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The Potential of IVF

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Intermountain Embryonics

Abstract

As in-vitro fertilization (IVF) has become more available and more affordable, it has become one of the top breeding technologies in the beef and dairy industry. Intermountain Embryonics of Twin Falls, Idaho has made it an available technology for producers in Idaho and parts of surrounding states. Intermountain Embryonics has struggled to show potential clients the financial potential IVF has to offer. This study shows the revenues, expenses, and risks involved in IVF. This study looks at the comparison of breeding natural service with a bull, artificial insemination, and in-vitro fertilization. The comparison shows that natural service comes with the least amount of risk while also producing the lowest profit for the producer. Artificial insemination involves a slightly higher degree of risk with more of a profit. Three different IVF scenarios based on expenses associated with the number of donor cows show the most profit as well as the most risk. While all three IVF scenarios show the most risk, they also show producers the opportunity they have to make an impressive profit which artificial insemination does not show in this study.

I. Introduction

Intermountain Embryonics is a small company that was started by veterinarians Hoyt Rees and Rebecca Holmbeck only a few years ago. As In-Vitro Fertilization (IVF) became more affordable and efficient, they chose to help beef and dairy producers improve genetics, production rates, as well as feed efficiency. Intermountain Embryonics has a mobile lab that is used for on-farm processes such as oocyte pick up (OPU) and embryo implants. The steps of the process that lie in between OPU and implants are performed at the lab. The freezing of embryos is also performed at the lab. Intermountain Embryonics is the only bovine IVF lab in the area which allows them the opportunity to take advantage of a larger customer base. Intermountain Embryonics has been able to assist many beef and dairy producers, from central Idaho to North Western Utah, North Eastern Nevada, and a small part of South Eastern Oregon, get more out of their best genetics.

IVF is the quickest and most efficient way to make bovine embryos. Bovine IVF allows beef and dairy producers to advance the genetic potential of their herd in order to stay competitive in today's markets. Producers use IVF to improve the health, efficiency, and productivity of their herd by increasing the production from the top genetics in their herd.

IVF is the process of making embryos in a lab by fertilizing oocytes (female egg cells) with sperm. IVF is a time-sensitive process that includes many different steps. The first step is referred to as oocyte pick-up or OPU. The oocytes are collected from both ovaries of a donor cow into a collection tube with the use of an ultrasound-guided needle. The oocytes are then sorted in a petri dish, cleaned from any debris, and

graded based on the quality of the oocyte under a microscope. There are five different oocyte grades which are determined by the quality of the cytoplasm and cumulus of the oocyte. A Grade 1 oocyte is one that has a normal colored cytoplasm with no dark spots as well as three or more layers of cumulus surrounding the cytoplasm. A Grade 2 oocyte is one that has a normal colored cytoplasm along with at least two or more layers of cumulus surrounding the cytoplasm but does not have as much cumulus as a Grade 1. A Grade 3 oocyte has a normal colored cytoplasm with at least one layer of cumulus surrounding it. Another grade is "naked" which is an oocyte that does not have any cumulus surrounding the cytoplasm. The fifth grade is "irregular" which is an oocyte that has an off-colored or spotted cytoplasm. Figure 1 gives a microscopic view of what the different grades of oocytes look like. Once graded, the oocytes are then transported

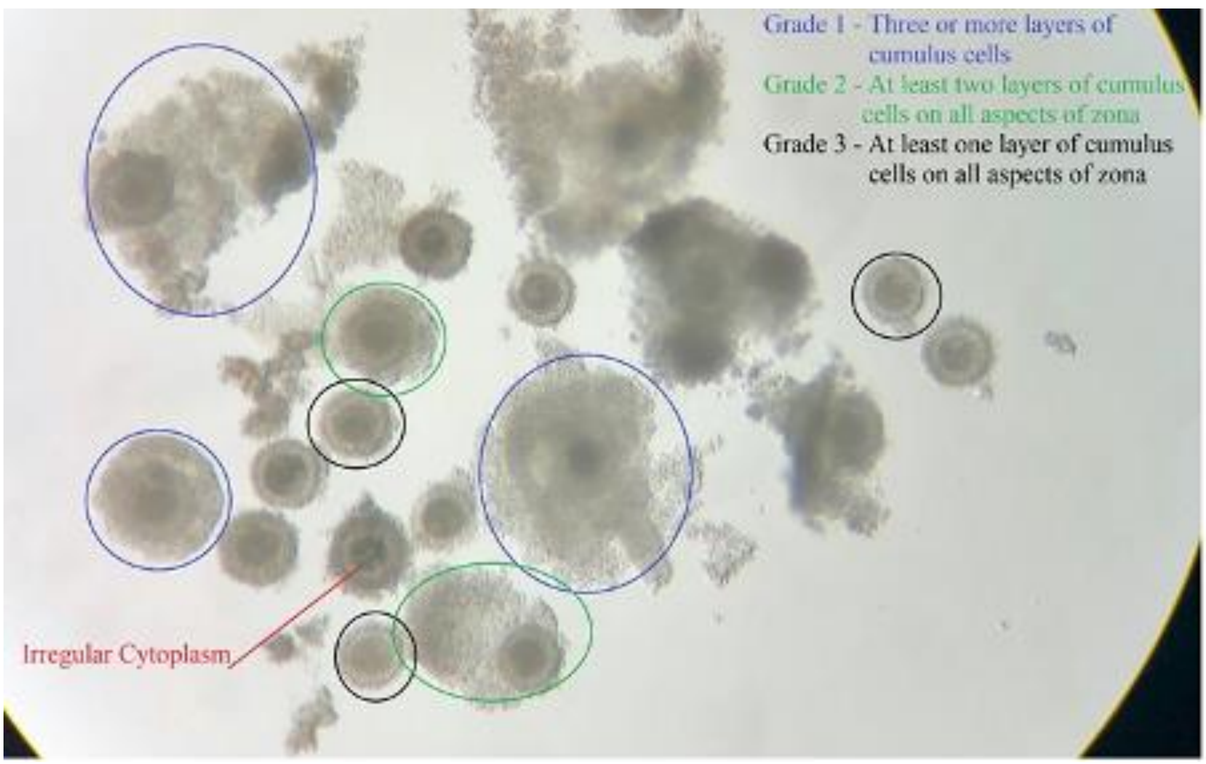


Figure 1: Microscopic view of oocytes

back to the lab in a tube containing maturation media. Media is a solution that feeds cells and supports growth. Different types of media support growth at different stages. .

