This document highlights the collaborative efforts of the NCERA57 committee (2019-2024) across multistate stations as illustrated by Accomplishments and Publications within each fiscal year (FY) starting October 1 and running through the annual meeting date (end of May). Accomplishments are highlighted for specific objectives for the NCERA57 committee (2019-2024) listed below and supported by corresponding publications within a given year.

**NCERA57 Project Objectives (2019-2024):**

1. Improve boar performance through research on: technology to reduce the number of sperm required for maximal fertility in artificial insemination, impacts of seasonal infertility on spermatogenesis, semen and male fertility as well as methods to mitigate these impacts, improved quality of insemination doses of semen through improved semen evaluation, additives and male selection, and evaluation of timed AI procedures with frozen semen.
2. Improved sow and gilt performance via research on: endocrine control of female reproduction, development of protocols for timing of ovulation and insemination, pubertal development, mammary gland development and physiology, epigenetic impacts on the fetus of summer heat stress and the potential effects of endocrine disruptors.
3. Increase the basic knowledge of folliculogenesis, spermatogenesis, fertilization, early embryo development, conceptus signaling for the establishment of pregnancy, uterine morphogenesis, endometrial secretion and immune function, and regulation of placental attachment and growth to be applied to future methods for improving reproduction efficiency of swine.
4. Increase the utilization of the rapidly advancing technology of functional genomics, proteomics and bioinformatics toward research regarding many of the items in objectives 1, 2 and 3.
5. Provide unique mechanisms for open scientific exchange and dialogue to advance research initiatives of participating scientists, and exchange of information and techniques that enhance teaching and adaptation of technology through the cooperative extension service, higher education and the swine industry.
6. Unique to this committee is the development of innovative teaching methods for undergraduate education. This will be continued with emphasis on how to increase student engagement, development of on-line resources that are available to multiple universities and instructors, and how to adapt to the changing type of student present in the land-grant universities.
7. Continuation of the biennial symposia that brings together university educators, extension scientists, reproductive physiologists and swine industry representatives to ensure researchers understand the swine industry, the industry is aware of current developments and technologies and educators can gather the latest information to implement in university and extension programs.
8. Collaborative USDA research grants between groups of researchers will be pursued to fund research on the objectives.

**Multistate Station Report of Collaboration FY2020:**

**Accomplishments Supporting Objectives FY2020**

* *In support of Objective 1* – Researchers determined boars with varicocele had decreased semen quality during and after a heat stress event (USMARC and UNL).
* *In support of Objective 2 & 4* –Investigators reported on pubertal neuroendocrine development in gilts (USMARC and WVU).
* *In support of Objective 3 & 4* – A team of researchers evaluated the metabolite profile of uterine flushings during early embryo elongation in swine (USMARC and UNL).
* *In support of Objective 3 & 5* – *S*owBridge (IPIC) talk on Dealing with Delayed Puberty in Gilts. Expert Panel: R Knox, K. Stewart, and T. Safranski. SowBridge (Iowa State, Univ. Illinois, Purdue, Univ. Missouri).
* *In support of Objective 1 & 4* – Researchers identified potential biomarkers in sperm that may provide early indication of fertility reduction due to elevated environmental temperature (Univ. of Illinois, Purdue, Univ. Wisc).
* *In support of Objective 1 & 4* –Researchers developed predictors and mediation methods for sperm quality in agricultural species (Univ Wisc, Miss. State).
* *In support of Objective 1 & 3* – Researchers collaborated with industry on the implications of low-dose semen (Purdue, Univ. of Illinois).
* *In support of Objective 3* –Experts hosted an all-day workshop at Purdue University for heritage Large Black swine breeders (Purdue, Univ. of Missouri).
* *In support of Objective 1* –Researchers validated a novel microscopic imaging approach for high-throughput evaluation of sperm quality (MSSTATE and University of Illinois, UC publication) and demonstrated the usefulness of nanotechnology-based approaches to improving sperm quality (MSSTATE and Wisconsin University).
* *In support of Objective 1* – Investigators from different stations examined the mechanisms underlying LH-independent testosterone production (UNL).
* *In support of Objective 1 & 3* – Collaborators evaluated sperm kinematics in semen from GnRH-II receptor knockdown and littermate control boars (UNL).
* *In support of Objective 2* –Research stations collaborated to compare endocrine profiles of GnRH-II receptor knockdown vs. littermate control gilts (UNL, USMARC).
* *In support of Objective 2 & 5* –Researchers created a vulva scoring scale and industry wide preliminary investigation into pelvic-organ-prolapse (POP) among sows (ISU).
* *In support of Objective 2 & 4* – Researchers evaluated the impact of heat stress, and potential heat-stress mitigation, on ovarian function and reproductive success (ISU).

**Publications FY2020**

***Basic Science and Technology***

Gruhot, T.R., Rempel, L.A., White, B.R., Mote, B.E. 2020. The effect of varicocele on semen quality in boars exposed to heat stress. Translational Animal Science. 4(1):1-6. <https://doi.org/10.1093/tas/txaa003>.

Kerns K, Sharif M, Zigo M, Miller D, Sutovsky S. 2020. Sperm capacitation-induced zinc efflux is necessary for increased proteasomal activity and release from oviduct glycans of the sperm reservoir. *Int J Mol* Sci 21:2121.

Rubessa, M., Feugang, J.M., Kandel, M.E., Schreiber, S., Hessee, J., Salerno, F., Meyers, S., Chu, I., Popescu, G., Wheeler, M.B. 2020. High-throughput sperm assay using label-free microscopy: morphometric comparison between different sperm structures of boar and stallion spermatozoa. Animal Reproduction Science. 106509. <https://doi.org/10.1016/j.anireprosci>.

Sharif M, Kerns K, Sutovsky P, Bovin N, Miller. DJ Progesterone induces porcine sperm release from oviduct glycans in a proteasome-dependent manner. Submitted.

