of models referred to as "autoregressive integrated moving average" or ARIMA defined as (Box et al. [5])

$$(1 - \phi_1 B - \cdots \phi_p B^p)(1 - B)x_t = \theta_0 + (1 + \theta_1 B + \cdots \theta_q B^q)\epsilon_t,$$

where ϵ_t are uncorrelated input with mean 0 and variance σ^2, and θ_0 is a drift which models a deterministic trend.

The widely used method does not use covariates other than white noise input and past values of the time series itself. For hog time series x_t, at time t we only know $x_{t-4}, x_{t-5}, ...$ Thus, ARIMA forecasting in the context of most hog time series means 4 quarters ahead forecasting. This is why in general, RDD is superior to ARIMA forecasting, although on occasion ARIMA provides surprisingly precise forecasts.

3.3 An Alternative: Sequential GLM Predicion

To capture changing dynamics, and giving more weight to the recent past, sequential GLM (SGLM) prediction uses short time series of size L

$$y_{t-(L-1)}, \cdots, y_{t-1}, y_t$$

to predict y_{t+1}, $t = L, L+1, ...$, from past covariates. When the covariates are "well behaved," this can be done by employing linear or log-linear regression models (Kedem and Fokianos [4]).

As we shall see, in general sequential GLM outperforms both RDD and ARIMA.

In our work the identity and log links gave very similar results, and L was mainly either 22 (5.5 years) or 23 (5.75 years).

Advantages of Sequential GLM Prediction are listed as follows.

1. Easy to accommodate **changing** temporal dynamics.
2. Computationally simple and fast.
3. No problem with initial values.
4. Get **significant** MAE reduction relative to RDD.
5. Get **significan** MAE reduction relative to ARIMA with drift.
6. Get **significant** reduction of MAE($H - (\hat{M} + \hat{B})$).
7. Nimble and agile relative to RDD.
8. Helpful interpretation in terms of covariates.
9. MAE reduction is achieved by choosing useful covariates and an optimal L.
10. Realistic prediction intervals.
11. Easy and fast implementation by a web application **Shiny**.

3.3.1 Visual Interactive Web Application SHINY

We implement Sequential GLM by means of a visual interactive web application "Shiny" described in the Appendix A. With the help of Shiny we can:

a. Quickly see the effect of adding/removing covariates.
b. Easily modify the models interactively.
c. Discover useful covariates interactively.
d. Capture systemic **shocks** by experimenting with **differences** in certain covariates.
e. Obtain fast graphical comparison with RDD and ARIMA.
f. Assess model validity from prediction of the last 8 quarters.
g. Get MAE reduction by adjusting L.

3.4 Alternative State Space Model: RTVC

A regression model with time varying coefficients (RTVC) has the state space representation (Kedem and Fokianos [4]):

$$y_t = \mathbf{z}_t^{'} \beta_{\mathbf{t}} + v_t$$

$$\beta_t = \mathbf{F}_t \beta_{\mathbf{t-1}} + \mathbf{w}_t$$

This model is essentially the same as our sequential GLM model except for the choice of the parameter L. Controlling L significantly reduces the MAE, and hence we shall not pursue this model.

4 Discovering Potential Covariates

A way to discover potentially useful covariates needed for Sequential GLM is by the use of the measure of **coherence** (Khan et al. [6]). It operates on pairs of time series. Thus, given two jointly stationary time series (x_t, y_t), their linear dependence can be measured from a function of their individual spectra $f_x(\omega), f_y(\omega)$ and their complex cross spectral density $f_{xy}(\omega)$, defined in terms of ω =cycles/unit time, $\omega \in [0, 0.5]$.

That function is the squared **coherence**:

$$S(\omega) = \frac{|f_{xy}(\omega)|^2}{f_x(\omega) f_y(\omega)}, \quad 0 \le \omega \le 0.5$$

Fact: $S(\omega)$ acts much like a correlation in the frequency domain,

$$0 \le S(\omega) \le 1, \quad 0 \le \omega \le 0.5$$

This can be explained by means of a linear operation such as,

$$y_t = \sum_j h_j x_{t-j} + \epsilon_t$$

where ϵ_t is an independent noise component. The closer $S(\omega)$ is to 1 over a band of frequencies, the higher is the signal to noise ratio, and the stronger is the linear relationship between x_t snd y_t. In the extreme case, when $S(\omega) = 1$ for all $\omega \in [0, 0.5]$ then there is a perfect linear relationship between x_t and y_t:

$$y_t = \sum_j h_j x_{t-j}$$

Hog inventory time series are in general not stationary, however, the coherence can still point to useful relationships/covariates which we have used in Sequential GLM hog prediction. Many hog time series pairs exhibit a fairly large coherence as the following examples show.

Ideal Case

ADXXH refers to the survey indication corresponding to total hog inventory H. Since $ADXXH_{t-1}$ is obtained from $ADXXH_t$ linearly, the estimated coherence between $ADXXH_t$ and its shift $ADXXH_{t-1}$ should be close to 1 for all $\omega \in [0, 0.5]$. We see that clearly in Figure 9.

Mild Coherence

From Figure 10 the coherence between H_t and $P1_t - P3_t$ is rather mild. Hence $P1_t - P3_t$ is only a mildly useful covariate for predicting H_t.

Increased Coherence

However, from Figure 11 the coherence between H_t and $P1_{t-1} - P3_{t-3}$ is large for the frequency band $\omega \in [0.2, 0.3]$. Hence, $P1_{t-1} - P3_{t-3}$ is a potentially useful covariate for predicting H_t.

Interpreting High Coherence at $\omega = 0.5$

ADXXP is the survey indication corresponding to pig crop P. From Figure 12, its coherence with the combined weight group $G12_t = G1_t + G2_t$ is high at $\omega = 0.5$. Hence, $ADXXP_{t-2}$ is a potentially useful covariate for predicting $G12_t = G1_t + G2_t$.

5 Useful Covariates

The following covariates have been found useful in sequential GLM, where differences may point to possible "shocks" or irregular changes in hog time series.

01. $p_{diff} = P1_{t-1} - P3_{t-3}$
02. $ADXXHi = ADXXH_{t-i}$
03. $adh_{diffi} = ADXXH_t - ADXXH_{t-i}$
04. $comm2 = COMM_{t-2}$
05. $hogprice1 =$ NASS hog price
06. $hogprice2 =$ Swine monthly price cents/lb from the Web.
07. $adpi = adxxpi = ADXXP_{t-i}$
08. $adp_{diffi} = ADXXP_t - ADXXP_{t-i}$
09. $adxxg3_i = ADXXG3_{t-i}$
10. $adxxg4_i = ADXXG4_{t-i}$
11. $ADXXBi = ADXXB_{t-i}$

6 Application of Sequential GLM to Predicting Hog TS

In the following comparisons we shall refer to sequential GLM as SGLM for short. In all the figures the dashed lines are 95% prediction intervals.

6.1 SGLM total inventory prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 13. RDD MAE is 3.25 times greater than that of SGLM for the period 9/2012 - 6/2014.

6.2 SGLM Pig-crop Prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 14. RDD MAE is 3.26 greater than that of SGLM for the period 9/2012 - 6/2014.

6.3 SGLM G12 Prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 15. RDD MAE is 2 times greater than that of SGLM for the period 9/2012 - 6/2014. For the last 5 quarters SGLM gives near perfect prediction. For the 3rd quarter the clear wiener is ARIMA.

6.4 SGLM G3 Prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 16. The prediction of G3 proved challenging. Still, RDD MAE is 1.25 times greater than that of SGLM for the period 9/2012 - 6/2014. **The big drop in the last quarter is captured within the prediction interval**, pointing to a realistic prediction interval.

6.5 SGLM G4 Prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 17. RDD MAE is 3.125 times greater than that of SGLM for the period 9/2012 - 6/2014. SGLM gives good prediction in 6 out of 8 quarters. **The sharp spurious increase in RDD in the last quarter is avoided by SGLM**.

6.6 SGLM Sows Farrowed prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 18. RDD MAE is 2.9 times greater than that of SGLM for the period 9/2012 - 6/2014. **SGLM gives good prediction in 7 out of 8 quarters**.

6.7 SGLM Breeding Herd prediction

Comparison of SGLM with RDD and ARIMA is given in Figure 19. RDD MAE is 12.5 times greater than that of SGLM for the period 9/2012 - 6/2014. RDD performs well in this steady state case, yet its MAE is much larger than that of SGLM. **SGLM prediction is simple in this case: Only B0 is used**.

6.8 Check: H=M+B

Theoretically, H = Total Inventory, M = Market Hogs = $G12 + G3 + G4$, and B = Breeding Herd satisfy

$$H = M + B$$

Using the **predicted** values of $M = G12 + G3 + G4$ and of B we'll check how close $\hat{M} + \hat{B}$ is to H.

The difference $H - (\hat{M} + \hat{B})$ is given in Table 2. From the table, SGLM reduces the difference considerably relative to RDD for the period 9/2012 - 6/2014, particularly in the last 4 quarters.

Table 2: $H - (\hat{M} + \hat{B})$

Quarter	SGLM	RDD
2012Sep	-186	430
2012Dec	-777	6
2013Mar	-813	-1168
2013Jun	-1261	-1683
2013Sep	-394	-1072
2013Dec	-169	-966
2014Mar	-38	-2946
2014Jun	-496	-333
MAE Two yrs	517	1075
MAE Last yr	274	1329

6.9 Constraint: Balance Sheet

Define:

$$BSN_t = I_t - E_t - D_t - L_t$$

where I, E, D, L refer to import, export, death, and slaughter, respectively. The **Balance sheet residual** at time t, BSR_t, is defined as:

$$BSR_t = H_t - H_{t-1} - P_t - BSN_t$$

The accounting constraint requires that

$$|BSR_t| \leq 500.$$

BSN_t is obtained from HogLayout, whereas H_t, H_{t-1}, P_t are predicted values.

