SWINE HEALTH INFORMATION CENTER
FINAL RESEARCH GRANT REPORT FORMAT

Developing the Morrison Swine Health and Monitoring Project (MSHMP) to build capacity and enable the Swine Health Information Center – Project # 22-094

Principal Investigator: Cesar A Corzo
Institution: University of Minnesota

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Industry/Research Summary:
Objective 1: Monitor trends in pathogens incidence and prevalence – PRRSv, PEDv, PDCoV, Senecavirus and central nervous system associated viruses continued to be monitored and each maintained the historical pattern. We also investigated the relationship between the PRRS RT-PCR positivity rate between breeding and growing pigs finding a correlation; however, because no spatial information and prrs virus information was accounted for we need to interpret this information with caution, thus we are unable to conclude that the increase in PRRS positive rate in breeding herds is due to an increase in positivity rate in growing pigs. In addition, we also assessed the frequency of PRRS outbreaks in breeding herds managing mortality either through composting, incineration, or rendering. Numerical differences were detected but not enough evidence was found to conclude that one method is better than the other one and more analyses are needed. Regarding PEDV, we characterized the time positive herds required to stabilize the herd and concluded that those infected during the epidemic phase of the disease in the US took longer (e.g., 9 weeks) to reach stability than those infected during the endemic phase.
Objective 2: To conduct prospective monitoring of PRRSv sequence evolution and impact – We characterized the epidemiological situation of an emerging virus (L1C-124) that was thought to be a virulent and fast spreading one. Even though the virus did disseminate, it did not reach a speed and magnitude of other recent viruses. The clinical impact was also characterized but when compared to the recent L1C-144 we can conclude that it was not significantly different.
Objective 3: To expand participation of producers to allow for all to be involved – During 2022-2023 we have added 4 production systems. Our database now has 1,274 sow farms housing approximately 3.8M sows, 3,318 growing pig farms with 12.2M pig spaces and 48 boar studs totaling 12,799 boars. Our first publicly available MSHMP website has been completed, officially launched in Q3 of 2023, and has been continuously updated. This website was designed to optimize MSHMP output dissemination within both the participant and industry communities. The website represents a significant milestone in our mission to enhance collaboration and communication within the swine industry. The website has been designed with ten comprehensive sections, including Home, About, History, People, Reports, Outreach, Ongoing Projects, News, Resources, and Contact Us. The website has been accessed by individuals from 41 countries with the highest number of users from the US, China and Spain.

Keywords: Monitoring, Emerging, Compost, Rendering, Transport, Trends, PRRS, PEDv

Objective 1

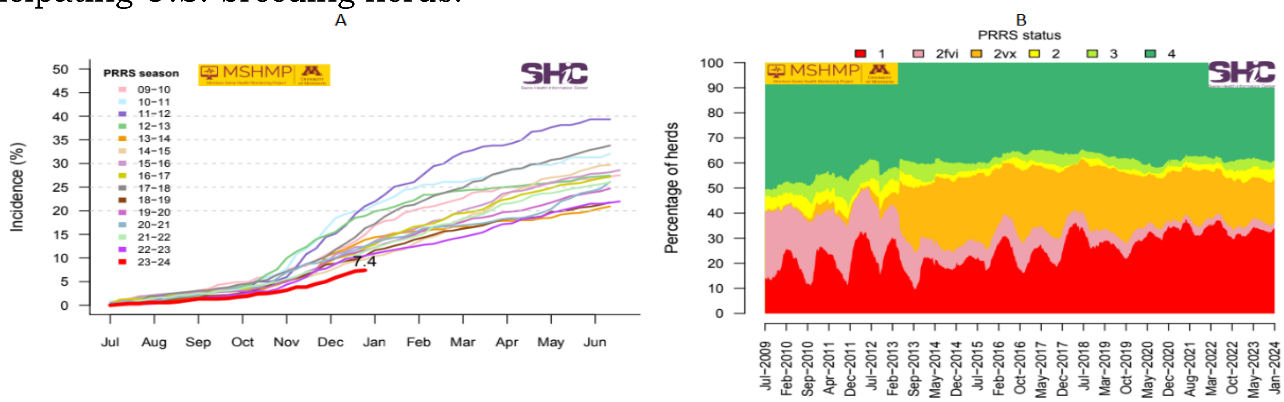
To monitor trends in pathogen incidence and prevalence.

i. Characterize the time lags between weekly PRRS RT-PCR positivity in the growing finish herds compared to the breeding herd.

ii. Investigate the association between carcass disposal methods and disease occurrence (e.g. PRRS) in the MSHMP breeding herd population.