Walsh, S.C., Miles, J.R., Yao, L., Broeckling, C.D., Rempel, L.A., Wright-Johnson, E.C., Pannier, A.K. 2020. Metabolic compounds within the porcine uterine environment are unique to the type of conceptus present during the early stages of blastocyst elongation. Journal of Molecular Reproduction and Development. 87:174-190. <https://doi.org/10.1002/mrd.23306>.

Boettcher AN, Kiupel M, Adur MK, Cocco E, Santin AD, Bellone S, Charley SE, Blanco-Fernandez B, Risinger JI, Ross JW, Tuggle CK, Shapiro EM. Human Ovarian Cancer Tumor Formation in Severe Combined Immunodeficient (SCID) Pigs. Front Oncol. 2019 Jan 22;9:9. doi: 10.3389/fonc.2019.00009. eCollection 2019. PMID: 30723704.

Schultz, R., Serao, N.L., Ross, J.W. 2019. Genetic improvement of livestock, from conventional breeding to biotechnological approaches. In: Animal Agriculture:Sustainability, Challenges and Innovations. Eds. Bazer, F.W., Wu, G. In Press (Elsevier).

Mayorga E.J., Renaudeau, D., Ramirez, B.C., Ross, J.W., Baumgard, L.H. 2019. Heat stress adaptation in pigs. Animal Frontiers 9:54-61.

***Boar Performance***

Feugang JM, Rhoads CE, Mustapha PO, Tardif S, Parrish JJ, Willard ST, Ryan PL. 2019. Treatment of boar sperm with nanoparticles for improved fertility. Theriogenology 137:75-81.

Hufana-Duran D, Duran PG, Venturina E, Peralta MD, Parrish JJ. 2019. Predicting bull fertility by sperm nuclear shape in water buffalo (bubalus bubalis). Thai J. Vet Med 49:75-81.

Lugar, D.W., Harlow, K.E., J. Hundley, M. Goncalves, J. Bergstrom, and K.R. Stewart. 2019. Effects of increased levels of supplemental vitamins during the summer in a commercial AI boar stud. Animal 1-13. doi:10.1017/S1751731119001150

***Genetics and Genomics***

Wijesena, H.R., Rohrer, G.A., Nonneman, D.J., Keel, B.N., Petersen, J.L., Kachman, S.D., Ciobanu, D.C. 2019. Evaluation of genotype quality parameters for SowPro90, a novel genotyping platform for swine. Journal of Animal Science. 97(8):3262-3273. <https://doi.org/10.1093/jas/skz185>.

Lents, C.A., Lindo, A.N., Hileman, S.M., Nonneman, D.J. 2020. Physiological and genomic insight into neuroendocrine regulation of puberty in gilts. Domest Anim Endocrinol. 11:106446. doi: 10.1016/j.domaniend.2020.106446.

***Sow and Gilt Performance***

Harlow, K., Ferreira, C.R., Sobreira, T.J.P., Casey, T. and K.R. Stewart. Lipidome profiles of postnatal day 2 vaginal swabs reflect fat composition of gilt’s postnatal diet. PLoS ONE 14(9): e0215186. <https://doi.org/10.1371/journal.pone.0215186>

Harlow, K., Suarez-Trujillo, A., Hedrick, V., Sobreira, T.J.P., Aryal, U.K., Stewart, K.R. and T. Casey. Temporal analysis of vaginal proteome reveals developmental changes in lower reproductive tract of gilts across the first two weeks of postnatal. Sci Rep. 2019 Sep 13;9(1):13241. doi: 10.1038/s41598-019-49597-w.

Leonard, S.M., Xin, H., Brown-Brandl, T.M., Ramirez, B.C., Dutta, S., Rohrer, G.A. 2020. Effects of farrowing stall layout and number of heat lamps on sow and piglet production performance. Animals. 10:348. [https://doi.org/doi:10.3390/ani10020348](https://doi.org/doi%3A10.3390/ani10020348).

Seibert, J.T., Adur, M.K., Schultz, R.B., Thomas, P.Q., Kiefer, Z.K., Keating, A.F., Baumgard, L.H., Ross, J.W. 2019. Differentiating between the effects of heat stress and lipopolysaccharide on the porcine ovarian heat shock protein response. J Anim Sci. 97:4965-4973. doi: 10.1093/jas/skz343. PMID: 31782954.

Bidne KL, Romoser MR, Ross JW, Baumgard LH, Keating AF. 2019. Heat stress during the luteal phase decreases luteal size but does not affect circulating progesterone in gilts1. J Anim Sci. 97:4314-4322. doi: 1093/jas/skz251.

Hines EA, Romoser MR, Kiefer ZE, Keating AF, Baumgard LH, Niemi J, Gabler NK, Patience JF, Haberl B, Williams NH, Kerr BJ, Touchette KJ, Ross JW. 2019. The impact of dietary supplementation of arginine during gestation in a commercial swine herd: I. Gilt reproductive performance. J Anim Sci. 97:3617-3625. doi: 10.1093/jas/skz233.

***Teaching and Extension***

Boyd, R., Zier-Rush, C., Moeser, A., Culbertson, M., Stewart, K., Rosero, D., & Patience, J. 2019. Review: Innovation through research in the North American pork industry. Animal, 13(12), 2951-2966. doi:10.1017/S1751731119001915