For the period 9/2012-6/2014 we have mean $(|BSR|)$ as follows:

$$\text{SGLM} : \text{mean}(|BSR|) = 459.79$$

$$\text{RDD} : \text{mean}(|BSR|) = 679.92$$

Thus, on average SGLM satisfies the accounting constraint $|BSR_t| \leq 500$ whereas on average RDD does not. It seems that incorporating the accounting constraint in the observation equations as in RDD does not guarantee fulfillment of the constraint by the forecasts.

7 Forecasting State-Level Inventories

The U.S. level forecasts of hog inventories are now used in quarterly forecasting of hog inventories on state-level. In doing so we revise the restricted least squares formulation of Busselberg (2013) by using the more precise quarterly SGLM forecasts described hitherto. The state-level inventory items to be allocated are pig crop (P), sows farrowed (S), market hogs $G_{12} = G_1 + G2$, G_3, G_4, and breeding herd (B). From this we obtain state allocations of total hog inventory (H), total market hogs (M), and litter rate (T), where $T = M + B$, $M = G_{12} + G_3 + G_4$, and $T = P/S$.

Given an observation model $y = X\beta + \epsilon$ plus the restriction $U\beta = q$, then the restricted least squares estimator is given by

$$\hat{\beta}_{rls} = \hat{\beta} + (X'X)^{-1}U'[U(X'X)^{-1}U']^{-1}(q - U\hat{\beta})$$

where $\hat{\beta}$ is the ordinary least squares estimator. Let q be the 6×1 vector of U.S. level estimates, $\mathbf{I}$ a 6×6 identity matrix, $\mathbf{1}$ a 50×1 vector of 1's, and $U' \equiv \mathbf{I} \otimes \mathbf{1}$. Let β_{sv} and β_{sr} denote the ordered vector of state surveys and vector of ordered state recommendations, respectively, and define $D = \mathrm{d}iag(\beta_{sr} - \beta_{sv})$. Then the restricted least squares formulation can be adapted to adjust the survey results if we write $D = (X'X)^{-1}$, and approximate $\hat{\beta} \approx \beta_{sv}$, in which case

$$\beta_{adjust} = \beta_{sv} + DU'[UDU']^{-1}(q - U\beta_{sv}).$$

Then *conditional* on q

$$\Sigma_{\beta_{adjust}} = [\mathbf{I} - DU'[UDU']^{-1}U]\Sigma_{\hat{\beta}_{sv}}[\mathbf{I} - DU'[UDU']^{-1}U]'$$

from which we can easily get the covariance matrix of $(T, M, P/S)$.

Typical error figures for March 2014 are given in Table 3, where the error is computed relative to the state recommendation. We can see that the adjusted state allocation estimates are close to the state recommendations. Similar results were obtained for March 2013, September 2013, and December 2013. The R code for forecasting state allocation is available.

Table 3: SGLM-predicted state allocation error: March 2014.

State	H	P	S	G_{12}	G_3	G_4	M	B	T
AL	0.043	0.133	0.075	0.002	0.001	0.087	0.026	0.128	0.062
AR	0.217	0.132	0.077	0.461	0.016	0.010	0.327	0.123	0.059
AZ	0.012	0.132	0.102	0.051	0.000	0.005	0.032	0.139	0.033
CO	0.001	0.024	0.021	0.015	0.006	0.046	0.018	0.068	0.044
GA	0.014	0.067	0.069	0.040	0.003	0.005	0.028	0.074	0.002
IA	0.067	0.134	0.078	0.101	0.007	0.116	0.080	0.203	0.060
IL	0.099	0.017	0.028	0.142	0.008	0.014	0.094	0.142	0.011
IN	0.042	0.185	0.116	0.097	0.003	0.006	0.059	0.170	0.079
KS	0.018	0.025	0.013	0.029	0.007	0.003	0.015	0.044	0.011
KY	0.001	0.011	0.041	0.024	0.001	0.042	0.023	0.176	0.033
MI	0.040	0.104	0.037	0.072	0.001	0.057	0.054	0.076	0.069
MN	0.089	0.084	0.059	0.122	0.003	0.129	0.100	0.061	0.027
MO	0.059	0.105	0.014	0.097	0.004	0.051	0.058	0.060	0.092
MS	0.022	0.040	0.015	0.034	0.001	0.012	0.020	0.038	0.024
MT	0.005	0.017	0.001	0.012	0.001	0.042	0.001	0.033	0.020
NC	0.025	0.117	0.023	0.053	0.004	0.022	0.028	0.002	0.096
ND	0.010	0.011	0.012	0.000	0.008	0.001	0.001	0.033	0.003
NE	0.071	0.012	0.003	0.096	0.007	0.074	0.074	0.055	0.016
OH	0.078	0.197	0.018	0.121	0.006	0.055	0.087	0.028	0.182
OK	0.042	0.106	0.031	0.035	0.007	0.064	0.036	0.063	0.078
PA	0.056	0.061	0.062	0.079	0.004	0.066	0.062	0.005	0.000
SC	0.013	0.070	0.051	0.036	0.002	0.011	0.015	0.048	0.020
SD	0.034	0.055	0.043	0.045	0.002	0.037	0.035	0.030	0.013
TN	0.011	0.048	0.080	0.007	0.003	0.065	0.020	0.078	0.035
TX	0.064	0.017	0.016	0.073	0.012	0.004	0.036	0.245	0.000
UT	0.023	0.003	0.006	0.014	0.001	0.014	0.011	0.114	0.008
VA	0.004	0.238	0.139	0.003	0.001	0.002	0.002	0.182	0.087
WI	0.049	0.143	0.148	0.089	0.005	0.041	0.045	0.071	0.005
WY	0.029	0.037	0.034	0.141	0.019	0.085	0.086	0.058	0.002

8 References

1. Busselberg, S. (2013). The use of signal filtering for hog inventory estimation. NASS Report.

2. http://www.nppc.org/pork-facts/

3. http://www.extension.umn.edu/youth/mn4-H/events/ project-bowl/docs/pb-gl-Quick-Facts-The-Pork-Industry-at-a-Glance.pdf

4. Kedem, B. and Fokianos, K. (2002). *Regression Models for Time Series Analysis.* John Wiley & Sons, Hoboken, NJ.

5. Box, G.E.P.,Jenkins, G.M., Reinsel, G.C. (2008). *Time Series Analysis*, 4th ed., John Wi-

ley & Sons, Hoboken, NJ.

6. Khan, D., Katzoff, M., and Kedem, B. (2014). Coherence structure and its application in mortality forecasting. *J. Stat. Theory and Practice*, 8, 578-590

APPENDIX A Hog Modeling Shiny Web App

To aid the development of the Sequential GLM models for hogs, a visual interactive web application has been developed. An R package called "Shiny" is used to develop the web app. "Shiny" package is available on the Comprehensive R Archive Network (CRAN). The web app consists of 10 files, including two R source files, seven R data files and a readme help file. The two source files are named "ui.R" and "server.R" respectively. The user interface is defined in the "ui.R" script and the main program of the application is included in the "server.R" script. There are seven R data files correspond to seven different categories of hog inventories at the US level, including total hogs (hp.RData), pig crop (pigcrop.RData), sows farrowed (sow.RData), market hogs less than 119 lbs (g12.RData), market hogs between 120 and 179 lbs (g3.RData), market hogs over 180 lbs (g4.RData) and breeding herd (bh.RData).

The program loads one of the seven R data files selected by the user. The user may modify the seven ".RData" files as needed. For example, when new data become available, the user may include the new data in the data file. A simple function to update the ".RData" file is available that would include the new observations from "HogLayout.csv" to ".RData" files. Manually entering and updating the data files is a useful option option. The user may also include new useful covariates in ".RData" to expand the list of potential covariates or remove any unnecessary covariates from the old list.

To run the shiny application, one may follow the procedure described below:

1. Create a folder (eg. \shinyHogs). Move all ten files to the folder just created.

2. Using the R console, load the "Shiny" package (the package must be installed first) and use the *setwd()* command to properly set the working directory to the path of the folder just created.

```
> library(shiny)
> runApp("your_path/shinyHogs")
```

Once the preceding commands are executed in R using the R console, a dynamic web page would be opened in the default web browser.

