Determination of scimitar-horned oryx (*Oryx dammah*) causes of infertility

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INTRODUCTION

The scimitar-horned oryx (*Oryx dammah*) is a species of antelope that used to be common in the arid grasslands of Northern Africa prior to their extinction in the wild (Gilbert and Woodfine, 2003). The scimitar are primarily grazers, but may also shift to other food sources, such as browse, when required to do so. Due to the nature of their native homeland, they are known to migrate annually over large distances in search of food and water (Gilbert and Woodfine, 2003). Scimitar-horned oryx herds are typically relatively small, between 10 and 30 animals, but during these large migrations several herds have been known to join together and travel as one large group of hundreds of animals (Gilbert and Woodfine, 2003). Traveling immense distances with such a large number of individuals has made them susceptible to human predators, and from the Neolithic to the late 20th century they have been a favorite animal of the hunt and an important aspect of the culture and livelihood of several Sahelo-Saharan tribes (Gilbert and Woodfine, 2003).

Due to hunting, as well as habitat loss, drought, and competition with domestic livestock, the range of the scimitar-horned oryx has been declining since the Roman times and since the late 1980s the species has been extinct in the wild and therefore exists only in captivity (Gilbert and Woodfine, 2003). Because of these unfortunate circumstances, the future of the species depends entirely on the breeding success of these animals in captivity. While some of these animals do exist in zoos, the majority of them are found on ranches and in captive breeding programs, many of which are located in Texas. This means that breeding programs, such as those similar to Fossil Rim Wildlife Center, are essential to the success of the species and that isolating specific causes of infertility in these animals is vital so that management can better understand how their decisions affect female fertility and also so that alterations can be made to keep these animals as fertile as possible.

There is some evidence for elephants, white rhinoceros, wildebeest, and some felid species that when females are kept in non-breeding situations for extended periods of time, reproductive changes may occur that can negatively impact their fertility (Penfold *et* al. 2013). Additionally, it is a concern that if females are not bred at a young age that the same effects may occur. These issues are of special concern to those in the zoo world where breeding is often put on hold to accommodate for the limited amount of space and longer life span of captive individuals (Penfold *et* al. 2013). In addition, breeding facilities have begun to focus their attention on the spreading and prolonging of genetic diversity and while this is important, it is also being realized that finding the best breeding combinations to accomplish this task may be occurring at the expense of fertility. Determining whether the same effect on female infertility is seen in ungulate species, and if there is a specific amount of time where females can be kept from breeding and still remain fertile, will greatly assist the captive managed world in managing their breeding programs and figuring out a lifelong reproductive plan for any given species.

This issue holds further importance for scimitar-horned oryx because of the high hopes for the reintroduction of these animals to their original homeland in the Sahara desert region of Northern Africa (Gilbert 2003). This reintroduction process will be highly dependent on the breeding success of scimitar-horned oryx in captivity and the ability of the captive breeding programs to produce a large enough population that will be able to sustain themselves when released in the wild. Therefore, the scimitar-horned oryx breeding program at Fossil Rim and other captive breeding centers is a crucial asset to the survival of this species, and identifying ways to improve female fertility and sustain production may be the key to reintroducing these animals back to Northern Africa where they belong.

In addition to conducting a detailed infertility study related to bull absence from the herd, further goals of this study are to answer several supplementary questions regarding scimitar-horned oryx reproduction. These additional questions deal with determining the reproductive lifespan of the females and pinpointing the youngest and oldest ages when they typically are successful at reproducing, the effect of age on female fertility and reproductive success, and also what percentage of the herd is reproducing from year to year. These questions will be answered based on the data collected at Fossil Rim Wildlife Center only and will therefore be biased to their conditions and care; however, there are future hopes that this data will be combined with information from other facilities and it will assist in the creation of a universal management plan for all captive scimitar-horned oryx populations.

METHODS

Data Collection and Compilation

Fossil Rim Wildlife Center, located in Glen Rose, Texas, has been caring for and breeding scimitar-horned oryx on property since the early 1980s. The current herd of 17 females, 1 bull, and 11 calves resides in the Front Pasture with roan antelope, wildebeest, blackbuck, ostrich, blesbok, and white-tailed deer herds of various sizes. The scimitar-horned oryx herd has varied greatly in size over the last thirty years and has lived in congruence with various other species, in addition to those it shares a pasture with today.

Due to the nature of the research questions, no new data collection was necessary for this study. The data collection process consisted of sifting through old records to determine the breeding history of scimitar-horned oryx at Fossil Rim. This information came from herd cards, husbandry reports, veterinary reports, and the individual records kept for each animal.

All of the available information for the scimitar-horned oryx that were on property since 1983 was compiled and put into a herd database (Appendix 1). This database includes tag number, ISIS (now ZIMS) number (if applicable), birth date, arrival date at Fossil Rim, sire and dam information, departure date, date of death, and other relevant information. The information collected in the herd database was used to determine which individuals had adequate records kept that would be useful for this study. During the early stages of the breeding program there was not a great deal of data collection, but as the facility grew in size and numbers, more detailed records were kept. Fossil Rim has on record that over 230 scimitar-horned oryx have passed through the facility over the last 30 years, with 103 of those individuals having an ISIS number (International Species Information System). These animals with ISIS numbers had more complete records kept, including their location at Fossil Rim, breeding history, arrival, and death dates; for this reason, they were the main focus of this study.