The day following OPU, the oocytes are fertilized with any commercially available sexed or conventional semen of the client's choice. A single straw of sexed semen can be used to fertilize oocytes from up to six donors. One straw of conventional semen can be used to fertilize oocytes from up to 20 donors. Oocytes from one donor can be split and mated to different bulls. This gives producers the opportunity to maximize the use of semen and get several different matings from one OPU session. This step is part of what makes IVF extremely efficient. The oocytes are exposed to the semen for seven hours. The fertilized oocytes are then referred to as embryos.

Once fertilization is complete, the embryos are grown in an incubator for seven days. Throughout those seven days, the media they are growing in is changed. The media feeds the embryos proper nutrients they need for the stage they are at to help the embryos continue to grow. On the seventh day, embryos that have matured to the proper stage of development are either transferred into recipient animals (fresh transfer) or frozen to be transferred in the future. Fresh transferred embryos typically provide the best pregnancy rate because those embryos did not go through the stress of freezing. The selection of recipient animals is a very important part of the process. Recipient animals must have shown heat seven to eight days before implanting the embryos. The recipient animals must be watched closely for signs of heat to get the best pregnancy rate.

The production of oocytes from a single IVF session varies widely due to many different factors such as breed, age, nutrition, reproductive status, as well as genetics. On average, a Bos Taurus beef breed will produce anywhere from 14 to 18 oocytes and four to seven of those oocytes will become embryos. There are some factors affecting

oocyte production that can be controlled. Stress is one of those factors, therefore it is very important to keep the stress of donor animals very low. Nutrition can also have an impact on oocyte production. Ensuring donor animals are getting proper nutrition is essential to maximize production and oocyte quality.

Educating potential clients that IVF is a profitable investment has been a difficult task for Intermountain Embryonics. While IVF is a relatively expensive process, it has recently become more affordable. Intermountain Embryonics wants to be able to show potential clients the benefits and possible profit they could gain from incorporating IVF into their operation. This paper will go through the methodology of finding the possible profit and risk for incorporating IVF into an operation. It will look at three different scenarios based on the number of donors that would be collected. It will also look at IVF compared to artificial insemination and natural service by a bull.

II. Literature Review

Bovine IVF began after IVF in humans had been successful. IVF in cattle was initially used for the same reason it is used in humans, the treatment of infertility. There has been a success in using IVF on cows with fertility issues however, it soon became a way to improve genetic selection and decrease generation interval. There was a large amount of research done on bovine IVF because of the easy access to materials from slaughterhouses. Ovaries were obtained from a slaughterhouse in which oocytes were collected from those ovaries and researchers would continuously perform the IVF process using different culture media and conditions to find the most effective in producing embryos. With this research, they have been able to find the best media for embryos to grow and develop successfully. There are still different media options out

there today. Intermountain Embryonics has tried a couple of options and found the one that they see works best.

P.J. Hansen states that IVF can assist in improving genetic selection and crossbreeding (Hansen, P.J. 120). An operation can improve their herd's quantitative traits by implementing IVF. Specifically, in the dairy industry, IVF is advantageous when using sexed semen as most dairies do. When using sexed semen to artificially inseminate (AI), you only have one chance for pregnancy per straw of semen. While, on the other hand, using sexed semen for IVF gives you many chances to get multiple calves from a single straw of semen. There are two very important factors that determine the production of embryos, oocytes, and semen. The quality as well as quantity can impact the development of embryos. It has been assumed that higher quality oocytes are those that develop into embryos while the lower quality oocytes tend to lack in development. When it comes to quality, the more oocytes a donor produces, the greater chance there is of making embryos. Semen plays a vital role in producing embryos in IVF as different bulls have different semen motility and concentration. Hansen states that differentiation between bulls may be due to the reaction of sperm cells with culture media. Hansen adds that the recipient cow of an embryo can also be an important factor in successful pregnancies. Recipient cows must be healthy and capable of carrying an embryo.

There have been some companies that have performed IVF with the use of exogenous hormones while other companies have performed it without exogenous hormones. Exogenous hormones can stimulate ovarian follicle development, ovulation, and corpus luteum lysis, which all affect the estrus cycle. Companies that use the

exogenous hormones believe the stimulation of follicles makes it more likely for the cow to produce a good quality oocyte which will then be more likely to develop into a transferable embryo. On the other hand, companies that don't use exogenous hormones can collect donors weekly while using exogenous hormones limits collection to every two weeks. It is believed that the ability to collect donors weekly provides more opportunity to produce more total high-grade embryos in a shorter period of time. Intermountain Embryonics has found that they are more successful when exogenous hormones are not used. Although without stimulation, the follicles are not as pronounced on an ultrasound as they would be if the donor was given stimulation drugs. They have been able to use high-end ultrasound equipment to be successful in the collection of oocytes.

Many producers use sex-sorted semen to have more control over whether a male or female calf is produced. However, sex-sorted semen typically has a lower pregnancy rate. Producers have turned to IVF to get the most out of the use of their sex-sorted semen. The study by Xu et al. includes an experiment to study the developmental potential of embryos produced with sex-sorted semen. In this experiment, they compare the developmental rates of embryos produced with unsorted and sex-sorted semen from the same four bulls. To further examine the development of embryos produced with sex-sorted semen, they observed the development of nine different sets of embryos that were each produced with sex-sorted semen from a different bull. In this study, they found that there was a large amount of variation among the developmental rates of embryos produced with the unsorted semen from the four bulls. While three of the four bulls had similar embryo developmental rates between

unsorted and sorted semen, one of the bulls showed a higher developmental rate on embryos produced with the unsorted semen compared to the embryos produced with the sex-sorted semen (Xu et al. 2514). Their examination of the development of embryos produced with sex-sorted semen showed that three out of the nine bulls had higher embryo development rates compared to the other six bulls. They also found that the sex-sorted semen from those three bulls was highly fertile and the embryo development rate was comparable to the development rate of embryos produced with unsorted semen.