**Multistate Station Report of Collaboration FY2021:**

**Accomplishments supporting Objectives FY2021:**

* *In support of Objective 1, 3 & 4* – Impact of heat stress on the boar and impact on placental gene expression (USDA-USMARC, Wisconsin).
* *In support of Objective 1 & 4* – Developed predictors and mediation methods for sperm quality in agricultural species (Wisconsin, Miss. State).
* *In support of Objective 2 & 4* – Managing growth and puberty development in replacement gilts (USDA-USMARC, NC).
* *In support of Objective 2 & 4* – Mapping genetic variants associated with age at puberty and sow fertility (USDA-USMARC, Missouri).
* *In support of Objective 3* – GnRH2 in the boar (UNL, USDA-USMARC).
* *In support of Objective 3* – GnRH2 in the gilt ovary (UNL, USDA-USMARC).
* *In support of Objective 2 and 4* – Effects of heat stress on the hepatic and ovarian proteome in gilts (Iowa State, USDA-USMARC).
* *In support of Objective 5* – Extension program targeted to translating science into usable information for swine farms (Purdue, Missouri, Illinois).
* *In support of Objective 3* – Investigating survivability in swine (Purdue, Iowa).
* *In support of Objective 1, 3 & 4* – Determined the effects on the sperm proteome of a mild acute increase in scrotal temperature in pigs with over 800 proteins identified (Illinois, Wisconsin).
* *In support of Objective 1, 3 & 4* – Identified 4 potential biomarkers found in sperm that may provide early indication of fertility reduction due to elevated environmental temperature (Illinois, Wisconsin).
* *In support of Objective 1* – Number of sperm in AI and impacts on fertilization (Illinois, Purdue, Wisconsin).
* *In support of Objective 2* – In utero heat stress alters postnatal phenotypes in swine (Missouri, Purdue, Iowa).
* *In support of Objective 3 & 4* –Gene Editing to Investigate Role of Conceptus Factors in Establishment of Pregnancy (Missouri, TX).
* *In support of Objective 1* – Researchers validated a novel microscopic imaging approach for high-throughput evaluation of sperm quality (MSSTATE and University of Illinois) and demonstrated the usefulness of nanotechnology-based approaches to improving sperm quality (MSSTATE and Wisconsin University).

**Publications FY2021**

***Basic Science and Technology***

Wijesena, H.R., Kachman, S.D., Lents, C.A., Riethoven, J.J., Trenhaile-Grannemann, M.D., Safranski, T.J., Spangler, M.L., Ciobanu, D.C. 2020. Fine mapping genetic variants associated with age at puberty and sow fertility using Sowpro90 genotyping array. Journal of Animal Science. 98(10):1-12. <https://doi.org/10.1093/jas/skaa293>.

Azain, M., Cline, P.M., Tsai, T.C., Lents, C.A., Stelzleni, A.M., Dove, C.R. 2020. Interaction of dietary carbohydrate and fat on glucose metabolism in growing pigs. Research Square. pp. 22. <https://doi.org/10.21203/rs.3.rs-48869/v1>.

Nastasijevic, I., Schmidt, J.W., Boskovic, M., Glisic, M., Kalchayanand, N., Shackelford, S.D., Wheeler, T.L., Koohmaraie, M., Bosilevac, J.M. 2020. Seasonal prevalence of Shiga toxin-producing Escherichia coli on pork carcasses for three steps of the harvest process at two commercial processing plants in the United States. Applied and Environmental Microbiology. 87(1):e01711-20. <https://doi.org/10.1128/AEM.01711-20>.

Chaudhari, J., Liew, C., Workman, A.M., Riethoven, J.M., Steffen, D., Sillman, S., Vu, H.L.X. 2020. Host transcriptional response to persistent infection with a live-attenuated porcine reproductive and respiratory syndrome virus strain. Viruses. 12(8):817. <https://doi.org/10.3390/v12080817>.

Vande Pol, K.D., Tolosa, A.F., Shull, C.M., Brown, C.B., Alencar, S.A., Lents, C.A., Ellis, M. 2021. Effect of drying and/or warming piglets at birth under warm farrowing room temperatures on piglet rectal temperature over the first 24 h after birth. Translational Animal Science. txab060. <https://doi.org/10.1093/tas/txab060>.

Kerns K, Sharif M, Zigo M, Miller D, Sutovsky S. 2020. Sperm capacitation-induced zinc efflux is necessary for increased proteasomal activity and release from oviduct glycans of the sperm reservoir. *Int J Mol* Sci 21:2121.

Sharif M, Kerns K, Sutovsky P, Bovin N, Miller. DJ 2021. Progesterone induces porcine sperm release from oviduct glycans in a proteasome-dependent manner. *Reproduction*. 161:449-457.

Johnson, JS, JM Maskal, AW Duttlinger, KR. Kpodo, BR McConn, CJ Byrd, BT Richert, JN Marchant-Forde, DC Lay, SD Perry, MC Lucy, TJ Safranski. In utero heat stress alters the postnatal innate immune response of pigs. J. Anim. Sci. 98 (12):1-13.

Bernhard, CJ, KG Sharp, TJ Safranski, WR Lamberson and MC Lucy. Reproduction and reproductive tract morphology of male and female pigs whose mothers were heat stressed during the second month of gestation. J. Anim Sci. 98(11): 1-12.

Maskal, J.M., AW Duttlinger, KR Kpodo, BR McConn, CJ Byrd, JN Marchant-Forde, DC Lay, SD Perry, MC Lucy, TJ Safranski, JS Johnson. Evaluation and mitigation of the effects of in utero heat stress on piglet growth performance, postabsorptive metabolism, and stress response following weaning and transport. J. Anim. Sci., 98(9):1-13.

Ciccarelli M, Giassetti MI, Miao D, Oatley MJ, Robbins C, Lopez-Biladeau B, Waqas MS, Tibary A, Whitelaw B, Lillico S, Park CH, Park KE, Telugu B, Fan Z, Liu Y, Regouski M, Polejaeva IA, Oatley JM. Donor-derived spermatogenesis following stem cell transplantation in sterile *NANOS2*knockout males. Proc Natl Acad Sci U S ***A***. 2020 Sep 29;117(39):24195-24204. PMID: 32929012

Park CH, Jeoung YJ, Uh KJ, Park KE, Bridge J, Powell A, Li J, Pence L, Zhang Y, Liu T, Sun H, Gu Y, Shen Y, Wu J, Belmonte J-C, Telugu BP\***.** Extraembryonic Endoderm (XEN) Cells Capable of Contributing to Embryonic Chimeras Established from Pig Embryos. Stem Cell Reports. 2021 Jan 12;16(1):212-223. doi: 10.1016/j.stemcr.2020.11.011. PMID: 33338433

Geisert R.D., A.E. Meyer, C.A. Pfeiffer, D.N. Johns, K. Lee, K.D. Wells, T.E. Spencer, and R.S. Prather. 2021. Gene Editing to Investigate Role of Conceptus Factors in Establishment of Pregnancy. Reproduction 161: R79-R88.