PRRS occurrence continues to follow the pattern observed in the past recent years, with the lowest cumulative yearly incidence (Figure 1A) contrasting to consistently higher weekly prevalence (Figure 1B). This can be partially justified by the fact that sites now remain longer at an unstable status, with median time to stability increasing from 32 weeks during 2015-2016 to 35 weeks during 2017-2020. In addition, we believe that higher prevalences could also be the result of better monitoring strategies (E.g., processing fluids) as demonstrated in an MSHMP project recently published.

Figure 1. PRRS cumulative yearly incidence (A) and weekly prevalence (B) in participating U.S. breeding herds.



PED has returned to endemic levels of transmission during this past year. We have also leveraged historical PED information from this project for an updated epidemiological characterization of this disease in US breeding herds. We have shown that 46% of the monitored farms have never reported a PED outbreak, while 50% of them reported either 1 or 2 outbreaks during the entire study period (Figure 2). Of those that reported more than one outbreak, 44% reported another outbreak occurring within 2 years. We have also shown that PED incidence in summer and fall is consistently lower than the incidence in winter and spring each year (Figure 3). Noteworthy, the median time to stability (TTS) of the PEDV epidemic period (i.e., from May 1, 2013 to December 31, 2014) was 23 weeks, while the median TTS of the endemic period (i.e., January 1, 2015 to June 30, 2023) was 14 weeks (Figure 4). This likely reflects the fact that overtime the industry has developed rapid and effective control/elimination strategies to mitigate the PEDV impact.

Figure 2. Percent of breeding herds reporting zero, one, or more PED outbreaks during 2013-2023.

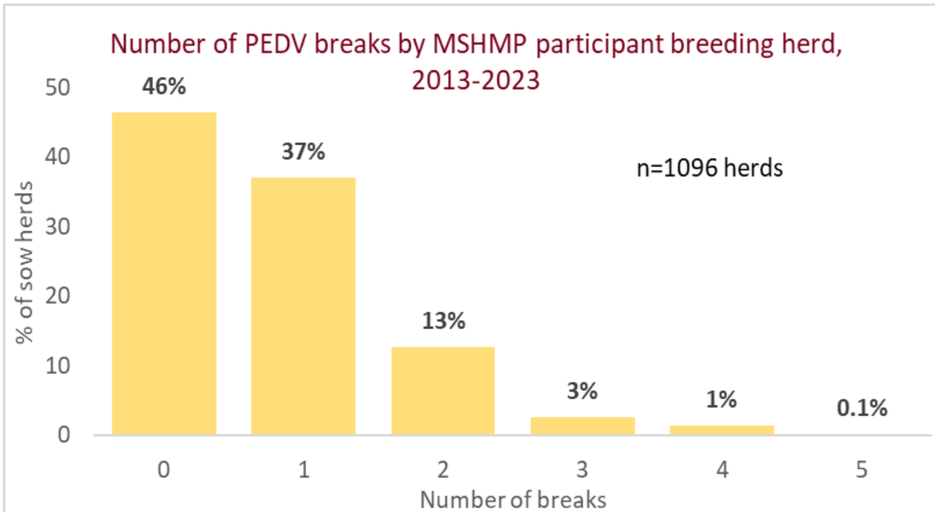


Figure 3. PEDV incidence by season. Yearly incidence for winter represents December of the described year to March the following year.