Figure 20: Shiny App User Interface

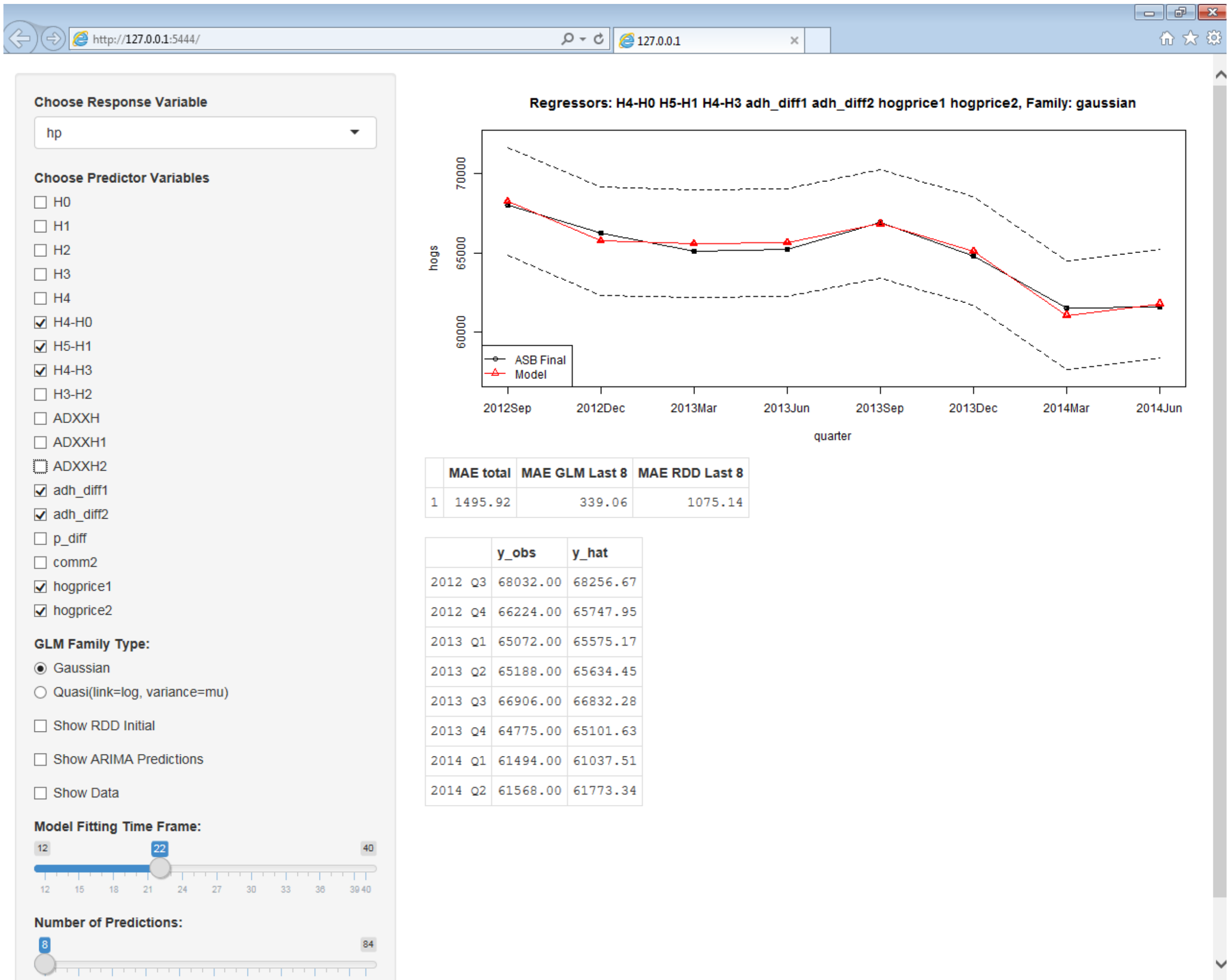


Figure 20 shows the layout of the web app. The user interface has a sidebar panel on the left hand side that allows the user to choose various hog time series inputs to the program, and a main panel on the right hand side which outputs the results of the program according to model inputs. The app is "reactive" in the sense that it automatically re-executes the program and updates the resulting output when the hog time series inputs change.

On the top of the sidebar panel, there is a drop down menu that allows the user to choose a particular category of the hog inventory the user wishes to model. The selected variable corresponds to the response variable of the Sequential GLM. The drop down menu is followed by a group of check boxes. It is a list of potentially useful covariates of the Sequential GLM (identified by the use of the measure of coherence). It gives the user options to add/remove covariates. The next section is a set of two radio buttons that allow the user to switch between two GLM families Gaussian (identity link) and Quasi (log link and constant variance equal to mu). Three single check boxes come next. Users may check the boxes to overlay predictions from Busselberg's State Space model and the best ARIMA model in the plot output located on the top of the main panel. When the "Show Data" check box is checked, a table of the data is displayed at the bottom of the main panel. The last portion of the sidebar panel consist of two slide bars. The first slide bar allows the user to adjust the model fitting time frame L. Recall that in the Sequential GLM, L is the length of time series used to fit (train) the model. One may move the slider back and forth to identify the optimal L. Users may include more predictions in the output plot and table by moving the slider in the last slide bar.

The results of the program are displayed in the main panel that consists of four parts. A time series plot of the predicted values from various models versus the observed values lies at the top. Then there is a table that compares the mean absolute deviation (MAE) of different models. The next portion is a table that shows numerical values of the predictions from Sequential GLM and the observations. The last portion is a table of the data which is hidden by default. The plot and the tables are updated automatically when changes of the inputs are made by the user in the sidebar panel.

With the help of the "Shiny" app, the user may quickly see the effect of adding/removing covariates. It gives the user an easy way to modify the models and identify useful covariates interactively. The quality of the model may be assessed in the time series plot of predicted versus observed and the MAE table. Fast graphical and quantitative comparison with RDD and ARIMA can be obtained as well. As noted earlier, MAE reduction can be achieved by adjusting L.

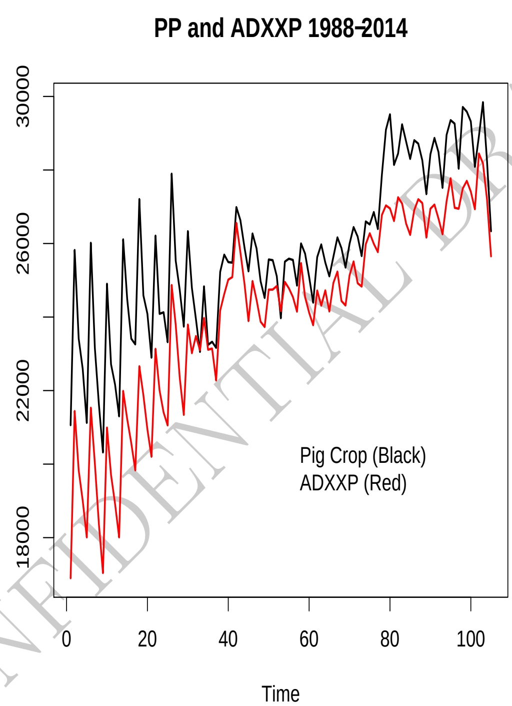


Figure 3: Pig crop and indication time series.

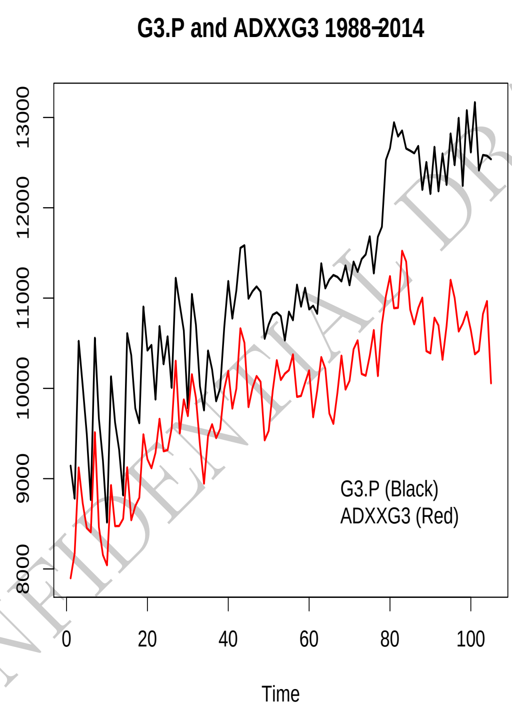


Figure 4: G3 and indication time series.

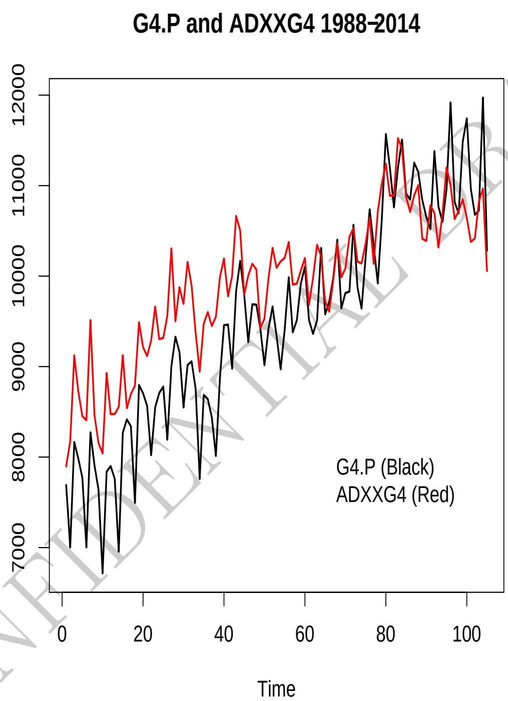


Figure 5: G4 and indication time series.

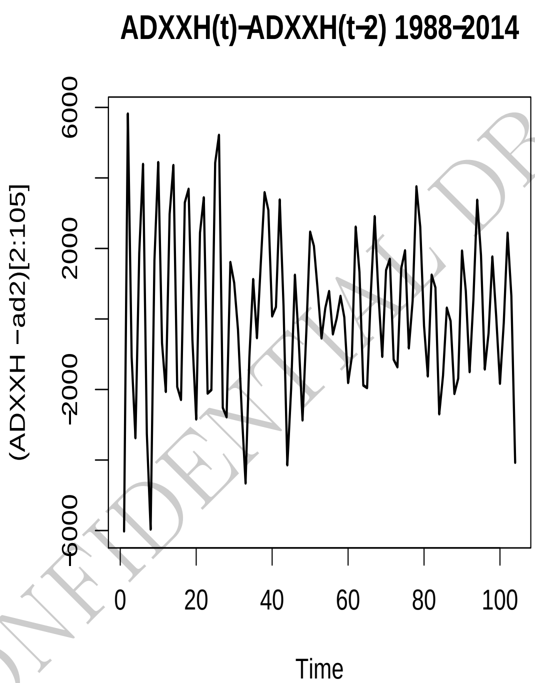


Figure 6: Useful covariates.