For the 103 animals with ISIS numbers, a herd history database was created to show the dates that each animal was born, arrived at Fossil Rim, reached sexual maturity, moved locations, gave birth, died, and other relevant information (Appendix 2). This database shows which animals were on property at any date between 1983 and today, which females were part of the herd, and whether or not a breeding bull was present.

Once this database was completed, a separate spreadsheet was constructed to show the reproductive status of each female (Appendix 3). This spreadsheet includes a number of cases, where each case represents a

single breeding year for one female. The reproductive status of each female over the previous three years was also included for each case so that conclusions could be drawn about infertility caused by inaccessibility to a breeding bull in prior years.

A fourth database was created that included only the cases where a breeding bull was present for that year (Appendix 4). Included in this database is a column that represents the number of prior years that the female was isolated from a male and whether or not she successfully gave birth that year. This database was created so that it could be easily manipulated in a way that would make it easy to answer the inquiry question and additional questions about scimitar-horned oryx reproduction that are described in detail in Appendix 5.

Data Analysis

The effect of nonbreeding herds on female fertility

The reproductive status and breeding success spreadsheets were used to draw conclusions about how time gaps in breeding affect female fertility. Patterns in the birthing rates were identified with special attention paid to the birthing ratios after females had been in a nonbreeding herd for one or more years prior. These cases were split into three different categories based on the number of years prior that they had been separated from a male; the categories were assigned as 1-2 years, 3-4 years, and greater than 4 years. The breeding success of each case was then assessed and scored as either a success, a calf was born, or a failure, there was no calf born. A column graph was constructed to show the comparison of the reproductive success and failure for each of the three categories and then G^2 and Z-score statistical tests were performed to determine whether there was a statistical difference in breeding success based on the length of time that the bull was absent from the herd and if there was a significantly higher failure rate if the length of time in the bachelorette herd was longer.

Female reproductive lifespan

The reproductive lifespan was determined by identifying the female cases whose records included a known date and age of their first and last calving. For both instances the appropriate calving date was subtracted from the female's birthdate to get the exact age in days when the female gave birth. The age at the time of conception was found by subtracting 246 days, Dittrich's (1972) approximated gestation period, from this age and then dividing by 365 to get the female's age in years. For the first calving, the data was further broken down from all females that gave birth to their first calf to a subcategory that included only the females that gave birth to their first calf and had been exposed to a bull since immaturity.

For the females used in the analysis for age of last conception, the age that they were permanently removed from the herd bull was also noted for comparison and examination. Descriptive statistics were found (including mean, standard deviation, range, and quartile values) and box-and-whisker plots were created for both the first conception and last conception. The reproductive lifespan of individual scimitar-horned oryx females was then computed by subtracting their age at first conception from their age at last conception. The mean, standard deviation, range, and quartile values were found for this set of data and a box-and-whisker plot was constructed.

The effect of age on female reproductive success

The effect of age on female reproductive success was determined by taking all of the cases where mature females were exposed to a bull (after females reached their first birthday they were considered to be sexually mature) and scoring them either as a reproductive success, where they gave birth to a calf, or a failure, where they did not give birth to a calf. The ages in years of the females were combined to form six categories, 1-3, 4-6, 7-9, 10-12, 13-15, and 16-20 and the total number of successes and failures for females in those age categories was displayed in a column graph. Statistical tests, including G^2 and Z-score, were also performed.

Percentage of breeding success

Lastly, the percentage of breeding success for the entire herd was determined for the years when the total size of the herd was known, from 2011-2014. The number of females that successfully gave birth was divided by the total number of mature females in the herd. This data was displayed as a series to show how the percent of breeding success changed from year to year.

RESULTS

The effect of nonbreeding herds on female fertility

The reproductive success of 30 females that had been separated from a bull for at least one year prior was used to determine the effect of bull absence on breeding success. Twelve of 13 females that had been separated from a bull for 1-2 years prior were able to breed successfully, while only 2 of 11 females that had been separated from a bull for 3-4 years successfully reproduced. For the cases where the bull was separated for more than 4 years, 2 of 6 were able to successfully reproduce (Figure 1). These results show that the duration that the bull was absent from the herd had a significant effect on the likelihood of breeding success (G^2= 16.33, df=2, p<0.001). Additionally, if the bull was absent for only 1-2 years prior, reproductive success was more likely than would be expected by chance (z= +2.82). Conversely, when the bull was absent for 3-4 years reproductive success was less likely to occur (z=-2.34). There were insufficient samples to make a determination if the bull was absent for greater than 4 years.