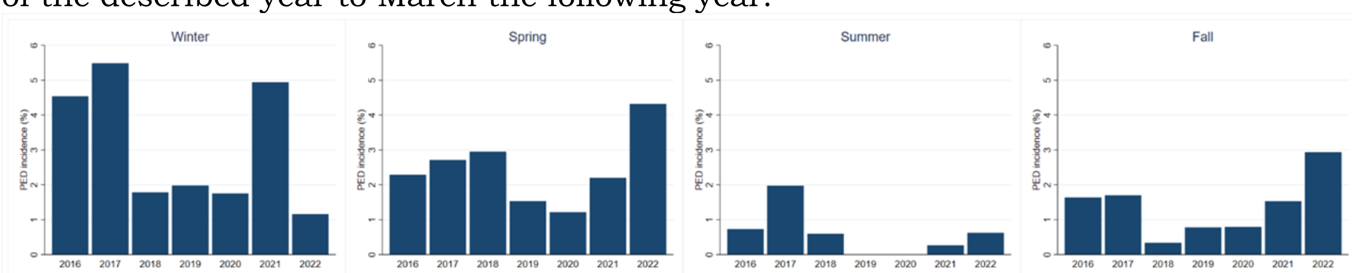
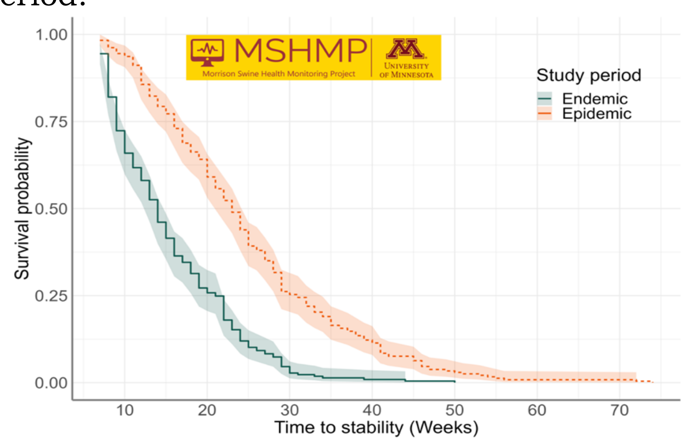


Figure 4. Cumulative probability of 'surviving' (i.e. not achieving stability) at a certain time interval for each period.



For our objective 1.i (characterize the time lags between weekly PRRS RT-PCR positivity in the growing finish herds compared to the breeding herd), we have explored PRRSV RT-PCR submissions from MSHMP participants obtained from the UMN and ISU Veterinary Diagnostic Laboratories covering 2015 to 2020. The 5-weeks moving average of percent positive per category is shown in Figure 5. Briefly, the proportion of positive submissions remained mostly below 0.1 (10%) in adult/farrowing samples, while it remained mostly between 0.2-0.4 (20% to 40%) in nursery/finisher samples. Figure 6 shows the standard estimation of lagged time-series cross-correlations between the weekly proportion of positives in the different age categories. In summary, it shows the correlation (y-axis) between positivity rate in nursery/finish and in adult/nursery and the lag (x-axis), i.e. time elapsed, between the two time series. If there is a positive correlation (y-axis), it means that an increase in one time series is correlated to an increase in the other time series. Alternatively, if there is a negative correlation (y-axis), it means there is an inverse relation between the two time series (one increases while the other decreases). Moreover, when the correlation occurs at a negative lag (x-axis), we can interpret that the first time series (adult/farrowing) leads (i.e. precedes) the second time series (nursery/finisher). If the correlation occurs in a positive lag (x-axis), the first time series lags (i.e. follows) the second time series. In this case, the highest correlation found (as observed by the peak in Figure 6) was a positive correlation at week 1, meaning the adult/farrowing positivity rate follows the same trend as the nursery/finisher positivity rate with only a one-week lag. These results should be interpreted with caution given that the analysis did not take into account spatial distribution of the origin of these RT-PCR positive results and virus diversity to imply that the RT-PCR results from one population are responsible for the positivity rate of the other population.

Figure 5. Weekly 5-weeks moving average of PRRSV PCR positivity rate by age category of submitted samples.