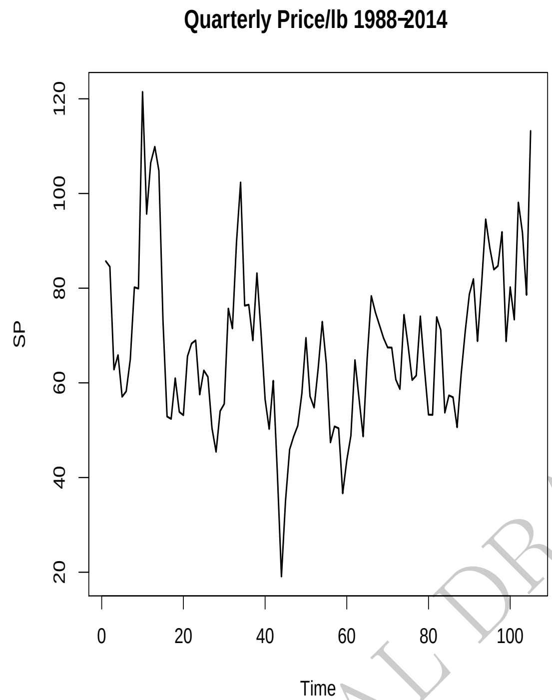


Figure 7: Useful covariate: Quarterly price/lb.
Source: www.indexmundi.com/commodities/?commodity=pork&months=360

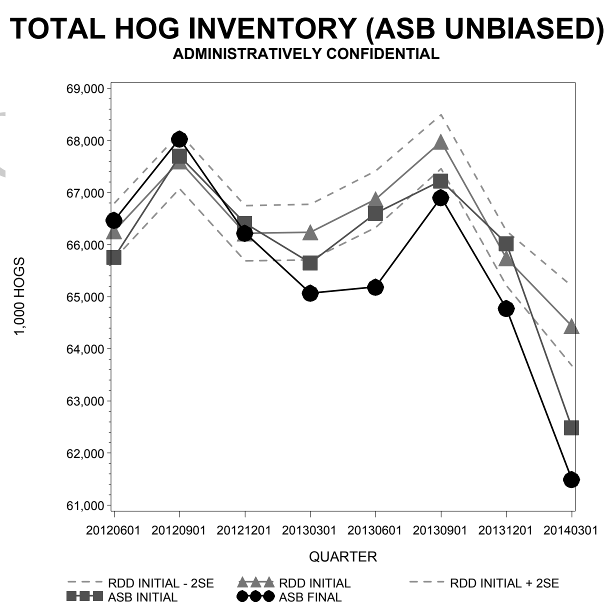


Figure 8: RDD Prediction of Total Inventory. a. Narrow PI's. b. Excessive prediction at 3/2014.

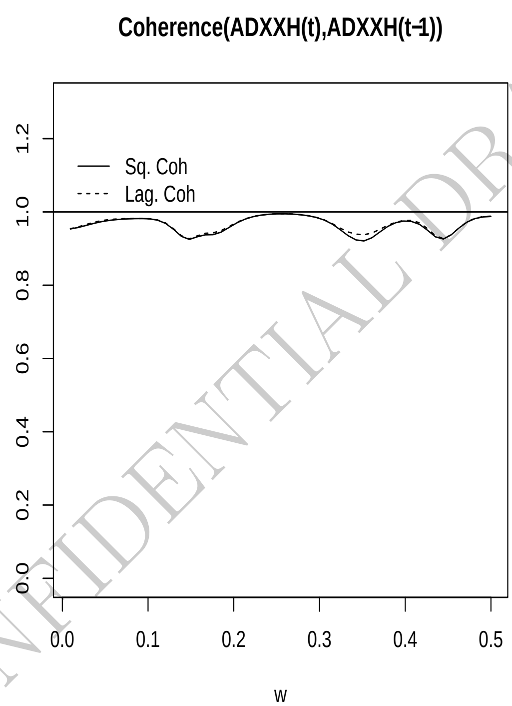


Figure 9: Coherence between $ADXXH_t$ and its shift $ADXXH_{t-1}$ is large.

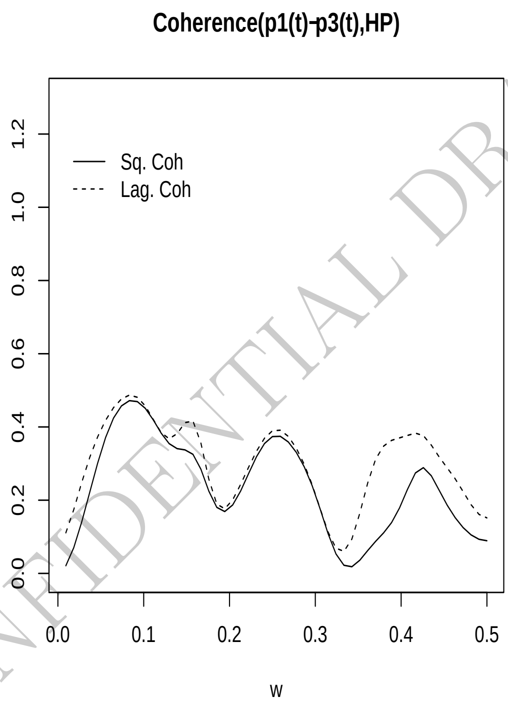


Figure 10: Mild coherence.

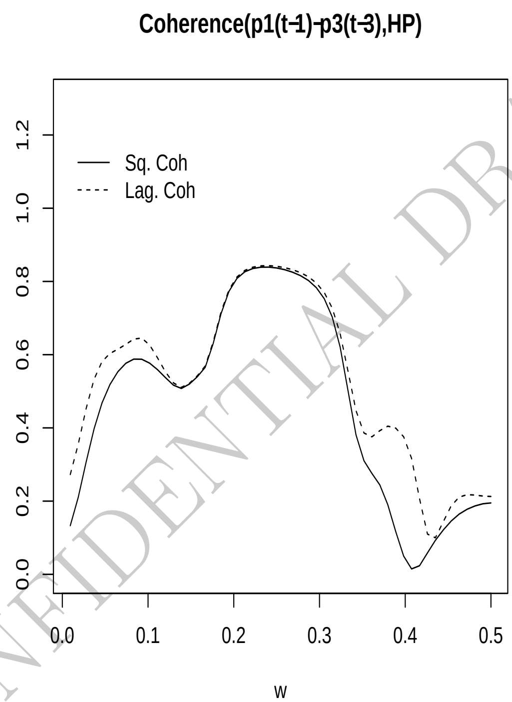


Figure 11: Increased coherence between total inventory and a difference in pig crop at a previous period.

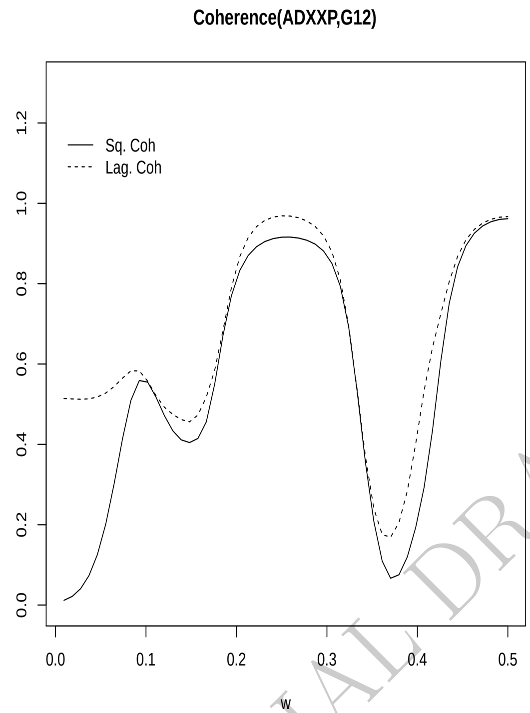


Figure 12: Coherence between ADXXP and G12.