A study done in Brazil compares pregnancy and birth rates of calves from a large-scale IVF program using either reverse sex-sorted semen or sex-sorted semen in different beef and dairy breeds. Oocyte pick up was performed on Holstein, Gir, and Nelore donors. Reverse sex-sorted semen is semen that has been frozen and is sorted for sex after it is thawed right before use. Sex-sorted semen is semen that is sorted for sex before freezing. Cooled semen is semen that is used directly after being collected. Reverse sex-sorted and sex-sorted semen from Holstein, Gir, Nelore, Brahman, and Braford bulls was used to fertilize the oocytes. More specifically, oocytes from Holstein and Gir donors were fertilized with sex-sorted semen from Holstein bulls as well as reverse sex-sorted semen and cooled semen from Holstein and Gir bulls. Oocytes from Nelore cows were fertilized using reverse sex-sorted and cooled semen from Nelore, Brahman, and Braford bulls. They used female sexed semen on oocytes from Holstein and Gir donors while male sexed semen was used to fertilize oocytes from Nelore donors. The results of this study show that a total of 9438 viable oocytes were collected from a total of 645 oocyte pick-ups. A total of 2729 embryos were produced from

oocytes that were fertilized with reverse sex-sorted semen, which means that 29% of the oocytes developed into embryos. Out of the 2729 embryos, 2404 were transferred into recipient cows. They observed a 41% average pregnancy rate from those transferred embryos, meaning 986 embryos developed into pregnancies. From those pregnancies, 966 calves were born and 910 were sexed as the semen had been sorted for an average 94% sex-sorted efficiency. While sex-sorted semen produced more embryos from viable oocytes, it did not always show a higher pregnancy rate.

A study published in 2002 by Patrick Lonergan on the factors that influence oocyte and embryo quality in cattle suggests the differences in the embryo development in vivo and in vitro. An experiment within this study was conducted and the results showed that a higher proportion of in vivo matured oocytes developed into embryos after being fertilized in vivo compared to oocytes matured in vivo and fertilized in vitro. However, they mention that it is important to realize that the oocytes that were fertilized in vivo were ovulated oocytes whereas the oocytes that were fertilized in vitro were collected prior to ovulation (Lonergan 431). They also conducted two experiments to observe the impact that culture in vitro versus in vivo has on the yield and quality of embryos. In the first of the two experiments, zygotes (fertilized oocytes) were either cultured in vitro or in vivo in a ewe oviduct. The in vitro cultured zygotes resulted in an 82.5% cleavage (division of cells) rate while they were unable to record a cleavage rate for the zygotes cultured in vivo due to degeneration of non-developing embryos in the oviduct. However, there was a large difference in the quality of embryos produced in vivo and in vitro. The end results showed significantly more embryos produced and survived in vivo culture than in vitro culture. In the second experiment, they used

zygotes that were matured and fertilized in vivo. The zygotes were either surgically recovered on the first day and cultured in vitro or they remained in vivo for culture and were surgically recovered on the seventh day. They also had a control group that consisted of zygotes that were matured, fertilized, and cultured in vitro. They observed that whether the zygotes were cultured in vivo or in vitro did not affect cleavage rates or embryo yield. They also found that both groups that were matured and fertilized in vivo had higher cleavage rates as well as embryo yield when compared to the in vitro control group. While the findings from these two experiments show more success when embryos are cultured in vivo rather than in vitro, many advances have been made to the process of in vitro as well as the media that is used in the process since 2002.

In 2007, Lonergan published another study on the improvements of embryo technologies over the years. Lonergan, again, points out that during the process of in vitro, about 80% of the oocytes collected are fertilized and will cleave at least once and from that 80%, only 30-40% develop into transferable embryos. He mentions that this could be due to the quality of the oocytes collected since studies have shown that the culture environment has little influence on the ability of an oocyte to develop into an embryo (Lonergan 320). Despite the low percentage of embryos developed from the IVF process, this study still shows IVF as being the most efficient way of producing large numbers of embryos. Lonergan states that it is possible to produce 80-100 calves per donor per year using IVF compared to one calf per cow per year with the use of artificial insemination (AI) and about 20-25 calves per donor per year with the use of multiple ovulation embryo transfer.

Embryo transfer has been used in the dairy industry for many years. Dairy producers began using conventional flushing as it was an efficient way to improve selection intensity. In the dairy industry, producers want their top cows, with superior genetics, to produce several calves in a single year to potentially increase the number of replacement heifers. Studies have shown that genetic progress for milk production has the potential to increase by 10% with the use of embryo transfer. Now producers have the option of IVF which is even more advantageous than conventional flushing. IVF can increase the reproductive life of cows that do not respond well to superovulation treatments or cows that only produce unfertilized oocytes. Studies have shown that within just 50 days, the herd pregnancy rate can increase by four times using IVF compared to conventional flushing. Researchers have also seen annual genetic progress improve 10 to 30% from the conventional approach to IVF. This improvement is mostly due to the flexibility in sires that IVF has to offer. With the use of IVF, producers can choose to mate one donor to several sires in a single collection session, while conventional flushing limits the producer to using one sire per collection. IVF can also be performed on a female at different stages of reproduction, such as the prepubertal period and even up to three months of pregnancy. The advantage of collecting prepubertal heifers is important to dairy producers as they want to decrease generation interval. A study was done by Bousquet et al. that explains the difference in embryo and calf production of IVF on mature donors, IVF on prepubertal donors, and conventional flushing. They found that IVF on both mature cows and prepubertal heifers can be done four times more frequently per year than conventional flushing. The number of transferable embryos per year in the use of IVF on mature cows was two

times the number of transferable embryos per year in the use of IVF on prepubertal heifers, and four times that of conventional flushing. The pregnancy rate of those embryos was 53% for both IVF on mature cows and IVF on prepubertal heifers and 60% for conventional flushing. While the pregnancy rate for conventional flushing is slightly higher, the number of calves born from IVF on mature cows, IVF on prepubertal heifers, and conventional flushing was 50, 25, and 14 respectively.