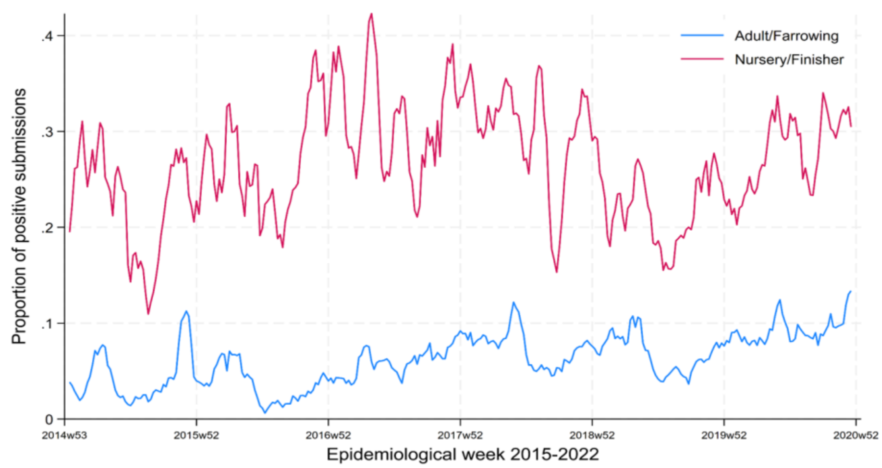
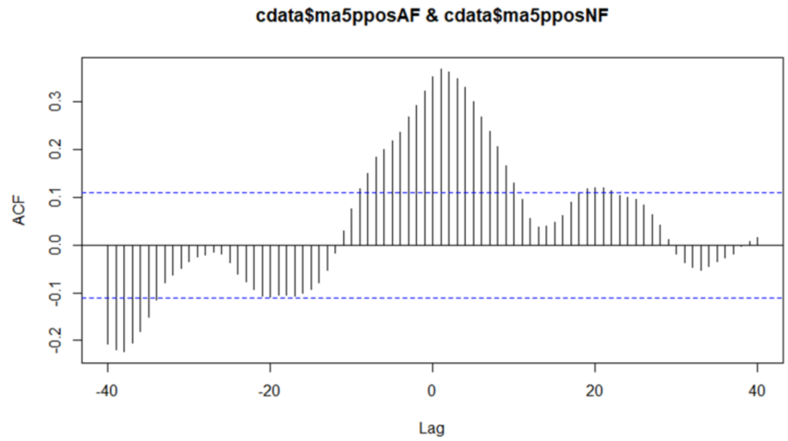


Figure 6. Cross-correlation between weekly percent PRRS PCR positive in adult/farrowing and in nursery/finisher.



In objective 1.ii, we aimed to investigate the association between carcass disposal methods and PRRS occurrence. We requested mortality management information in-person to MSHMP participating systems attending the Allen D. Leman Swine Conference in 2023 and via email. In addition, information collected through past variant outbreak investigations was also added to the analysis. As an initial assessment, we looked at the number of reported PRRS outbreaks per site during the 2023 calendar year. So far we have analyzed data from 133 breeding sites from 8 production systems. The proportion of sites that manage their mortality through compost that had at least one PRRS outbreak (29.73%) was numerically higher than the proportion of sites that did rendering and had at least one PRRS outbreak (21.05%). However, a few sites had two outbreaks throughout 2023, which are described in Table 1. When accounting for the production system as a random effect variable and for average inventory, air filtration status, and State as fixed effect variables, composting versus rendering was not associated with the number of PRRS outbreaks (p=0.67). While interesting and certainly surprising, these results still need to be reassessed once we obtain more data from participating systems and increase the time frame of the study.

Table 1. Sites that do composting, incineration, or rendering by the number of PRRS outbreaks reported in 2023.

Mortality management	No outbreaks	One outbreak	Two outbreaks	Total
Compost	52 (69.33%)	15 (20.00%)	8 (10.67%)	75
Incineration	20 (100.00%)	0 (0%)	0 (0%)	20
Rendering	30 (78.95%)	7 (18.42%)	1 (2.63%)	38
Total	102	22	9	133

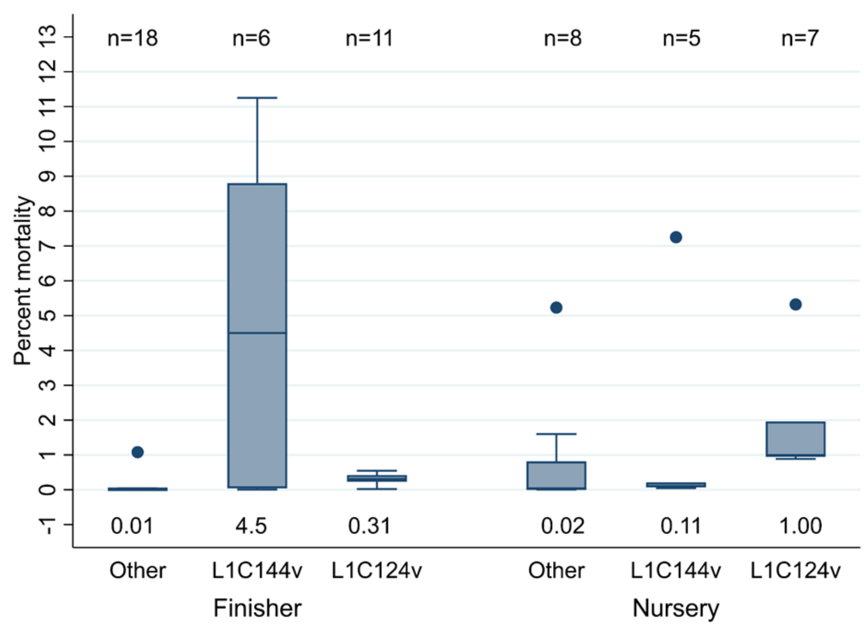
With these results, we demonstrate that the project is an important source of timely and relevant information for the industry, contributing to nation-wide decisions on disease control and/or eradication while addressing field-relevant questions.