Pfeiffer C.A., A.E. Meyer, K.E. Brooks, P.R. Chen, J. Milano-Foster, L.D. Spate, J.A. Benne, R. Cecil, M.S. Samuel, L.A. Ciernia, M.F. Smith, K.D. Wells, T.E. Spencer, R.S. Prather, and D. Geisert. 2020. Ablation of conceptus *PTGS2* provides a new understanding of early pregnancy events in the pig. Biol Reprod [102:475-488. doi.org/10.1093/biolre/ioz192](https://nam02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fdoi.org%2F10.1093%2Fbiolre%2Fioz192&data=04%7C01%7C%7C8a2d946e44d24b4a54b708d916203c38%7Ce3fefdbef7e9401ba51a355e01b05a89%7C0%7C0%7C637565149969496019%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=%2BPGC6jMBNV2oISOZ13OzZ%2Bb04X4i%2FIFYBp9OT1cOgfs%3D&reserved=0).

Cho J, Uh K, Ryu J, Fang X, Bang S, Lee K. Development of PCR based approach to detect potential mosaicism in porcine embryos. Journal of Animal Reproduction and Biotechnology. 2020 Dec. 35. 4.

Uh K, Ryu J, Farrell K, Wax N, Lee K. TET family regulates the embryonic pluripotency of porcine preimplantation embryos by maintaining the DNA methylation level of NANOG. Epigenetics. 2020 Nov;15(11):1228-1242. doi: 10.1080/15592294.2020.1762392. Epub 2020 May 13.

Tumova L, Zigo M, Sutovsky P, Sedmikova M, Postlerova P (2020) Is the ubiquitin-proteasome system involved in the degradation of porcine beta-microseminoprotein during sperm capacitation? Int. J. Mol. Sci., 21(11):4151.

Kerns K, Sharif M, Zigo M, Xu W, Hamilton L, Sutovsky M, Ellersieck M, Drobnis EZ, Oko R, Miller D, Sutovsky P (2020) Sperm cohort-specific zinc signature acquisition and capacitation-induced zinc flux regulate sperm-oviduct and sperm-zona pellucida interactions. Int. J. Mol. Sci., 21(6):2121; Special Issue on Advances in Molecular Regulation of Spermatozoa Function,

Zigo M, Maňásková-Postlerová P, Zuidema D, Kerns K, Jonáková V, Tůmová L, Bubeníčková F, Sutovsky P (2020) Porcine model for the study of sperm capacitation, fertilization and male fertility. Cell Tissue Res., 380(2):237-262.

Zuidema D, Sutovsky P (2020) The domestic pig as a model for the study of mitochondrial inheritance. Cell Tissue Res., 80(2):237-262. Special Issue on Animal Models,

Pfeiffer, C.A., A.E. Meyer, K.E. Brooks, P.R. Chen, J.M. Foster, L.D. Spate, J.A. Benner, R. Cecil, M.S. Samuel, L.A. Ciernia, M.F. Smith, K.D. Wells, T.E. Spencer, R.S. Prather. 2020. Ablation of conceptus PTGS2 provides a new understanding of early pregnancy events in the pig. Biol. Reprod. Doi: 10/.1093/biolre/ioz192 PMID: 31616930, PMCID: PMC7523696.

Stoian, A., R.R.R. Rowland, V. Petrovan, M. Sheahan, M.S. Samuel, K.M. Whitworth, K.D. Wells, J. Zhang, B. Beaton, M. Cigan, R.S. Prather. 2020. The use of cells from ANPEP knockout pigs to evaluate the role of aminopeptidase N (APN) as a receptor for porcine deltacoronavirus (PDCoV). Virology. 2020 Feb; 541:136-140. doi: 10.1016/j.virol.2019.12.007. Epub 2019 Dec 24. PMID: 32056711, PMCID: PMC7112016

Chen, P.R., L.D. Spate, E.C. Leffeler, J.A. Benne, R.F. Cecil, T.K. Hord, R.S. Prather. 2020. Removal of hypotaurine from porcine embryo culture medium does not impair development of in vitro fertilization or somatic cell nuclear transfer-derived embryos at low oxygen tension. Molecular Reproduction and Development https:/doi: 10.1002/mrd.23393. PMID 32495478, PMCID: PMC7496716.

Cecil, R.F., J.A. Benne, P.R. Chen, T.K. Hord, L.D. Spate, M.S. Samuel, R.S. Prather. 2020. Chemical stimulation of hypoxia in somatic cell nuclear transfer donor cells permits metabolic reprogramming and improved SCNT efficiency. Molecular Reproduction and Development https:/doi: 10.1002/mrd.23392 PMID 32558023, PMCID: PMC7496615.

Lucas, C.G., A.M. Spate, M.S. Samuel, L.D. Spate, W.C. Warren, R.S. Prather, K.D. Wells. 2020. A novel swine sex-linked marker and its application across different mammalian species. Transgenic Research doi: 10.1007/s11248-020-00204-z. PMID: 32607872, PMCID: PMC7423754

Ostedgaard, L.S., M.P. Price, K.M. Whitworth, M.H.A. Alaiwa, A.J. Fischer, A. Warrier, M. Samuel, L.D. Spate, P.D. Allen, B.M. Hilkin, G.S. R. Ibarra, M.E. Ortiz, B.J. Goodelll, S.E. Mather, L.S. Powers, M.R. Stroik, N.D. Gansmer, C.E. Hippee, K. Zarei, J.A. Goeken, T.R. Businga, E. A. Hoffman, D.K. Meyerholz, R.S. Prather, D.A. Stoltz, M.J. Welsh. 2020. Lack of submucosal glands impairs respiratory host defenses in pigs. eLife 2020;9:e59653. DOI: <https://doi.org/10.7554/eLife.59653>. PMID:33026343, PMCID: PMC7541087