Many studies that compare IVF to AI show that IVF costs more than AI. However, none show the profit gained from using IVF compared to AI. While IVF is more expensive, it typically yields a higher profit. A study done by Kaniyamattam, Block, Hansen, and De Vries from the Department of Animal Sciences at the University of Florida compares in-vitro produced embryo transfer to artificial insemination in terms of genetic, technical, and financial herd performance on a dairy operation. They financially simulated a 1,000 cow herd over 15 years. They used a default cost of $165 to produce and transfer 1 embryo. They found in year 15, the cost of fresh embryos broke even with artificial insemination. They also assumed that frozen embryos were sold for $195 per embryo. In their model, surplus heifer calves were priced at $500. To evaluate the premium price for surplus heifers born from IVF, they calculated it as a net present value. They did this by assuming that 85% of the heifer calves kept would become cows in the herd and that the expression of genetic differences occurred at about 3.5 years of age. They used a discount rate of 5%. They used different prices for fresh embryos to show different scenarios. They found that when the cost of a fresh embryo was $200, there was an average loss of $222/cow per year for the IVF investment. When the cost of a fresh embryo was reduced to $150, the average loss was $126/cow per year. They

found that in order to show a net gain from the investment, the fresh embryo cost would have to be $50. This showed a net gain of $65/cow per year which was greater than that of using AI. The profit of IVF and AI broke even when the fresh embryo cost was $84. The model shows that, if the fresh embryo costs $165, it will take at least 13 years for the profit per cow per year from the IVF investment to break even with that of AI.

III. Data

I was able to obtain my data from a client of Intermountain Embryonics. This client runs a club calf operation therefore, they are looking for the most efficient way to implement top bloodlines into their herd. Since Intermountain Embryonics has only been in business since 2017, their clients only have one calf crop from IVF if any at all. This client in particular began using Intermountain Embryonics to implement IVF into their operation in 2018, therefore they only have complete data for one year. All of the data is based on 48 embryos, produced via IVF from their donor cows, that were implanted in 2018.

The data set includes how many recipient cows that were implanted with an embryo accepted the embryo and were confirmed pregnant with the embryo, how many of those recipient cows were bred by the bull, how many recipient cows were open and did not have a calf, and how many calves died and whether they were an embryo calf or a calf sired by the clean-up bull. If an embryo does not result in a pregnancy and the recipient cow is bred naturally by the clean-up bull, that calf is sold as a meat calf because it will likely not be a quality club calf. The data also includes how much each calf was sold for and whether it was an embryo calf or a meat calf. Any calves that died are also included in the data. They also provided me with expenses such as travel fees

for us to travel to their ranch, how much they spend on semen for the IVF process, and how much it costs to synchronize each recipient cow so she comes into heat and will be ready for an embryo. Expenses related to the process of IVF, such as the cost to collect a donor, the cost to produce an embryo, and the cost to implant the embryo, were obtained from Intermountain Embryonics.

The data also assumes that 48 different cows were bred with the process of AI. It shows how many of those 48 cows took to AI, how many were bred by the bull, how many were open, and how many calves died. The sale price for each calf, whether an AI calf or a meat calf, was provided by the club calf operation. They also provided me with the cost of semen to breed each cow and the cost to synchronize each cow.

Another assumption in the data is that another 48 cows were bred only by the bull. The data shows how many of these 48 cows were pregnant, open, and how many calves died. Since all of these calves would be sold as meat calves, the sale price for a meat calf was assigned to each cow that had a calf.

With the data that I was provided and found the minimum, maximum, and average of the calf sale price for each IVF scenario, the AI scenario as well as the natural service by the bull. The table below shows that the sale price of an embryo calf is greater than that of an AI calf and even more so of a calf sired naturally by the clean-up bull. I also used the data to calculate the birth rates of either the embryo transfer calves, AI calves, and the meat calves of which were bred natural service by the clean-up bull for each scenario.

	Embryo Calf Sales	AI Calf Sales	Natural Service Calf Sales
Minimum	$0.00	$0.00	$0.00
Average	$1,783.00	$1,415.00	$788.00
Maximum	$7,250.00	$4,500.00	$840.00

Table 1: Minimum, Average, and Maximum of each scenario

IV. Methodology

It can often be difficult to decide if a new investment is right for a particular operation. This is the problem Intermountain Embryonics is having with too many of their potential clients. With a year's worth of data, I can compare birth rates of different breeding options, find the minimum, maximum, and average sale prices of calves for each breeding option, as well as compare profits from each breeding option, all while accounting for risk.

First, I used the data from each scenario to calculate the conception rate of each scenario. Conception rate is a very important number to many producers, whether dairy or beef. With the data from the IVF scenario, I calculated the birth rate of the embryo calves which is 41.67% and the birth rate of the meat calves which is 47.92%. Using the data from the AI scenario, I calculated the birth rate of calves that were sired by AI which is 62.50% and the birth rate of the meat calves in that scenario which is 29.17%. For the natural bull service scenario, I found the birth rate of calves sired by the clean-up bull which is 91.67%. In each scenario, I incorporated risk into the birth rates using the risk triangle function. The risk triangle function incorporates risk by using the

minimum, mean, and maximum as parameters. Incorporating risk adjusted the birth rates to 55.56% for embryo calves and 57.64% for meat calves in the IVF scenario. The risk did not change the birth rate of AI calves however, it did change the birth rate of meat calves in the AI scenario to 48.06%. In the natural bull service scenario, risk changed the birth rate to 93.22%. I then used the risk associated birth rates to find the number of calves from each breeding option. I calculated 20 embryo calves and 21 meat calves for the IVF scenario, 25 AI calves and 18 meat calves for the AI scenario, and 45 calves for the natural bull service scenario. Notice that the total number of calves in every scenario is less than the sample size of 48, this is due to the risk that is incorporated. The risk accounts for any cows that are open or calves that die.