Objective 2.
To conduct prospective monitoring of PRRS virus sequence evolution and impact.

i. Characterize PRRS outbreak production losses according to different viral and epidemiological characteristics and provide a benchmarking opportunity for practitioners and producers.

During 2023 we helped MSHMP participants in 26 PRRS outbreak investigations by comparing sequences to our extensively curated PRRSV ORF5 sequence dataset and also connecting practitioners from different systems whose sequences were highly similar so that through their discussions they could explore potential epidemiological links. This project provided a unique opportunity for reporting the spatial-temporal distribution of similar viruses to the one causing the outbreak, providing invaluable information during outbreak investigations. Through these comparisons, we began monitoring the emergence of another PRRSV variant (L1C.2, RFLP 124) in mid 2022, perceived to cause mild clinical disease. A total of 382 case sequences were identified in sixteen production systems. Although most sequences originated from breeding sites (n=223) compared to grow-finishing sites (n=127), they originated from 118 individual sites (73 grow-finishing, 37 breeding, and 8 with no farm type information), suggesting case counts based on the number of sequences may be inflated by repeated sequencing from the same site which ends overestimating the scenario. As opposed to what was thought by some in the industry, this variant showed limited prevalence and dissemination. Affected breeding sites had higher TTS than the average reported in the literature, at 87 weeks. However, TTS was 57 weeks in herds in which only the studied variant was detected during the unstable period and 91 weeks when multiple PRRSV variants were involved. The average mortality of growing pig sites affected by this variant was not statistically different from the one found in L1C144 variant affected sites (Figure 7).

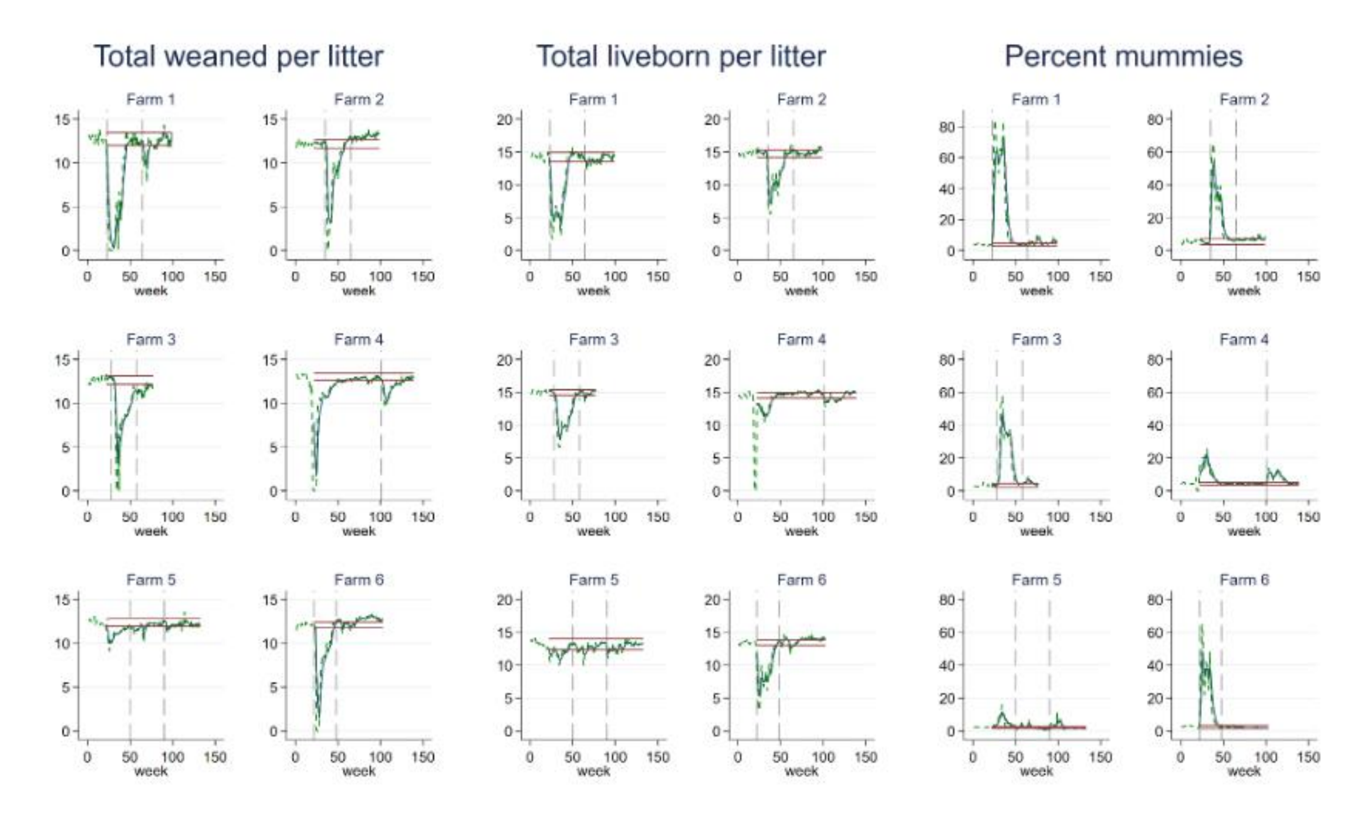
Figure 7. Median finisher and nursery mortality within four weeks of the outbreak by variant.