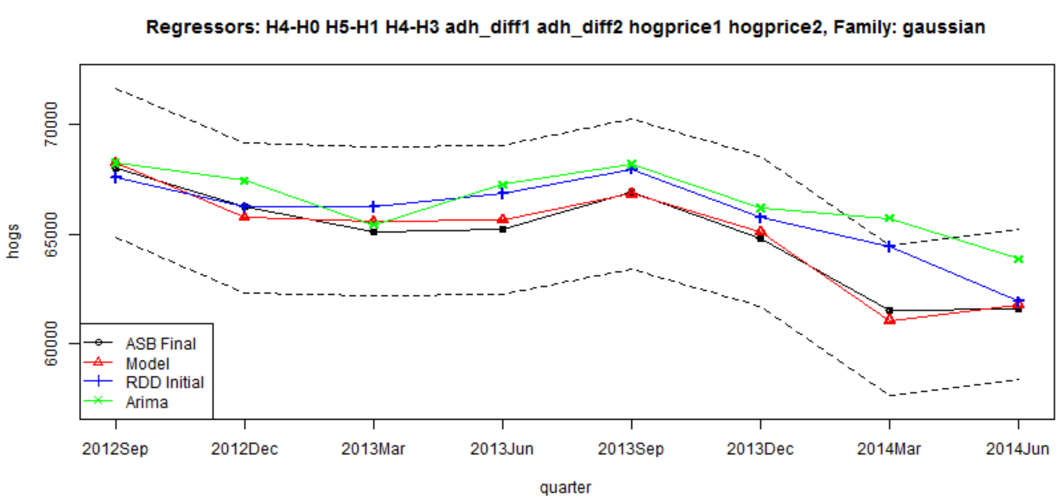


Figure 13: MAE: Total invntory prediction. GLM=339, RDD=1075, ARIMA=1500. L=22

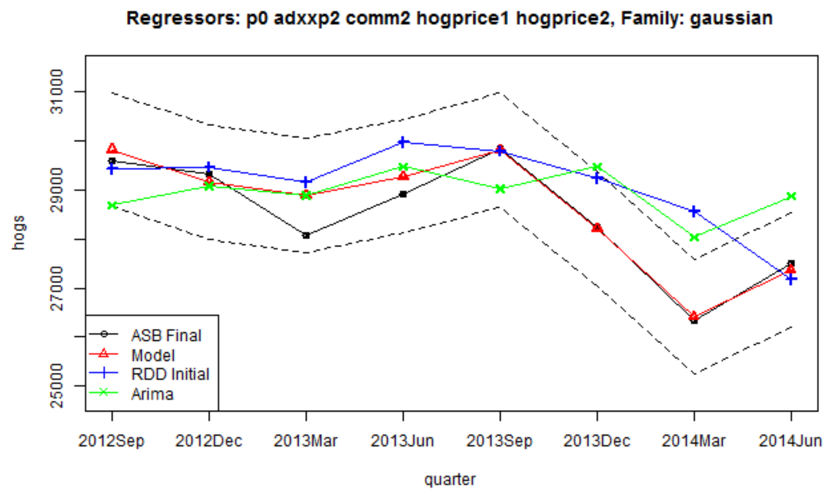


Figure 14: MAE: Pig-crop prediction. GLM=230, RDD=750, ARIMA=930. L=23

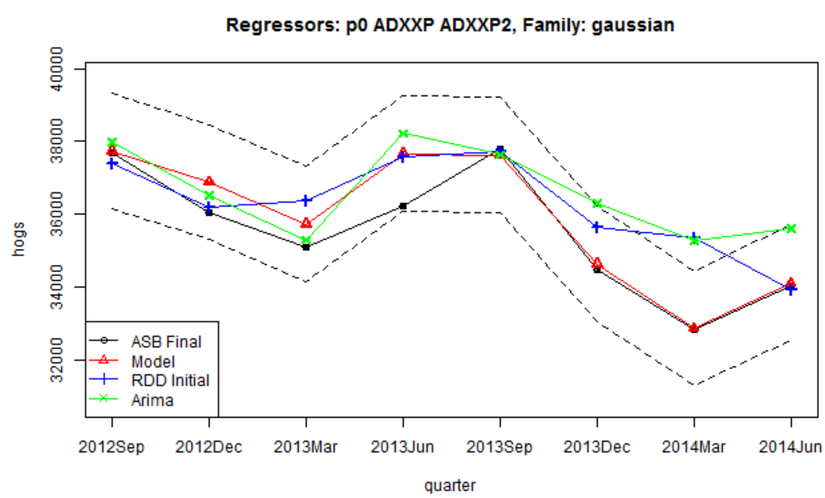


Figure 15: MAE: G12 prediction. GLM=426,RDD=864,ARIMA=1059. L=23.

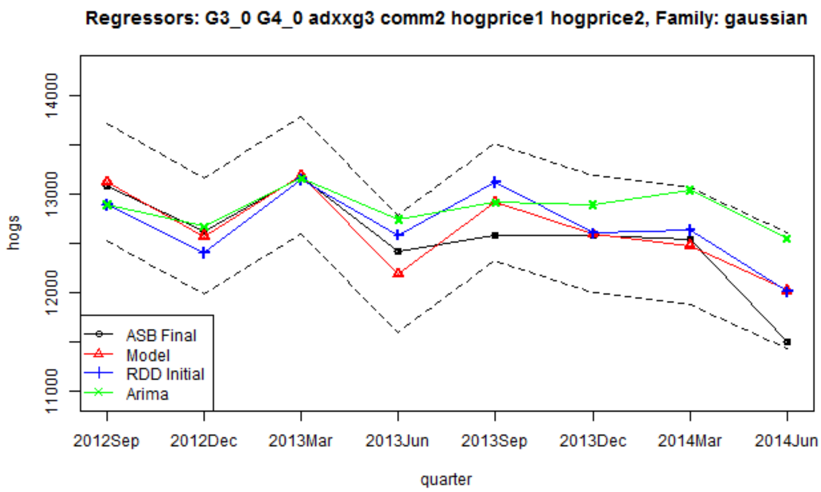


Figure 16: MAE: G3 prediction. GLM=159,RDD=200,ARIMA=331 L=23.

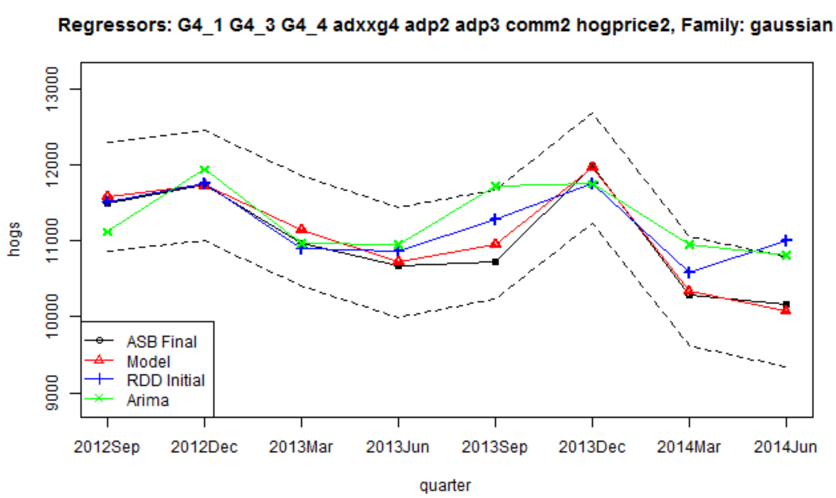


Figure 17: MAE: G4 prediction. GLM=88,RDD=275,ARIMA=386. L=22.

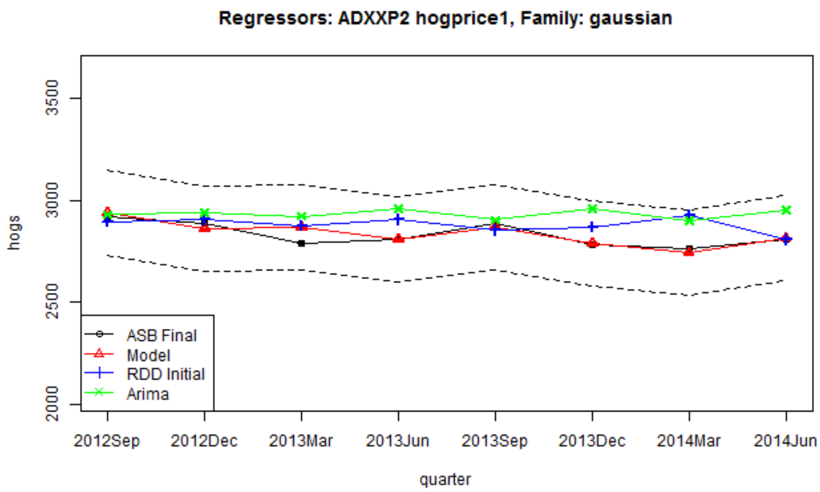


Figure 18: MAE: SF prediction. GLM=22,RDD=64,ARIMA=90. L=22.

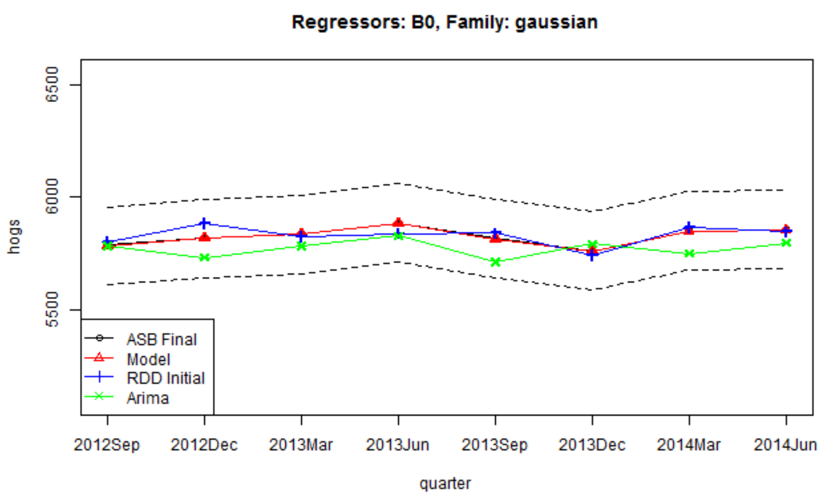


Figure 19: MAE: BH prediction. GLM=2,RDD=25,ARIMA=69. L=20.

Chapter 5 Appendix

Contents

Hog Disease Outbreak Detection

Yijun Wei

Summary

The purpose of this preliminary research is to design a model-assisted approach that adapts web-scraping and text mining to assist experts to adjust the final total hog number estimation from the hog model once a hog disease outbreak happens in the United States.

The entire model assisted process can be divided into three parts: disease outbreak identification, outbreak information extraction, and expert decision. This appendix only discusses the first two parts.

The disease outbreak identification is conducted based on the bimonthly reports from the Swine Disease Global Surveillance Project (SDGSP) (https://www.cahfs.umn.edu/services-tools/swine-disease-global-surveillance-program), which aims to provide a near real-time identification of hazards that will assist in estimating the risks to the industry globally. These reports are created based on screening from multiple data sources, such as news websites, blogs, and government official websites.

Once the hog disease outbreak is detected from the SDGSP website, news, and blogs related to the disease outbreak are web-scraped, and information of the disease outbreak is extracted using text mining. The text mining approach used in this study is named Information Extraction (IE), which is employed to identify structured information from the unstructured target. IE used in this study implies identifying the related information, such as temporal information, spatial information, and reporting media source of the disease outbreak, and hence is divided into three parts, i.e., processing the unstructured text, identifying keywords, and extracting the related information. To be specific, the unstructured text is first processed so that keywords (for example, in this study, outbreak) can be identified. Then all the words are tagged, and Named Entity Recognition (NER) process, which attempts to classify and locate the named entity (pre-defined types such as the person names, locations, etc...), is performed. Finally, the relationship (usually the verb) between the keywords and Named Entity is analyzed to classify the Named Entity (location, media, or person).

An example that illustrates the entire process is elaborated below. Since there is no hog disease happening in the United States at the moment, the example below discusses an African Swine fever (ASF) outbreak in China. The example is separated into three sections. 1. Detecting whether the disease outbreak is occurring by web scraping the reports in SDGSP website. 2. Web scraping one related news item from **The Pig Site** (https://thepigsite.com/). 3. Identifying where the outbreak is occurring, the media source that reports the outbreak, and the related statistics.