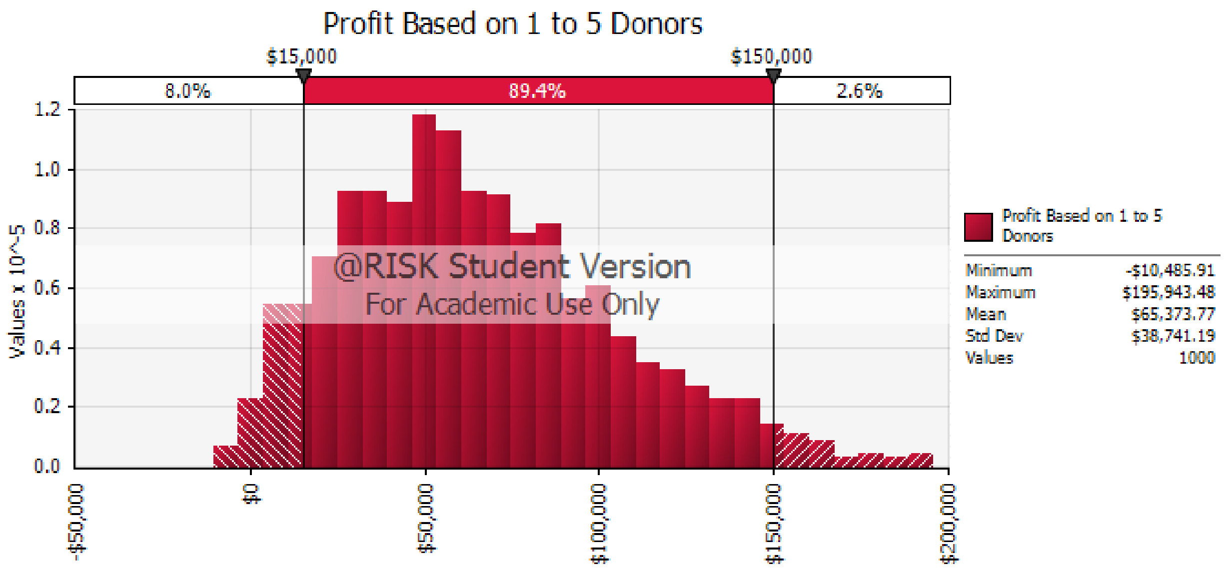
I used the calf sale price minimum, maximum, and averages shown in Table 1 for each scenario to incorporate risk into the sale prices using the risk triangle function. With risk, the embryo calf sale price and meat calf sale price are $3,420.33 and $527.67, respectively, for the IVF scenario. The AI scenario shows the sale price of AI calves to be $2,085 and the meat calf sale price to be $525 with risk. The sale price for calves sired naturally by the bull is $536.67 with risk accounted for. For the IVF scenario, I multiplied the number of embryo calves by the embryo calf sale price and the number of meat claves by the meat calf sale price for that scenario to find the income generated by each group of calves. I added these two incomes together to calculate the total income from calves for that scenario. I repeated these calculations for each scenario to find the total income from calves depending on that specific scenario. The total income from calves for the IVF, AI, and natural bull service scenarios are $80,801.56, $61,434.89, and $24,014.33 respectively.

When it comes to expenses, I split the IVF scenario into three smaller scenarios which all have the same income but different expenses based on the number of donors being collected. The three IVF scenarios are based on collecting one to five donors, six to ten donors, and eleven or more donors. Each IVF scenario has expenses associated with the IVF process per donor and an expense for producing embryos per embryo. The cost for the IVF process for one to five donors is $150 per donor, $100 per donor for six to ten donors, and $80 per donor for eleven or more donors. In calculating expenses, I assumed only fresh embryos will be used and there will be 11 or more embryos produced since the sample size is based on 48 embryos. The cost to produce eleven or more fresh embryos is $80 per donor. There is also an expense associated with implanting the embryos into each recipient, which stays constant at $35 across each of the three IVF scenarios. There are also fixed IVF costs which include travel fees for Intermountain Embryonics to travel to the ranch which is $700 and the cost of semen which is $650. These fixed costs will remain constant across all three IVF scenarios. Expenses for the AI scenario include $30 per cow for semen to inseminate and $25 per cow for synchronization. There are no expenses in the data for the natural bull service scenario. The total expenses for one to five donors IVF scenario calculates to $15,270. Total expenses for six to ten donors IVF scenario is $12,870. Total expenses for eleven or more donors IVF scenario is $11,910. Total expenses for the AI scenario is $2,640.

Finally, I calculated the profit of each scenario by subtracting total expenses from total income from calves. I used a program called @Risk to run a simulation on each scenario's profit. @Risk simulates the profit 1,000 times to create a distribution. By