In addition, we continue to work on understanding the impact of the L1C144 variant. Data from 6 breeding farms from three different production systems that have experienced a PRRS outbreak associated with the recently emerged L1C144 variant have been curated for our analysis.

A visual summary of the PRRS production impact of the latter group of data is shown in Figure 8 which is our first step at characterizing this impact. In the graphs we have included a green dashed line representing the raw data, a blue line representing the exponentially weighted moving average (EWMA) of such production parameter and red horizontal lines representing the upper and lower confidence intervals considering the first 21 weeks as a baseline. Lastly, we have also included a gray vertical lines representing the onset of the L1C144 outbreak.

Figure 8. Exponentially weighted moving average of production parameters of farms affected by L1C144.



The majority of the L1C144 farms evaluated showed similar patterns of production impact, such as a steep decrease in total weaned per litter and a steep increase in percent mummies. As we continue to build this dataset, we will be able to better characterize the production impact of PRRS outbreaks on breeding herds.

Objective 3
To expand participation of producers to increase representativity and access to timely information on disease occurrence and streamline public access to information relevant to the industry.

i. Continue to add production systems together with inclusion of boar stud and growing pig sites of existing participants.
ii. Continue to finetune the first publicly available MSHMP website to optimize project output dissemination within both the participant and industry communities.

For objective 3.i, during 2023 we were able to add 4 more participants to our project accounting for 65K sows approximately. After The Early Regional Occurrence Warning (TEROW) tool was launched in Q2 of 2023, three different MSHMP and non-MSHMP participating production systems accounting for approximately 100K sows have expressed interest in joining MSHMP. We are still in the process of waiting for a response regarding whether they would like to proceed with enrollment. Thanks to this project, a group of five companies have reached out to us seeking help regarding the current situation of PRRS in a specific area of the midwestern United States. The five companies have provided data to complement and characterize the region from a farm census perspective together with allowing us to conduct disease occurrence calculations. One company was not an MSHMP participant and agreed to join due to the valuable nature of the project. This company particularly controls a large amount of growing pig sites in a specific area, thereby contributing significantly to the characterization of disease pressure in that area. The group has had 2 meetings and agreements regarding reporting disease have been made with the goal of informing each other what the current situation in the region currently is but most importantly, active growing pig testing is occurring which allows MSHMP to learn the intricacies of the data and process.