Original text

```
`The Ministry of Agriculture and Rural Affairs said the first outbreak
is on a farm in the Xushui district of Baoding city which has 5,600
hogs, some of which died because of the swine fever, though it did not
provide a death toll.\n\nThe farm has been quarantined and the herd
slaughtered, it added.\n\nReuters reports that the second outbreak is in
the remote Greater Khingan Mountains in Inner Mongolia, where 210 of the
222 wild boar raised on the farm died, the ministry said in a separate
statement. The rest have been slaughtered, it said.\n\nChina has
reported more than 100 cases of African swine fever in 27 provinces and
regions since last August. The disease is deadly for pigs but does not
harm humans.'
```

Extracted information

1. Noun: 'outbreak', Source: 'The Ministry of Agriculture and Rural Affairs', Location: 'a farm in the Xushui district of Baoding city', Stats: 'has 5,600 hogs'
2. Noun: 'outbreak', Source: 'Reuters', Location: 'remote Greater Khingan Mountains in Inner Mongolia', Stats: '210 of the 222 wild boar died'

More details will be discussed below.

```
In [1]: from __future__ import division
        from urllib.request import urlopen
        from urllib.error import HTTPError
        from bs4 import BeautifulSoup
```

```
import re
import numpy as np
from newspaper import Article
import newspaper
import feedparser as fp
import nltk
from nltk.corpus import stopwords
import operator
import string
from nltk import sent_tokenize
import re
from IPython.display import Image
from nltk.sem import relextract
```

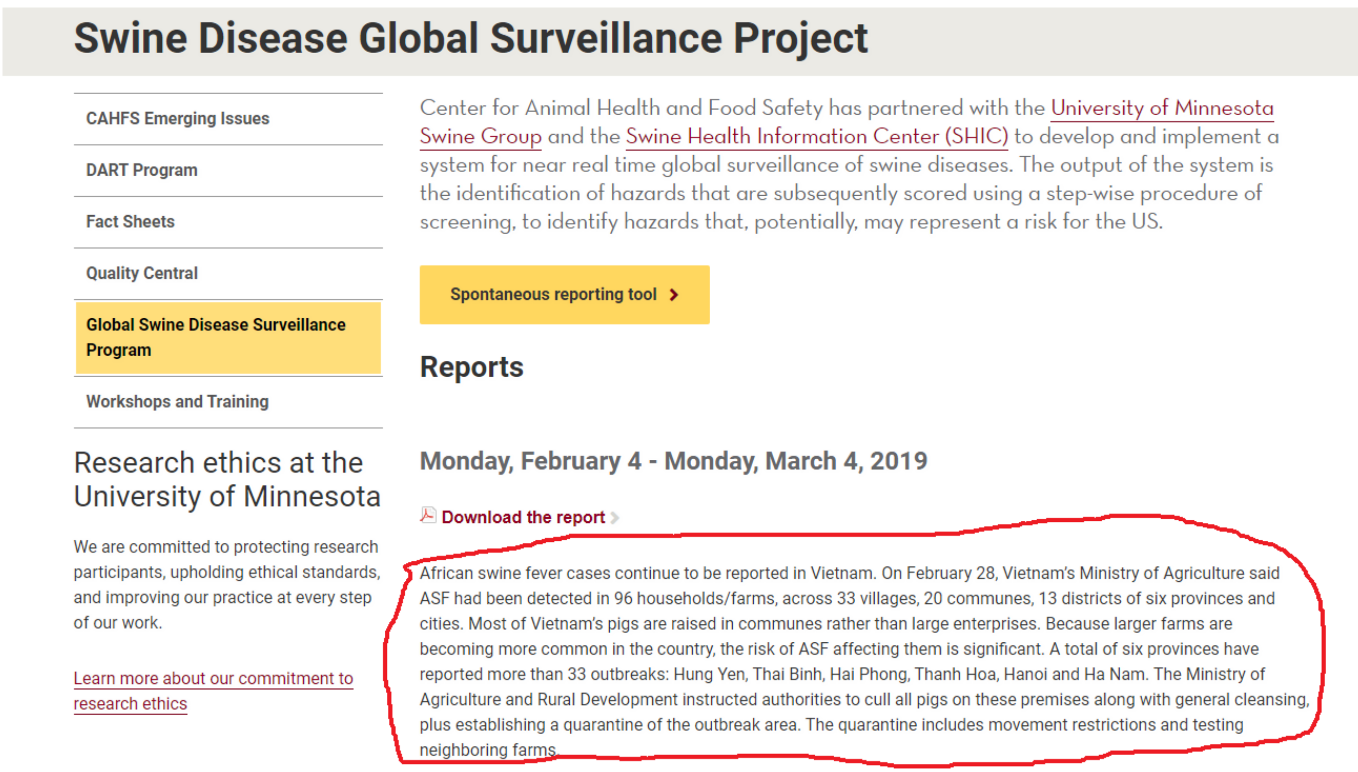
1. Extract the report in SDGSP websites to detect the hog disease outbreak

Web scraping the summary of the most recent report in SDGSP website

The summary of the most recent report in the SDGSP website, which is circled with a red rectangle below, is web-scraped to verify if there is an outbreak disease occuring at the moment.

In [2]:
```
Image("O:/Desktop/hog model/umswinemonitor.png")
```

Out[2]:



Swine Disease Global Surveillance Project

CAHFS Emerging Issues
DART Program
Fact Sheets
Quality Central
Global Swine Disease Surveillance Program
Workshops and Training

Research ethics at the University of Minnesota

We are committed to protecting research participants, upholding ethical standards, and improving our practice at every step of our work.

Learn more about our commitment to research ethics

Center for Animal Health and Food Safety has partnered with the University of Minnesota Swine Group and the Swine Health Information Center (SHIC) to develop and implement a system for near real time global surveillance of swine diseases. The output of the system is the identification of hazards that are subsequently scored using a step-wise procedure of screening, to identify hazards that, potentially, may represent a risk for the US.

Spontaneous reporting tool ›

Reports

Monday, February 4 - Monday, March 4, 2019

Download the report ›

African swine fever cases continue to be reported in Vietnam. On February 28, Vietnam's Ministry of Agriculture said ASF had been detected in 96 households/farms, across 33 villages, 20 communes, 13 districts of six provinces and cities. Most of Vietnam's pigs are raised in communes rather than large enterprises. Because larger farms are becoming more common in the country, the risk of ASF affecting them is significant. A total of six provinces have reported more than 33 outbreaks: Hung Yen, Thai Binh, Hai Phong, Thanh Hoa, Hanoi and Ha Nam. The Ministry of Agriculture and Rural Development instructed authorities to cull all pigs on these premises along with general cleansing, plus establishing a quarantine of the outbreak area. The quarantine includes movement restrictions and testing neighboring farms.

The code below uses python's `BeautifulSoup` package to web scrape the homepage of `SDGSP` website.

```
In [3]: html = urlopen('https://www.cahfs.umn.edu/services-tools/swine-disease-global-surveillance-program')
        bt4Obj = BeautifulSoup(html)
        names = bt4Obj.findAll('p', {'class':'views-field-field-read-more-link'})
        names_summary = bt4Obj.findAll('div', {'dir':'ltr'})
```

`names_summary` stores json format for the most recent report's summary mentioned above.

```
In [4]: names_summary
```

```
Out[4]: [<div dir="ltr">
     <h2><strong>Reports</strong></h2>
     <h3> </h3>
     <h3>Monday, March 4 - Monday, April 1, 2019</h3>
     <p class="views-field-field-read-more-link"><span class="file">
     <img alt="PDF icon" class="file-icon" src="/modules/file/icons/application-pdf.png" title="application/pdf"/>
     <a href="/sites/cahfs.umn.edu/files/2019-04-01_swinemonthlyreport.pdf" type="application/pdf; length=779139">
     Download the report</a></span></p><p><span>The March-April report provides details on further African swine
     fever (ASF) outbreaks in Vietnam as well as disease status in China, Europe, and Moldova. The report also
     features a fresh risk analysis of the potential for ASF to be introduced in the US through pork smuggled
     in air passengers' luggage, in addition to details on USDA seizure of 1 million pounds of contraband
     Chinese pork in New Jersey. Finally, the report includes information on foot-and-mouth disease in North
     and South Korea.</span></p>
     </div>]
```

The code below extracts text information. Once the text information is extracted, keywords such as `US`, `United States`, or `American` are checked to determine whether **there is any disease outbreak happened in the United States**.

```
In [5]: summary = []
        for i in names_summary:
            if i.a is not None:
        #         print ('https://www.cahfs.umn.edu' + i.a['href'])
```

```
#          print (i.findAll('p')[1])
        summary.append(i.findAll('p')[1])

for k in str(summary[0]).split("\n"):
    print(re.sub(r"[^a-zA-Z0-9]+", ' ', k).lower())
    summary_all = re.sub(r"[^a-zA-Z0-9]+", ' ', k).lower()
```

```
p span the march april report provides details on further african swine fever asf outbreaks in vietnam
as well as disease status in china europe and moldova the report also features a fresh risk analysis
of the potential for asf to be introduced in the us through pork smuggled in air passengers luggage
in addition to details on usda seizure of 1 million pounds of contraband chinese pork in new jersey
finally the report includes information on foot and mouth disease in north and south korea span p
```

Check whether there is an outbreak

In the extracted information on hog disease, is there any indication of disease within the US?