Koppes, E., B.K. Redel, M.A. Johnson, K.J. Shvorak, L. Ghaloul-Gonzalez, M.E. Yates, D.W. Lewis, S.M. Gollin, Y. Wu, S.E. Christ, M. Yerle, A. Leshinski, L.D. Spate, J. Benne, S. Murphy, M.S. Samuel, E.M. Walters, S.A. Hansen, K.D. Wells, J. Vockley, R.S. Prather, R.D. Nicholls. 2020. A porcine model of phenylketonuria generated by CRISPR/Cas9 genome editing. JCI Insight doi: 10.1172/jci.insight.141523. PMID: 33055427 PMCID: PMC7605535.

***Boar Performance***

Mills, K.M., Aryal, U.K., Sobreira, T., Minton, A.M., Casey, T., and K.R. Stewart. 2020. Shotgun proteome analysis of seminal plasma differentiate boars by reproductive performance. Theriogenology 157: 130-139. [doi.org/10.1016/j.theriogenology.2020.07.013](https://doi.org/10.1016/j.theriogenology.2020.07.013)

Lents, C.A., Supakorn, C., DeDecker, A.E., Phillips, C.E., Boyd, R.D., Vallet, J.L., Rohrer, G.A., Foxcroft, G.R., Flowers, W.L., Trottier, N.L., Salak-Johnson, J.L., Bartol, F.F., Stalder, K.J. 2020. Dietary lysine-to-energy ratios for managing growth and pubertal development in replacement gilts. Applied Animal Science. 36(5):701-714. DOI: <https://doi.org/10.15232/aas.2020-02016>

Rempel, L.A., Parrish, J.J., Miles, J.R. 2020. Genes associated with chromatin modification within the swine placenta are differentially expressed due to factors associated with season. Frontiers in Genetics. 11:1019. <https://doi.org/10.3389/fgene.2020.01019>.

Belstra, B.A., Willenburg, K.L., Gómez-López, D.H., Knox, R.V., Stewart, K.R., 2020. Effects of the number of sperm and site of uterine semen deposition on conception rate and the number of embryos in weaned sows receiving a single fixed-time insemination. Journal of Animal Science 98.

Kerns K, Jankovitz J, Minton A, Kuster C, Robinson J, Sutovsky P (2020) Relationship between the length of sperm tail mitochondrial sheath and fertility traits in boars used for artificial insemination. Antioxidants, 9(11):1033. doi: 10.3390/antiox9111033

Parrish JJ, PREDICITION OF FERTILITY IN MALES, US Patent App. 16/024,335; Patent granted May 2020.

***Genetics and Genomics***

Johnson, J.S., Stewart, K.R., Safranski, T.J., Ross, J.W. and L.H. Baumgard. 2020. In utero heat stress alters postnatal phenotypes in swine. Theriogenology, 154:110-119. [doi.org/10.1016/j.theriogenology.2020.05.013](https://doi.org/10.1016/j.theriogenology.2020.05.013)Wijesena, H.R., SD Kachman, CA Lents, JJ Riethoven, MD Trenhaile-Grannemann, TJ Safranski, ML Spangler, DC Ciobanu. Fine mapping genetic variants associated with age at puberty and sow fertility using SowPro90 genotyping array. J. Anim. Sci. 98(10): 1-12.

Johnson, J.S., KR Stewart, TJ Safranski, JW Ross, LH Baumgard. In utero heat stress alters postnatal phenotypes in swine. 2020. Theriogenology, 154: 110-119

***Sow and Gilt Performance***

Belstra, B.A., Willenburg, K.L, Gómez-López, D.H., Knox, R.V., and K.R. Stewart. 2020. Effects of number of sperm and site of uterine deposition on conception rate and number of embryos in weaned sows receiving a single fixed time insemination. J Anim Sci.,98:9, 1-10. doi:10.1093/jas/skaa260

Suarez-Trujillo, A., Senn, K., Teeple, K., Casey, T., and K.R. Stewart. 2020. Technical Note: A standardized model to study effects of varying 24 h colostrum dose on postnatal growth and development. TAS, txaa212, [doi.org/10.1093/tas/txaa212](https://doi.org/10.1093/tas/txaa212).

Leonard, S.M., Xin, H., Brown-Brandl, T.M., Ramirez, B.C., Johnson, A.K., Dutta, S., Rohrer, G.A. 2021. Effects of farrowing stall layout and number of heat lamps on sow and piglet behavior. Applied Animal Behaviour Science. 239:105334. <https://doi.org/10.1016/j.applanim.2021.105334>.

 ***Teaching and extension***

Mills, K.M., Schinckel, A.P., Casey, T.M., and K.R. Stewart. 2020. Evaluation of on-farm indicators of gilt reproductive performance potential at 21 days of age. TAS, txaa210, [doi.org/10.1093/tas/txaa210](https://doi.org/10.1093/tas/txaa210).