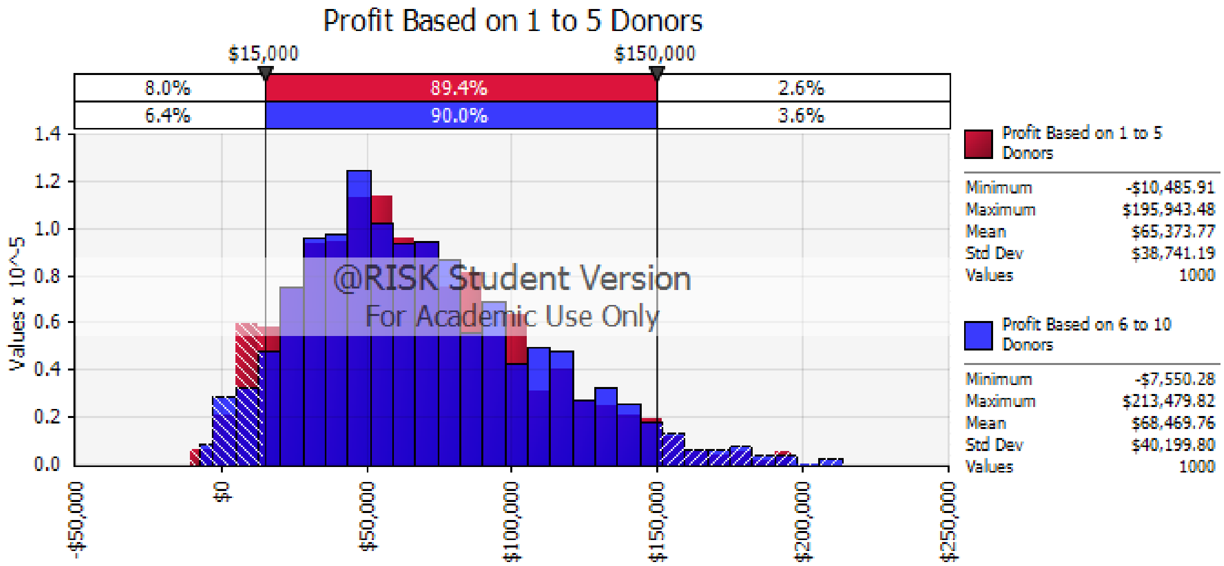
simulating the profits I will be able to compare the upside and downside risks, mean, and standard deviation of the scenarios.

V. Results



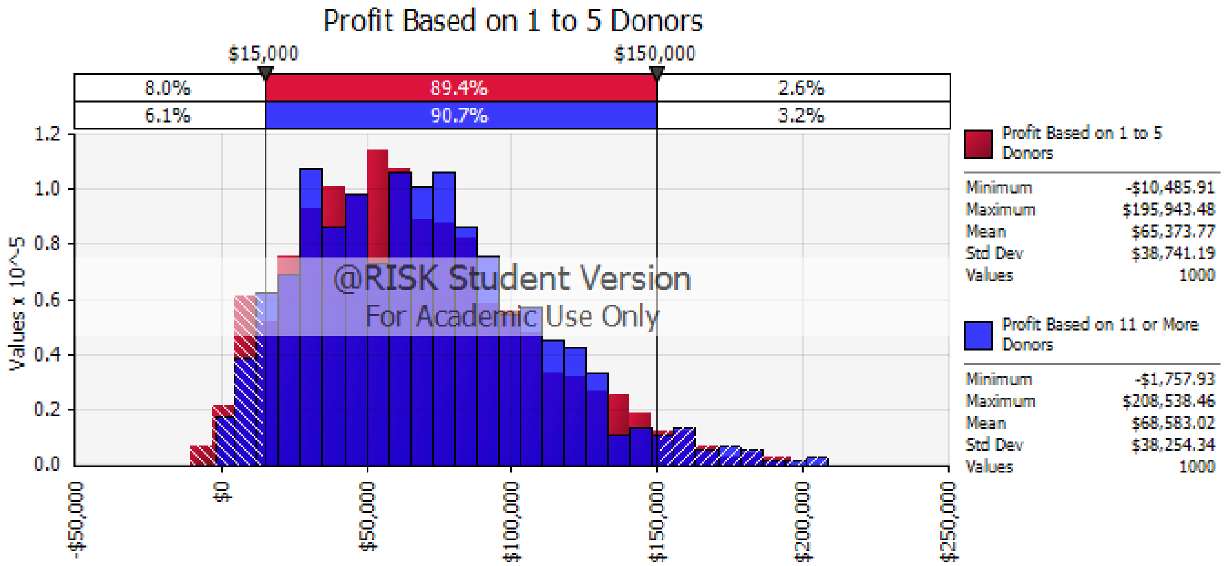
Graph 1: Profit Based on 1 to 5 Donors

The first IVF scenario based on one to five donors has a profit of $65,531.56. The distribution from simulating this profit shows a mean of $65,373.77 and a standard deviation of $38,741.19. This tells us that the profit from this scenario, on average, can be $38,741.19 higher or lower than the mean of $65,373.77. The distribution graph shows us that there is an 8% chance of making a profit lower than $15,000 and a 2.6% chance of making a profit higher than $150,000. This distribution graph does show a chance of not making a profit or even losing money in this scenario. However, there is a 92% chance of making a profit of more than $15,000.



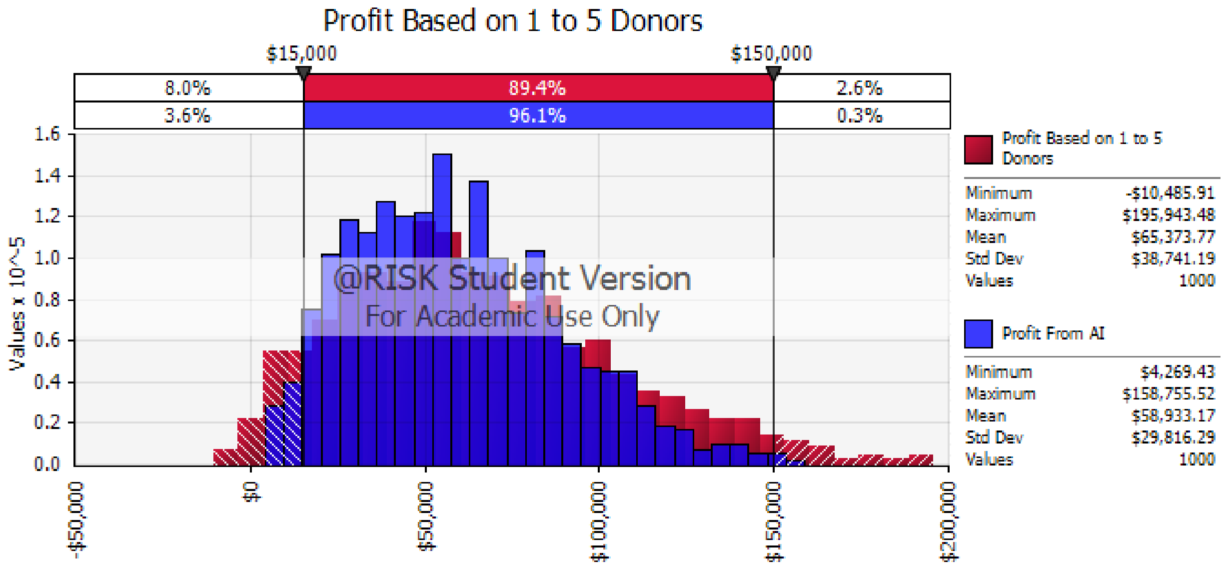
Graph 2: Profit Based on 6 to 10 Donors compared to Profit Based on 1 to 5 Donors