If no, the process stops

```
In [6]: [("united states" or 'america') in summary_all]

Out[6]: [False]
```

If yes, the process will be continued

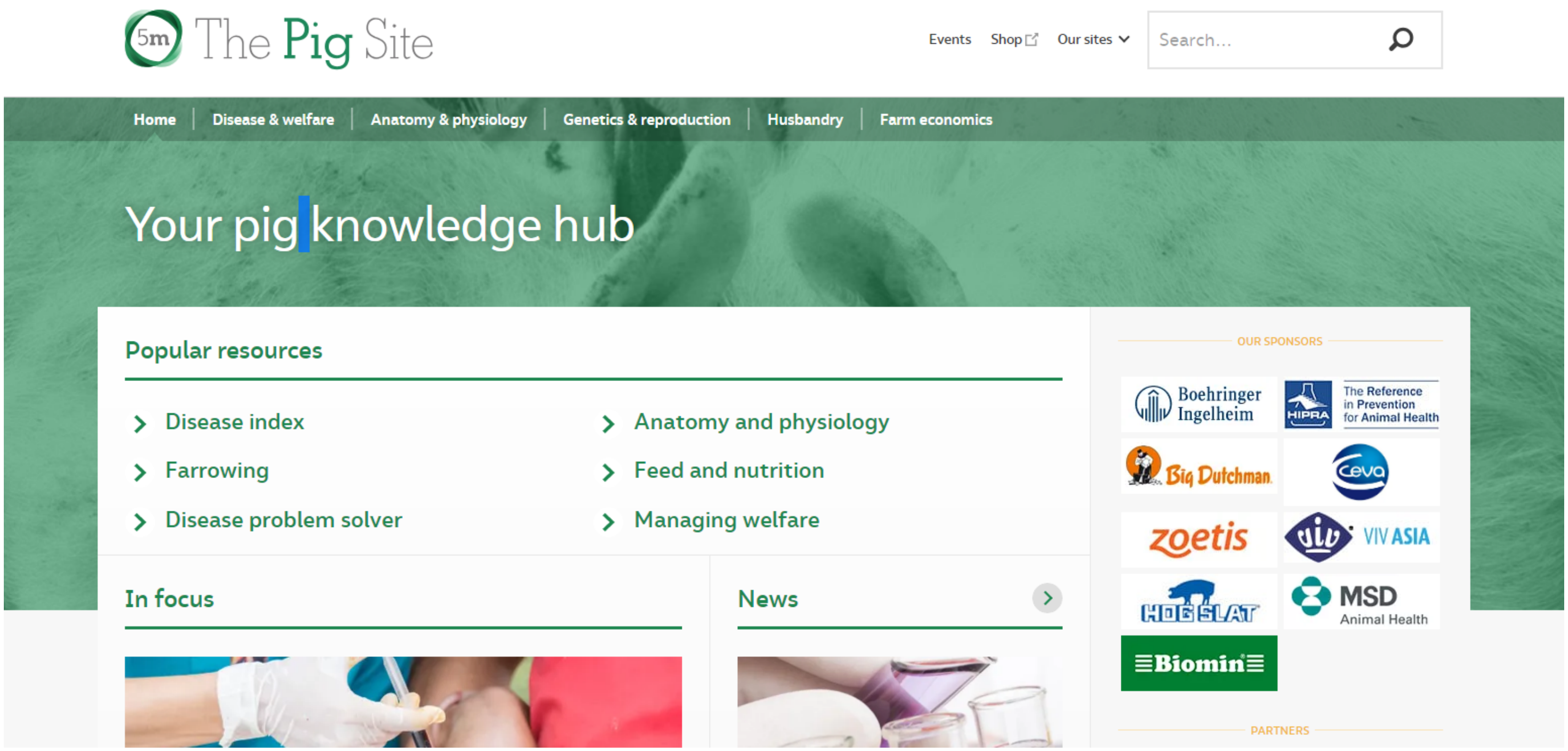
Below is an example of extracting information from the hog disease outbreak news. Since there is currently no hog disease outbreak in the United States, an example of African Swine fever occuring in China is used as an example.

2. Identify related news

Only one news item will be extracted from **The Pig Site** (`https://thepigsite.com/`) for this example. Other news could be analyzed in the same way.

In [12]:
```
Image("O:/Desktop/hog model/thepigsiteorig.png")
```

Out[12]:

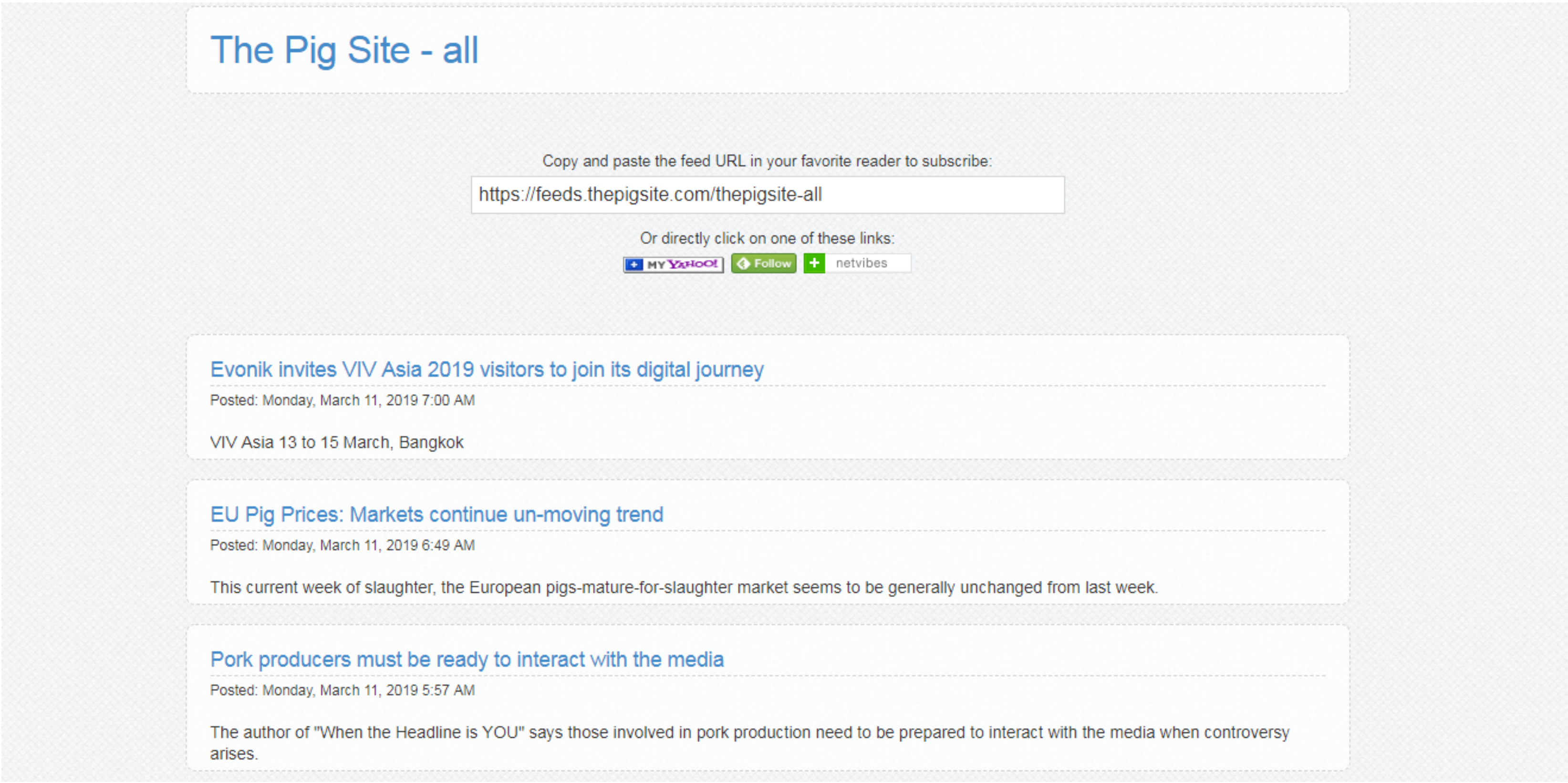


The RSS feed format that works better for web-scraping

RSS feed format allows people access to online information in a standardized, computer-readable format. The image below displays RSS feed format of **The Pig Site**, which is used to more efficiently web scrape news from the website.

```
In [13]: Image("O:/Desktop/hog model/thepigsiterss.png")
```

```
Out[13]:
```




```
In [7]: url = 'https://feeds.thepigsite.com/thepigsite-all'
```

Extract publish date and text title

The code below extract all the news from **The Pig Site**.

```
In [8]: d = fp.parse('https://feeds.thepigsite.com/thepigsite-all')

        thepigsite_paper_all_text = []
        thepigsite_paper_all_title = []
        thepigsite_paper_all_time = []

        for i in d.entries:
            content = Article(i.link)
            content.download()
            content.parse()
            content.nlp()
            thepigsite_paper_all_text.append(content.text)
            thepigsite_paper_all_title.append(content.title.lower())
            thepigsite_paper_all_time.append(content.publish_date)
```

Filter news by 'outbreak', 'hog disease', 'pig disease', 'african swine fever', 'ASF', and 'china'

```
In [9]: for i,j in enumerate(thepigsite_paper_all_title[:10]):
            print (i,j)
```

```
0 weaning your way to success
1 new proposals to boost security for uk tenanted farmers
2 is swine fever slowing down in china?
3 rural payments agency confirms 2018 bridging payments for uk farmers
4 socorex injection syringes and rigid extensions designed for precision and mobility
5 china expected to grow in importance for canadian pork exports
6 red meat from britain heading to canada
7 what an open farm day can do for you - and how to host one
8 farm practices survey indicates innovation is on the minds of uk farmers
```

```
9 china reports first african swine fever outbreak in tibet
```

```
In [16]: for i,j in enumerate(thepigsite_paper_all_title):
             if ('outbreak' or 'hog disease' or 'pig disease') in j.lower():
                 print (i,j)
```

```
55 china reports two new african swine fever outbreaks
67 china confirms african swine fever hits shandong province as national outbreak spreads
73 swine fever detected in vietnam and china reports first outbreak in guangxi region
84 how the us pork industry is preparing for a possible fad outbreak
```

Take the news named **China reports two new African swine fever outbreaks**, which is the 55th of all the news web-scraped from The Pig Site.

```
In [34]: text = thepigsite_paper_all_text[55]
```

`text` presents the selected news content.

```
In [35]: text
```

```
Out[35]:
'The Ministry of Agriculture and Rural Affairs said the first outbreak is on a farm in the Xushui district
of Baoding city which has 5,600 hogs, some of which died because of the swine fever, though it did not
provide a death toll.\n\n The farm has been quarantined and the herd slaughtered,
it added.\n\nReuters reports that the second outbreak is in the remote Greater
Khingan Mountains in Inner Mongolia, where 210 of the 222 wild boar raised on the farm died, the ministry
said in a separate statement. The rest have been slaughtered, it said.\n\nChina has reported more
than 100 cases of African swine fever in 27 provinces and regions since last August.
The disease is deadly for pigs but does not harm humans.'
```

3. Information extraction

The Name Entity Recognition (NER) can be split into four parts: 1. Normalize time 2. Normalize word 3. Keywords identification 4. Named Entity Recognition and information extraction

Normalize time

If there is temporal information, for instance, a date, that needs to be extracted or identified, the temporal information should be normalized to a specific format. For example, month/date/year h::m::s.
In this example, since no temporal information needs to be extracted, this step is not performed.