**Multistate Station Report of Collaboration FY2022:**

**Accomplishments supporting Objectives for FY2022:**

* *In support of Objective 1 & 3* – Reported the influence of fish oil supplementation on boar sperm quantity and spermatogenesis (Wisconsin, Iowa, and Ohio).
* *In support of Objective 1 & 3*– Published a book chapter on Animal Andrology (Illinois and Indiana).
* *In support of Objectives 1, 3, & 4* – Identified sperm proteome following acute scrotal temperature in pigs (Missouri and Illinois).
* *In support of Objective 1, 3, & 4* – Identified metabolites involved in binding of sperm to oviduct glycans to extend sperm lifespan (Missouri and Illinois).
* *In support of Objective 1, 3, 4 & 8* – Continued collaboration on USDA-NIFA grant: Proteomic identification of molecular pathways and biomarker related to porcine seasonal heat-induced infertility in males (Illinois and Wisconsin).
* *In support of Objective 1, 3, 4 & 8* – Continued collaboration on NIH grant: Accumulation, storage, and release of sperm in the oviduct (Illinois and Missouri).
* *In support of Objective 2, 3 & 4* – Characterized kisspeptin, NKB, and NK3R in the hypothalamus of gilts following Altrenogest treatment (USMARC, West Virginia, Ohio, and Mississippi).
* *In support of Objective 2, 3 & 4* – Identified biomarkers of fertility in gilts (BARC & Indiana)
* *In support of Objective 2, 3, 4 & 8* – Continued collaboration on National Pork Board Grant: Investigating survivability in swine (BARC, Indiana, and Iowa)
* *In support of Objective 3 & 4* – Characterized extensive transcriptomic differences in spherical, ovoid and tubular conceptus during the initiation of elongation in gilts (USMARC and Nebraska).
* *In support of Objective 3, 4 & 8* – New USDA-NIFA grant awarded: Influence of maternal and embryonic extracellular vesicles on the initiation of porcine conceptus elongation, #2021-67015-34416 (Nebraska and USMARC).
* *In support of Objective 5* – Planning committee for the SowBridge program, an extension program targeted to translating science into usable information for swine farms (Indiana, Missouri, and Illinois).
* *In support of Objective 5* – Organized and presented an Extension Webinar on farrowing induction in sows (Indiana and Pennsylvania).
* *In support of Objective 5 & 7* – Organized and hosted the 2022 NCERA57 Biannual Symposium: Managing the Hyperprolific Sow (Indiana, Wisconsin, Missouri).

**Publications FY2022**

***Basic Science and Technology***

Cline, P.M., Tsai, T.C., Lents, C.A., Stelzleni, A.M., Dove, C.R., Azain, M. 2021. Interaction of dietary carbohydrate and fat on glucose metabolism in growing pigs. Domestic Animal Endocrinology. 78. Article 106655. <https://doi.org/10.1016/j.domaniend.2021.106655>.

Meinen, R.J., Spiegal, S.A., Kleinman, P.J., Flynn, K.C., Goslee, S.C., Mikesell, R.E., Church, C., Bryant, R.B., Boggess, M.V. 2022. Opportunities to implement manureshed management in the Iowa, North Carolina, and Pennsylvania swine industry. Journal of Environmental Quality. <https://doi.org/10.1002/jeq2.20340>.

Velez, F.J., Bosilevac, J.M., Singh, P. 2021. Validation of high-resolution melting assays for the detection of virulent strains of Escherichia coli O26 and O111 in beef and pork enrichment broths. Food Control. 128. Article 108123. <https://doi.org/10.1016/j.foodcont.2021.108123>.

 ***Boar Performance***

Andrade, A., Grossfeld, R., Knox, R. V. 2021 In vitro effects of commercial freezing and thawing extenders on boar sperm quality. Anim. Reprod. Sci. Pages 106906 DOI: <https://doi.org/10.1016/j.anireprosci.2021.106906>.

Sharif, M., Hickl, V., Juarez, G., Di, X., Kerns, K., Sutovsky, P., Bovin, N., Miller, D. J. Hyperactivation is sufficient to release sperm from immobilized oviduct glycans. Sci Rep 12, 6446. <https://doi.org/10.1038/s41598-022-10390-x>

Sharif, M., Kerns, K., Sutovsky, P., Bovin, N., Miller, D.J. Progesterone induces porcine sperm release from oviduct glycans in a proteasome-dependent manner. Reproduction. 161(4):449-457. doi: 10.1530/REP-20-0474.

 ***Sow and Gilt Performance***

Arend, L.S., Knox, R.V. 2021. Fertility responses of melatonin-treated gilts before and during the follicular and early luteal phases when there are different temperatures and lighting conditions in the housing area. Anim Reprod Sci, 230, 106769. doi:10.1016/j.anireprosci.2021.106769

Knox, R.V., Arend, L.S., Buerkley, A.L., Patterson J.L., Foxcroft, G.R. 2021. Effect of physical or fenceline boar exposure and gonadotropins on fertility in gilts. J. Anim. Sci. DOI: 10.1093/jas/skab348.

Lindo, A.N., Thorson, J., Bedenbaugh, M.N., Mccosh, R.B., Lopez, J.A., Young, S.A., Meadows, L.J., Bowdridge, E.C., Fergani, C., Freking, B.A., Lehman, M.N., Hileman, S.M., Lents, C.A. 2021. Localization of kisspeptin, NKB, and NK3R in the hypothalamus of gilts treated with the progestin altrenogest. Biology of Reproduction. Article 103. <https://doi.org/10.1093/biolre/ioab103>.

Miles, J.R., Walsh S.C., Rempel L.A., Pannier A.K.. 2022. Mechanisms regulating the initiation of porcine conceptus elongation. Mol Reprod Dev. DOI: 10.1002/mrd.23623.

Mills, K.M., Ferreira, C.R., Stewart, K.R., Casey T.M. Biomarkers predictive of long-term fertility found in vaginal lipidome of gilts at weaning. J Anim Sci DOI: <https://doi.org/10.21203/rs.3.rs-210669/v1>

Mills, K.M., Shirley, L.K., Sharp, K., Garcia, R., Suarez-Trujillo, A., Stewart, K.R. 2021. Effects of induction on the farrowing process and piglet blood parameters at time of birth. TAS 5:108. doi: 10.1093/tas/txab032

Vande Pol, K.D., Tolosa, A.F., Bautista, R.O., Willard, N.C., Gates, R.S., Shull, C.M., Brown, C.B., Alencar, S.A., Lents, C.A., Ellis, M. 2021. Effects of drying and providing supplemental oxygen to piglets at birth on rectal temperature over the first 24 h after birth. Translational Animal Science. 5(3). Article txab095. <https://doi.org/10.1093/tas/txab095>.