The second IVF scenario based on six to ten donors has a profit of $67,931.56. The distribution after simulation for this scenario shows a mean of $68,469.76 and a standard deviation of $40,199.80. This means that the profit for the scenario based on 6 to ten donors, on average, can be $40,199.80 higher or lower than the mean of $68,469.76. The distribution graph of six to ten donors when compared to the distribution graph of one to five donors shows less lower tail risk and more upper tail risk. With this scenario, there is a 6.4% chance of making a profit under $15,000 and a 3.6% chance of making a profit above $150,000. In this scenario, there is a small chance of not making a profit or losing money on the investment while there is also a 93.6% chance of making a profit of more than $15,000. This scenario has the most upper tail risk, meaning there is more of a chance of making a profit of more than $150,000 with this scenario.



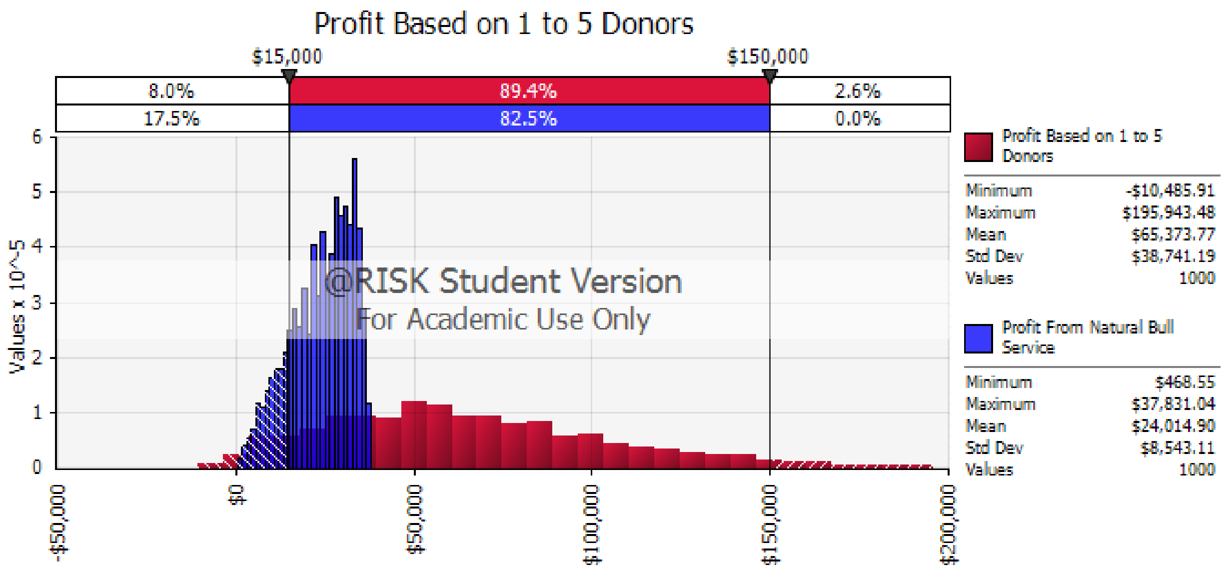
Graph 3: Profit Based on 11 or More Donors compared to Profit Based on 1 to 5 Donors

The third IVF scenario based on eleven or more donors has a profit of $68,891.56. The distribution after simulation for this scenario shows a mean of $68,583.02 and a standard deviation of $38,254.34. This means that this profit, on average, can be $38,254.34 higher or lower than the mean of $68,583.02. The distribution graph of eleven or more donors when compared to the distribution graph of one to five donors shows a 6.1% chance of making a profit under $15,000 and a 3.2% chance of making a profit above $150,000. This scenario shows an even smaller chance of breaking even or losing money to the investment and a larger chance of making a profit more than $15,000. The upper tail risk for this scenario is slightly smaller than the scenario based on six to ten donors.



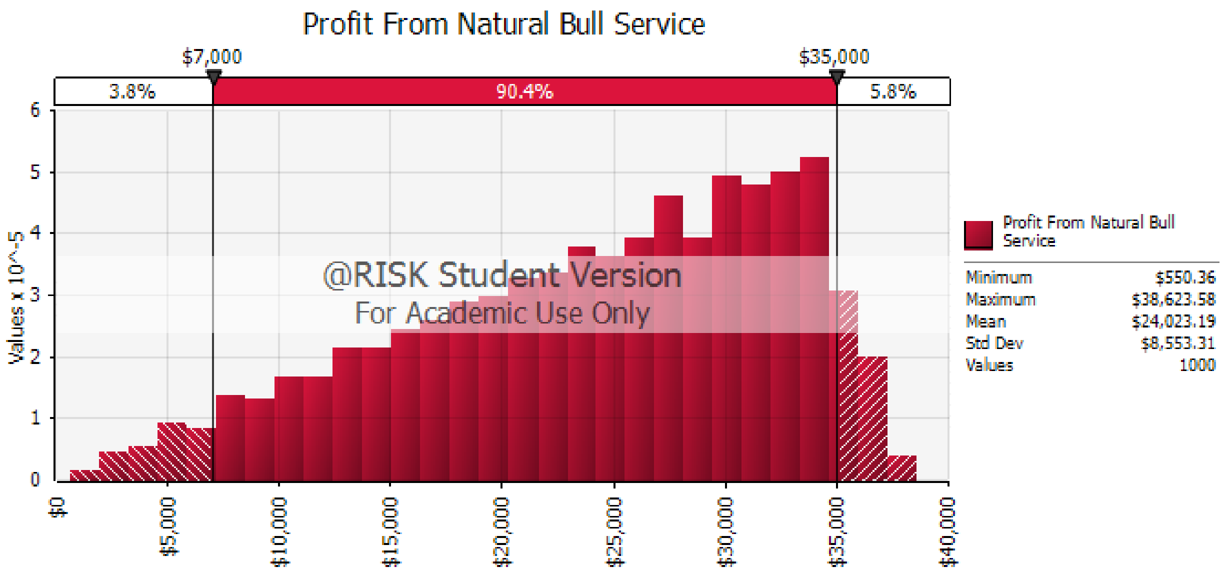
Graph 4: Profit From AI compared to Profit Based on 1 to 5 Donors