Normalize word

The plural, past tense, etc... should be converted to a singular form, current tense respectively. For example, **cats** should be normalized to **cat**, as indicated below.

```
In [38]: normalise('cats')
```

```
Out[38]: 'cat'
```

```
In [35]: import nltk
```

```
In [38]: lemmatizer = nltk.WordNetLemmatizer()
         stemmer = nltk.stem.PorterStemmer()
         def normalise(word):
             """Normalises words to lowercase and stems and lemmatizes it."""
             word = word.lower()
             word = stemmer.stem(word)
             word = lemmatizer.lemmatize(word)
             return word
```

```
In [57]: named_entities = []
```

```
        for i in text:
            chunked = nltk.ne_chunk(nltk.tag.pos_tag(nltk.word_tokenize(i)), binary=True)
            named_entities+=[ " ".join(w for w, t in elt) for elt in chunked if isinstance(elt, nltk.Tree) ]
```

```
In [59]: named_entities
```

```
Out[59]: ['Ministry',
          'Agriculture',
          'Rural Affairs',
          'Xushui',
          'Inner Mongolia',
          'China',
          'African']
```

```
In [37]: named_entities = []

         for i in text:
             chunked = nltk.ne_chunk(nltk.tag.pos_tag(nltk.word_tokenize(i)), binary=True)
             named_entities+=[ " ".join(w for w, t in elt) for elt in chunked if isinstance(elt, nltk.Tree) ]
```

```
In [39]: norm_text = ''
         for word in text:
             if word not in named_entities:
                 norm_text += normalise(word)
             else:
                 norm_text += word
```

Some examples of normalization in the text
quarantined to **quarantin**
raised to **raise**
slaughtered to **slaughter**

```
In [86]: norm_text
```

```
Out[86]:
'The Ministry of Agriculture and Rural Affairs said the first outbreak is on a farm in the Xushui
district of Baoding city which has 5,600 hog, some of which die because of the swine fever, though
it did not provide a death toll.\n\nThe farm has been quarantin and the herd slaughter, it add.\n\n
Reuters report that the second outbreak is in the remote Greater Khingan Mountains in Inner Mongolia,
where 210 of the 222 wild boar raise on the farm die, the ministry said in a separate statement.
The rest have been slaughter, it said.\n\nChina has report more than 100 case of
African swine fever in 27 province and region since last August.
The disease is deadli for pig but do not harm humans.'
```

Keywords identification

Check words frequency and determine keywords. Other methods include Rapid Automatic Keyword Extraction, and TF-IDF.

```
In [41]: stopword = stopwords.words('english')
         hog_dict = nltk.FreqDist(nltk.word_tokenize(norm_text))
         sorted_hog_word_freq = [(i,j) for i,j in sorted(hog_dict.items(), key=operator.itemgetter(1), reverse=True)
                 if i not in stopword]

In [42]: [i for i in sorted_hog_word_freq if i[0] not in (',','.')]

Out[42]: [('said', 3),
          ('farm', 3),
          ('ministry', 2),
          ('outbreak', 2),
          ('died', 2),
          ('swine', 2),
          ('fever', 2),
          ('slaughtered', 2),
          ('agriculture', 1),
          ('rural', 1),
          ('affairs', 1),
          ('first', 1),
```

```
('xushui', 1),
('district', 1),
('baoding', 1),
('city', 1),
('5,600', 1),
('hogs', 1),
('though', 1),
('provide', 1),
('death', 1),
('toll', 1),
('quarantined', 1),
('herd', 1),
('added', 1),
('reuters', 1),
('reports', 1),
('second', 1),
('remote', 1),
('greater', 1),
('khingan', 1),
('mountains', 1),
('inner', 1),
('mongolia', 1),
('210', 1),
('222', 1),
('wild', 1),
('boar', 1),
('raised', 1),
('separate', 1),
('statement', 1),
('rest', 1),
('china', 1),
('reported', 1),
```

```
 ('100', 1),
 ('cases', 1),
 ('african', 1),
 ('27', 1),
 ('provinces', 1),
 ('regions', 1),
 ('since', 1),
 ('last', 1),
 ('august', 1),
 ('disease', 1),
 ('deadly', 1),
 ('pigs', 1),
 ('harm', 1),
 ('humans', 1)]
```

Outbreak is defined as a keyword. Sentences that include **outbreak** are then extracted to get ready for further processing.

```
In [43]: text_with_keywords = []

         for i in sent_tokenize(text):
             if 'outbreak' in i:
                 text_with_keywords.append(i)

         text_with_keywords
```

```
Out[43]: ['The Ministry of Agriculture and Rural Affairs said the first outbreak is on a farm in the
          Xushui district of Baoding city which has 5,600 hogs, some of which died because of the swine fever,
          though it did not provide a death toll.',
          'Reuters reports that the second outbreak is in the remote Greater Khingan Mountains in Inner Mongolia,
          where 210 of the 222 wild boar raised on the farm died, the ministry said in a separate statement.']
```

Named Entity Recognition and information extraction

The important information is the location where the outbreak occurs, the temporal information, the source, and the statistics related to the outbreak. This information can be obtained by tokenizing each word first and then identifying the entity name. The entity could be a location or media. Finally, the verb between the outbreak and entity is used to determine the type of information.

```
In [44]: for i in text_with_keywords:
             k=''
             if j not in named_entities:
                 for j in nltk.word_tokenize(i):
                     k = k+ normalise(j) + ' '
             else:
                 k = k+ j + ' '
             print (nltk.pos_tag(nltk.word_tokenize(k)))
```

```
[('the', 'DT'), ('ministri', 'NN'), ('of', 'IN'), ('agricultur', 'NN'), ('and', 'CC'), ('rural', 'JJ'),
 ('affair', 'NN'), ('said', 'VBD'), ('the', 'DT'), ('first', 'JJ'), ('outbreak', 'NN'), ('is', 'VBZ'),
 ('on', 'IN'), ('a', 'DT'), ('farm', 'NN'), ('in', 'IN'), ('the', 'DT'), ('xushui', 'NNP'),
 ('district', 'NN'), ('of', 'IN'), ('baod', 'NN'), ('citi', 'NN'), ('which', 'WDT'), ('ha', 'VBZ'),
 ('5,600', 'CD'), ('hog', 'NN'), (',', ','), ('some', 'DT'), ('of', 'IN'), ('which', 'WDT'),
 ('die', 'VBP'), ('becaus', 'NN'), ('of', 'IN'), ('the', 'DT'), ('swine', 'NN'), ('fever', 'NN'),
 (',', ','), ('though', 'IN'), ('it', 'PRP'), ('did', 'VBD'), ('not', 'RB'), ('provid', 'VB'),
 ('a', 'DT'), ('death', 'NN'), ('toll', 'NN'), ('.', '.')]
[('reuter', 'NN'), ('report', 'NN'), ('that', 'IN'), ('the', 'DT'), ('second', 'JJ'),
 ('outbreak', 'NN'), ('is', 'VBZ'), ('in', 'IN'), ('the', 'DT'), ('remot', 'NN'), ('greater', 'JJR'),
 ('khingan', 'JJ'), ('mountain', 'NN'), ('in', 'IN'), ('inner', 'JJ'), ('mongolia', 'NNS'), (',', ','),
 ('where', 'WRB'), ('210', 'CD'), ('of', 'IN'), ('the', 'DT'), ('222', 'CD'), ('wild', 'JJ'),
 ('boar', 'NNS'), ('rais', 'VBP'), ('on', 'IN'), ('the', 'DT'), ('farm', 'NN'), ('die', 'NN'),
 (',', ','), ('the', 'DT'), ('ministri', 'NN'), ('said', 'VBD'), ('in', 'IN'), ('a', 'DT'),
 ('separ', 'JJ'), ('statement', 'NN'), ('.', '.')]
```

```
In [67]: grammar = "NP: {<DT><NN*>+<IN><DT>?<NN*>+<CC>?<JJ>?<IN>?<NN.*>+}"
```

```
cp = nltk.RegexpParser(grammar)
IN = re.compile(r'.*\bin\b(?!\b.+ing)')

for i in text_with_keywords[::-1]:
    k=''
    for j in nltk.word_tokenize(i):
        k = k+ normalise(j) + ' '
#     print (k)
    sentence = nltk.pos_tag(nltk.word_tokenize(k))
    sen2 = cp.parse(sentence)
```

Result

Two pieces of information are extracted from the text.

1. Noun: ‘outbreak’, Source: ‘The Ministry of Agriculture and Rural Affairs’, Location: ‘a farm in the Xushui district of Baoding city’, Stats: ‘has 5,600 hogs’

2. Noun: ‘outbreak’, Source: ‘Reuters’, Location: ‘remote Greater Khingan Mountains in Inner Mongolia’, Stats: ‘210 of the 222 wild boar died’

After the information is extracted from the news as above, the extracted information is sent to experts to increase or decrease the estimates from the hog model.