Walsh, S.C., Miles, J.R., Keel-Mercer, B.N., Rempel, L.A., Wright-Johnson, E.C., Lindholm-Perry, A.K., Oliver, W.T., Pannier, A.K. 2022. Global analysis of differential gene expression within the porcine conceptus transcriptome as it transitions through spherical, ovoid, and tubular morphologies during the initiation of elongation. Molecular Reproduction and Development. Article 23553. <https://doi.org/10.1002/mrd.23553>

***Genetics and Genomics***

Herrera-Uribe, J., Wiarda, J., Sivasankaran, S.K., Daharsh, L., Liu, H., Byrne, K.A., Smith, T.P., Lunney, J.K., Loving, C.L., Tuggle, C.K. 2021. Reference Transcriptomes of Porcine Peripheral Immune Cells Created Through Bulk and Single-Cell RNA Sequencing. Frontiers in Genetics. 12. Article 689406. <https://doi.org/10.3389/fgene.2021.689406>.

***Teaching and Extension***

Hines, E., Romoser, M., Cover, J. Improving the gilt selection process. Penn State Extension Report. <https://extension.psu.edu/improving-the-gilt-selection-process>

Knox, R. 2021. The New Building Designs on Swine Farms in China. June 2021. Illinois AgriNews.

Knox, R. 2021. New technology used in the swine breeding barn. Dec. 2021. Illinois AgriNews.

**Multistate Station Report of Collaboration FY2023:**

**Accomplishments supporting Objectives for FY2023:**

* *In support of Objectives 1 and 3* – Illustrated the influence of antioxidants on fertility of cryopreserved boar spermatozoa (Iowa and Missouri).
* *In support of Objectives 1 and 3* – Demonstrated that hyperactivation of sperm provides release from immobilized oviduct glycans (Illinois, Iowa, and Missouri).
* *In support of Objectives 1 and 3* – Reported the importance of zinc as a master regulator of sperm capacitation (Iowa and Missouri).
* *In support of Objective 1 and 3* – Evaluated the temperature preference of different commercial breeds of boars (Indiana and USDA-ARS-West Layfette
* *In support of Objectives 2 and 4* – Described the genetic basis of sow pelvic organ prolapse (Iowa, Minnesota, and the Netherlands).
* *In support of Objective 2 and 4* – Characterized the metabolome of encapsulated conceptuses undergoing initiation of elongation following culture (USDA, ARS, USMARC and Nebraska).
* *In support of Objective 5 and 7* – Initiated the planning of the 2024 NCERA57 Biannual Symposium with tentative title of “Maximizing Efficiency of Swine Herds” to be hosted at the University of Nebraska in May 2024 (Nebraska, USDA-ARS-USMARC, Missouri, and Pennsylvania).
* *In support of Objective 1, 3, 4, and 8* – Continued collaboration on a NIH grant: Accumulation, storage, and release of sperm in the oviduct (Illinois and Missour).
* *In support of Objective 2, 3, 4, and 8* – Continued collaboration on a USDA-AFRI-NIFA grant: Influence of Maternal and Embryonic Extracellular Vesicles on the Initiation of Porcine Conceptus Elongation (USDA-ARS-USMARC and Nebraska).
* *In support of Objective 3, 4, and 8* – Initiated a new collaborative USDA-AFRI-NIFA grant: Identifying AMR gene reservoirs and bacterial host-AMR gene associations to identify bacterial host range of AMR genes in swine production systems (Nebraska, Iowa, and USDA-ARS-USMARC).
* *In support of Objective 1, 3, 4, and 8* – Initiated a new collaborative USDA-AFRI-NIFA grant: Enhancing boar fertility in the face of climate change through the mitigation of in utero heat stress (Nebraska, USDA-ARS-USMARC, Indiana, and USDA-ARS- West Layfette).

**Publications FY2023**

***Basis Science and Technology***

Li, Y., Adur, M.K., Lonergan, S.M., Keating, A.F., Ross, J.W. MicroRNA21 inhibition affects porcine oocyte maturation and alters protein expression critical for metabolic pathway function. Mol Reprod Dev. 89(10):443-458. https://doi:10.1002/mrd.23641.

Miller, K.A., Johnson, E.M., Matchan, S.A., Goehring, D., Ross, J.W., Gabler, N.K. Strategies to manage barn feed supply to prolong and hold late finishing pigs during a supply chain disruption. Transl Anim Sci. 7(1):txac166. https://doi:10.1093/tas/txac166.

Studer, J.M., Schweer, W.P., Gabler, N.K., Ross, J.W. Functions of manganese in reproduction. Anim Reprod Sci. 238:106924. https://doi:10.1016/j.anireprosci.2022.106924.

 ***Boar Performance***

de Andrade, A.F.C., Balogun, K., Machaty, Z., Knox, R.V. Effects of supplemental antioxidants on in vitro fertility measures for cryopreserved boar spermatozoa. Theriogenology. 200:33-42. https://doi:10.1016/j.theriogenology.

Andrade, A.F.C., Knox, R.V., Torres, M.A., Pavaneli, A.P.P. What is the relevance of seminal plasma from a functional and preservation perspective? Anim Reprod Sci. 246:106946. https://doi:10.1016/j.anireprosci.2022.106946.

Lawlor, M., Zigo, M., Kerns, K., Cho, I.K., Easley, C.A., Sutovsky, P. Spermatozoan Metabolism as a Non-Traditional Model for the Study of Huntington’s Disease. Intl J of Molc Sci. 23(13):7163. https://doi:10.3390/ijms23137163.

Nogueira, E., Tirpák, F., Hamilton, L., Zigo, M., Kerns, K., Sutovsky, M., Kim, J., Volkmann, D., Jovine, L., Taylor, J., Schnabel, R., Sutovsky, P. A Non-Synonymous Point Mutation in a WD-40 Domain Repeat of EML5 Leads to Decreased Bovine Sperm Quality and Fertility. Front. Cell Dev. Biol. https://doi:10.3389/fcell.2022.872740.