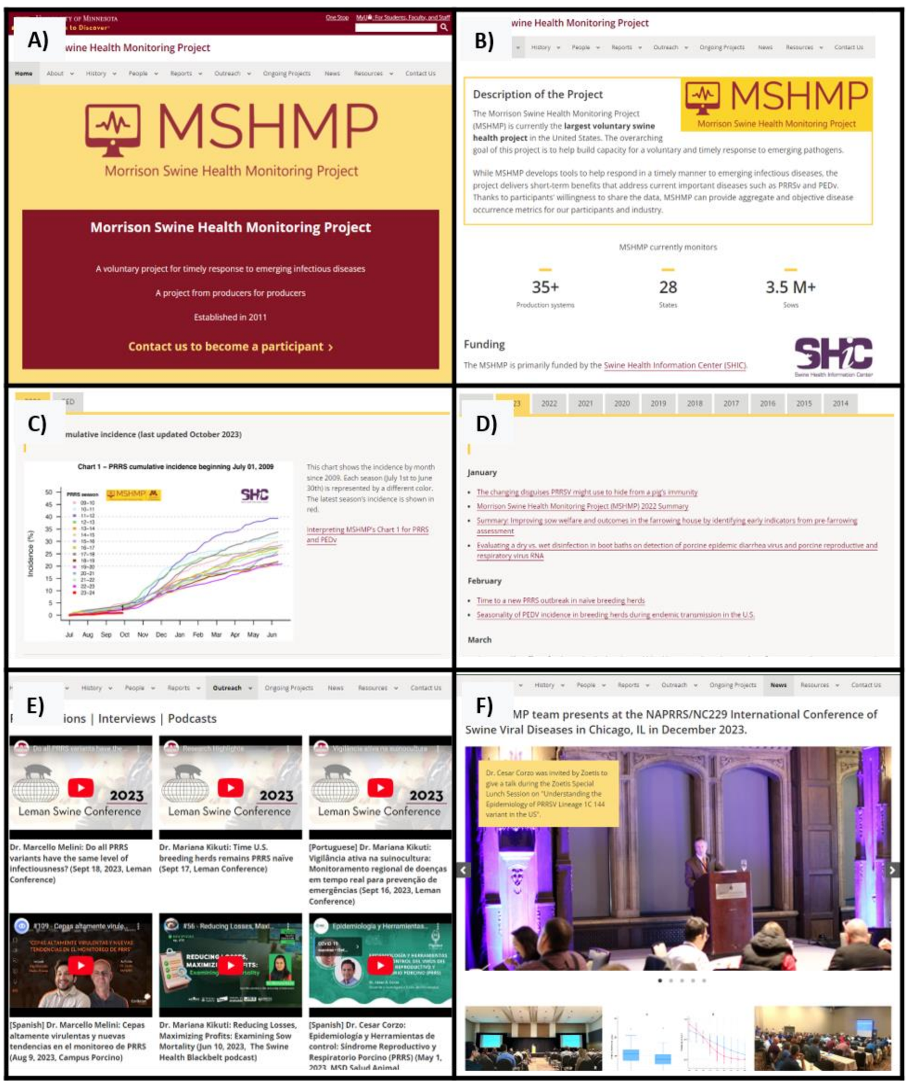
Regarding the second portion of objective 3, the design of our first publicly available MSHMP website has been completed and officially launched in Q3 of 2023, and has been continuously updated and finetuned. This website was designed to optimize MSHMP output dissemination within both the participant and industry communities. The website represents a significant milestone in our mission to enhance collaboration and communication within the swine industry. The website has been designed with ten comprehensive sections, including Home, About, History, People, Reports, Outreach, Ongoing Projects, News, Resources, and Contact Us (See the screenshot of the website in Figure 8 below).

In the past year, we have mainly done the following fine-tuning work for the launch of the website:

1. Enriching the content of the website horizontally and vertically. Horizontally, we have added a Home page (Figure 9A) and a News page (Figure 9F); vertically, we have greatly enriched the content of each page, such as the Outreach page shown in Figure 9E, updating the latest publications, podcasts, interviews, media outreach, that our MSHMP participants and the industry will value.
2. Adjust the webpage layout to make it more user-friendly and highlight key information through typography. For example, infographic in Figure 9B, callouts with photos in Figure 9C and 9F, tabs in Figure 9D.
3. Multiple meetings with internal website developers who donated their time to improve our website functionality. For example, adjust the size of the webpage to adapt it to monitors of different sizes; build a horizontal drop-down navigation menu to make it easier for users to find the content they are interested in.