The profit for the AI scenario is $58,794.89. The distribution after simulation for the AI scenario shows a mean of $58,933.17 and a standard deviation of $29,816.29. The mean and standard deviation tells us that the profit from AI, on average, can be $29,816.29 higher or lower than the mean of $58,933.17. The distribution graph of AI when compared to the distribution graph of one to five donors shows a significantly lower chance of making a profit under $15,000, but also shows a significantly lower chance of making a profit above $150,000. Although AI does not make as much of a profit as IVF, this distribution shows no chance for a profit below $0.



Graph 5: Profit From Natural Service compared to Profit Based on 1 to 5 Donors

The natural bull service scenario has a profit of $24,014.33. The distribution after simulation for this scenario shows a mean of $24,014.90 and a standard deviation of $8,543.11. This means that the profit from using natural service by the bull, on average, can be $8,543.11 higher or lower than the mean of $24,014.90. The distribution graph of natural bull service when compared to the distribution graph of one to five donors shows a 17.5% chance of making a profit under $15,000 and a 0% chance of making a profit above $150,000. This is not necessarily surprising based on the number range of each scenario. The distribution graph below for this scenario alone tells us more than a comparison does. It shows a 3.8% chance of making a profit below $7,000 and a 5.8 % chance of making a profit of more than $35,000. While this scenario has the lowest profit range, it shows a 0% chance of making a profit lower than $0.



Graph 6: Profit From Natural Service By the Bull

VI. Summary

Intermountain Embryonics would like to be able to show potential clients the possible profit they could gain from incorporating IVF into their operation. I was able to gather data from an existing client in which I compared profits from IVF, AI, and natural service by the bull. The IVF scenarios came out on top as far as profit followed by AI and then natural service. After simulating each profit, the distributions showed IVF having the most risk followed by AI and natural service having the lowest amount of risk. When comparing the distribution graphs, one could say that AI would be the most conservative option while also still making a decent profit. However, there are many advantages to IVF, which have been stated in this study, which make IVF a more intriguing option. While IVF has the most lower tail risk in all three scenarios, it also has the most upper tail risk. The risk that comes from IVF is associated with lower conception rates and higher expenses. The IVF profit, even considering the conception

rate of IVF, is significant enough for potential clients to see the potential in incorporating IVF into their operation. IVF may not be the right answer for every operation but it is important for producers to see what it has to offer to any operation.

Works Cited

Bousquet, D, et al. “Biotechnologies of Reproduction Applied to Dairy Cattle Production:

Embryo Transfer and IVF.” Canadian Journal of Animal Science, 30 July 2003, www.nrcresearchpress.com/doi/10.4141/A03-025#.Xyq-qC05S00.

Hansen, P.J. “Realizing the Promise of IVF in Cattle-an Overview.” Theriogenology,

Elsevier, 25 Oct. 2005,

www.sciencedirect.com/science/article/abs/pii/S0093691X05004097.

Holmbeck, Rebecca. “IVF A Powerful Technology.” *Line Rider*, no. Cow/Calf, Feb.

2020, pp. 60–65.

Hough, Bob. “In Vitro Fertilization: Speeding Genetic Gains.” Western Livestock

Journal,

20 Mar. 2019, www.wlj.net/top_headlines/in-vitro-fertilization-speeding-genetic-gains/article_d98f6446-e472-11e8-a8df-33f9a79fe9af.html.

“Intermountain Embryonics: Bovine IVF: Idaho.” Iembryonics,

www.intermountainembryonics.com/.

Kaniyamattam, K., et al. “Comparison between an Exclusive in Vitro–Produced Embryo

Transfer System and Artificial Insemination for Genetic, Technical, and Financial Herd Performance." Journal of Dairy Science, Elsevier, 27 Apr. 2017, www.sciencedirect.com/science/article/pii/S0022030217303478.

Lonergan, Patrick, et al. "Factors Influencing Oocyte and Embryo Quality in Cattle." Reproduction Nutrition Development, EDP Sciences, 1 Sept. 2001, rnd.edpsciences.org/articles/rnd/abs/2001/05/06/06.html.

Lonergan, Patrick. (2007). State-the-art embryo technologies in cattle. Society of Reproduction and Fertility supplement. 64. 315-25. 10.5661/RDR-VI-315.

Morotti, F., et al. "Pregnancy Rate and Birth Rate of Calves from a Large-Scale IVF Program Using Reverse-Sorted Semen in Bos Indicus, Bos Indicus-Taurus, and Bos Taurus Cattle." Theriogenology, Elsevier, 12 Dec. 2013, www.sciencedirect.com/science/article/pii/S0093691X13005177?via%3Dihub

Sirard, Marc-André. "40 Years of Bovine IVF in the New Genomic Selection Context." Reproduction, vol. 156, no. 1, 2018, doi:10.1530/rep-18-0008. https://rep.bioscientifica.com/view/journals/rep/156/1/REP-18-0008.xml

Xu, J., et al. "Developmental Potential of Vitrified Holstein Cattle Embryos Fertilized In Vitro with Sex-Sorted Sperm." Journal of Dairy Science, Elsevier, 3 Mar. 2010, www.sciencedirect.com/science/article/pii/S0022030206723268.