Sharif, M., Hickl, V., Juarez, G., Di, X., Kerns, K., Sutovsky, P., Bovin, N., Miller, D.J. Hyperactivation is sufficient to release sperm from immobilized oviduct glycans. Sci Rep. 12:6446. <https://doi.org/10.1038/s41598-022-10390-x>.

Spooner-Harris, M., Kerns, K., Zigo, M., Sutovsky, P., Balboula, A., Patterson, A. A re‑appraisal of mesenchymal‑epithelial transition (MET) in endometrial epithelial remodeling. Cell Tissue Res. 391(2):393-408. https://doi:10.1007/s00441-022-03711-z.

Zigo, M., Kerns, K., Sen, S., Essien, C., Oko, R., Xu, D., Sutovsky, P. Zinc is a master-regulator of sperm function associated with binding, motility, and metabolic modulation during porcine sperm capacitation. Commun. Biol. 5(1):538. [https://10.1038/s42003-022-03485-8](https://10.0.4.14/s42003-022-03485-8).

 ***Sow and Gilt Performance***

Arend, L.S., Vinas, R.F., Silva, G.S., Lower, A.J., Connor JF, Knox RV. Effects of nursing a large litter and ovarian response to gonadotropins at weaning on subsequent fertility in first parity sows. J Anim Sci. 101:skac398. https://doi:10.1093/jas/skac398.

Bhatia, V., Stevens, T., Derks, M.F.L., Dunkelberger, J., Knol, E.F., Ross, J.W., Dekkers, J.C.M. Identification of the genetic basis of sow pelvic organ prolapse. Front Genet. 14:1154713. https://doi:10.3389/fgene.2023.1154713.

Walsh, S.C., Miles, J.R., Broeckling, C.D., Rempel, L.A., Wright-Johnson, E.C., Pannier, A.K. Secreted metabolome of porcine blastocysts encapsulated within in vitro 3D alginate hydrogel culture systems undergoing morphological changes provides insights into specific mechanisms involved in the initiation of porcine conceptus elongation. Reprod Fertil Dev. 35(5):375-394. <https://doi.org/10.1071/RD22210>.

 ***Seasonality and Heat Stress***

Adur, M.K., Seibert, J.T., Romoser, M.R., Bidne, K.L., Baumgard, L.H., Keating, A.F., Ross, J.W. Porcine endometrial heat shock proteins are differentially influenced by pregnancy status, heat stress, and altrenogest supplementation during the peri-implantation period. J Anim Sci. 100(7):skac129. https://doi:10.1093/jas/skac129.

Brown-Brandl, T.M., Hayes, M.D., Rohrer, G.A., Eigenberg, R.A. Thermal comfort evaluation of three genetic lines of nursery pigs using thermal images. Biosystems Engineering. 225:1-12. <https://doi.org/10.1016/j.biosystemseng.2022.11.002>.

Raber, V.L., Pritchett, R.K., Robbins, L.A., Stewart, K.R., Gaskill, B.N., Green-Miller, A.R., Johnson, J.S. Evaluating the temperature preferences of sexually mature Duroc, Landrace, and Yorkshire boars. Transl Anim Sci. May 29;7(1):txad060. https://doi:10.1093/tas/txad060.

Ramirez, B.C., Hoff, S.J., Hayes, M.D., Brown-Brandl, T.M., Harmon, J.D., Rohrer, G.A. 2022. A review of swine heat production: 2003 to 2020. Frontiers in Animal Science. 3. Article 908434. <https://doi.org/10.3389/fanim.2022.908434>.

Roach, C.M., Bidne, K.L., Romoser, M.R., Ross, J.W., Baumgard, L.H., Keating, A.F. Impact of heat stress on prolactin-mediated ovarian JAK-STAT signaling in postpubertal gilts. J Anim Sci. 100(7):skac129. https://doi:10.1093/jas/skac129.

Romoser, M.R., Bidne, K.L., Baumgard, L.H., Keating, A.F., Ross, J.W. Effects of increased ambient temperature and supplemental altrenogest before pregnancy establishment in gilts. J Anim Sci. 100(2):skac007. https://doi:10.1093/jas/skac007.

Rudolph TE, Roach CM, Baumgard LH, Ross JW, Keating AF, Selsby JT. The impact of Zearalenone on heat-stressed skeletal muscle in pigs. J Anim Sci. 100(8):skac215. https://doi:10.1093/jas/skac215.

**Active Multistate Station Grants**

* NIH, R01HD095841, “Accumulation, Storage, and Release of Sperm in the Oviduct” Miller1, D. (PD), Prather2, R,. Sutovsky2, P. (1University of Illinois; 2University of Missouri)
* USDA-AFRI-NIFA Grant #2021-67015-34416, $500,000, Jul 1, 2021 – Oct 1, 2024, *“Influence of Maternal and Embryonic Extracellular Vesicles on the Initiation of Porcine Conceptus Elongation”* Pannier1, A.K. (PD), Miles2, J.R. (Co-PD), Rempel2, L.A. (1University of Nebraska; 2USDA, ARS, USMARC)
* USDA-AFRI-NIFA Grant #2022-08916, $999,618, May 1, 2023 – May 1, 2027, *“Identifying AMR gene reservoirs and bacterial host-AMR gene associations to identify bacterial host range of AMR genes in swine production systems”* Fernando1, S., Burkey1, T., Miller1, P., Schmidt2, A., Anderson2, C., Oliver3, W., Rempel3, L., Wells3, J. (1University of Nebraska; 2Iowa State University; 3USDA, ARS, USMARC)
* USDA-AFRI-NIFA Grant #2023-XXXXX, $650,000, May 1, 2023 – May 1, 2026, “*Enhancing boar fertility in the face of climate change through the mitigation of in utero heat stress*” Desaulniers1, A.T. (PD), Lents2, C., White1, B., Brito3, L, Johnson4, J. (1University of Nebraska; 2USDA, ARS, USMARC, 3Purdue University; 4USDA, ARS, West Lafayette)