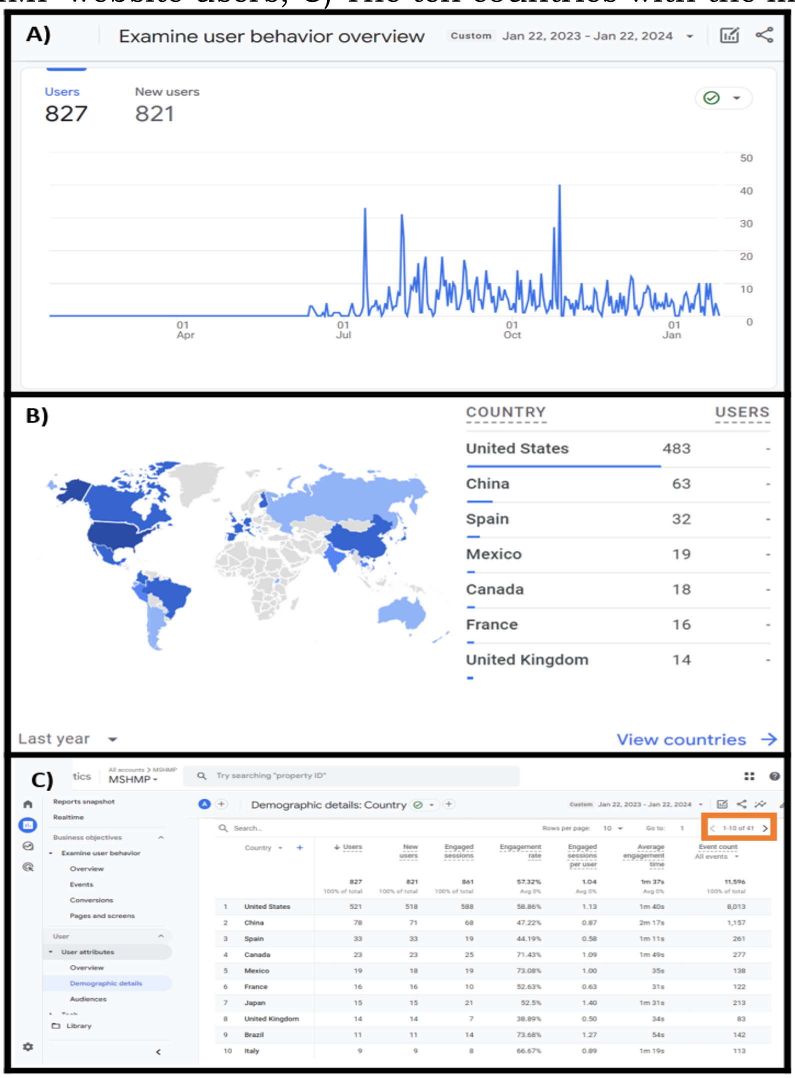
4. Design the home page.
5. Change the official URL to mshmp.umn.edu
6. The MSHMP team internally reviewed the webpage many times to prevent typo, improved the content and website structure, and quickly fulfilled the requirements from the internal review. We also invited peers to review the website before officially launching the site.
7. Make sure Google search works through UMN's internal setting and through Google's guidelines.
8. Create Google Analytics account to monitor the website visits over time.
9. Continuously update content to the website: PRRS and PED charts were updated twice a year in April and October; Outreach and News pages were updated as needed, etc.
10. Encourage people in the community to visit our website through different attempts: MSHMP weekly emails to participants and public receipts; oral and poster presentations in academic conferences; website launch science page.

Figure 9. MSHMP website screenshots: A) Home page; B) About MSHMP; C) MSHMP report-incidence chart; D) MSHMP report-science page; E) Outreach-presentations; F) News page.



After completing the above-mentioned steps, we have acquired expertise in website construction and content update, along with experienced effective collaboration with website developers to address issues, ensuring the website's long-term sustainability. As of January 22, 2024, the MSHMP website has accumulated 827 users from 41 countries, with the highest number of users originating from the United States, China, and Spain (Figure 10). This achievement reflects a global reach and impact within two quarters after its launch. The website will serve as an important source of access to MSHMP outputs for both participants and non-participants, facilitating effective communication and dissemination within the swine community. Most importantly, this website will highlight the importance of the collaborative nature of the project with the overall goal of giving our industry a chance to respond timely to an emergency.

Figure 10. MSHMP website analytics. A) Overall user year 2023; B) Geographic distribution of MSHMP website users; C) The ten countries with the most users



VII. MSHMP Related Publications and Presentations

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22. Mariana Kikuti: Reducing Losses, Maximizing Profits: Examining Sow Mortality (Jun 10, 2023, The Swine Health Blackbelt podcast). https://youtu.be/5Bggu-F86yM
23. Mariana Kikuti & John Deen discuss "Sow mortality in a pig production system in the midwestern USA: Reasons for removal and factors associated with increased mortality". Processing the Litter-ature. 2023.
24. Schieck Boelke, S. & Kikuti, M. Episode 34: Episode 35: Length of time farms stay naive of Porcine Reproductive and Respiratory Syndrome (PRRS). Minnesota's Swine & U podcast. 2023.
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