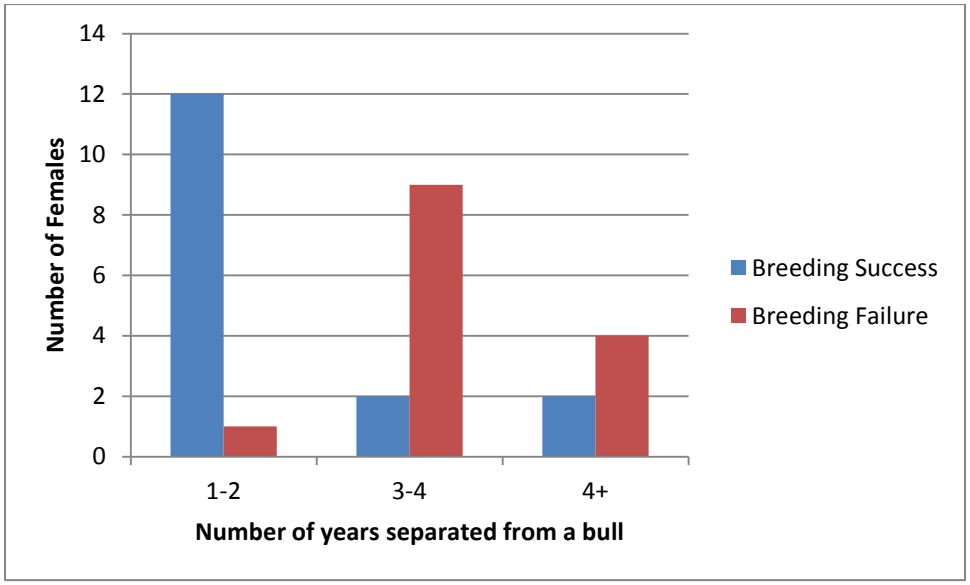

Figure 1. The duration of time that a bull was absent from the breeding herd had a significant effect on breeding success (G^2= 16.33, df=2, p<0.001). If the bull was absent for 1-2 years, success was more likely (z = +2.82) than if the bull was absent for 3-4 years (z= -2.34). There were insufficient samples to make a determination if the bull was absent for longer than 4 years.

Female reproductive lifespan

The typical age of first reproduction was determined to be 2.94±0.35 by combining the age of first conception for 25 different females. The minimum age at first conception was 1.05 years and the maximum age at first conception was 6.97 years, yielding a range of 5.93 years (Figure 2). Of these 25 females, six were exposed to a breeding bull constantly from immaturity until their first reproduction. For these six individuals the

average age of first conception was 1.31±0.22. Similarly, the minimum age at first conception was 1.05 years, but the maximum age was 1.59 years, which produced a range of only 0.55 years (Figure 2).

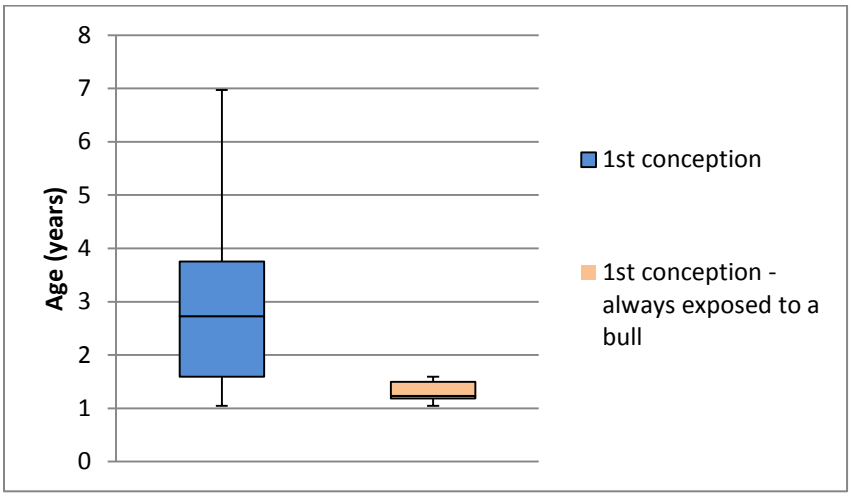

Figure 2. The typical age of a female's first conception is 2.94±0.35; however, if the female is exposed to an intact bull constantly from birth, the average drops to 1.31±0.22 years.

The average age for the last reproduction of eight females was determined to be 12.26±1.00 years. The minimum age at last conception was found to be 7.10 years, the maximum 16.49 years, which yielded a range of 9.38 years. The female that had her last reproduction at the age of 7.10 years was euthanized shortly after calving for medical purposes and is therefore considered an outlier. When excluding this individual and recalculating the average it was calculated at 13.00±0.78 years, with a minimum age at 10.89 years, the same maximum at 16.49 years, and a new range of 5.59 years (Figure 3). The age when the females were removed from the herd to be put into a bachelorette herd for the remainder of their life was also calculated; the average was found to be 17.13±1.27 years, with a minimum of 12.32 years, a maximum of 20.73 years, and a range of 8.41 years (Figure 3).

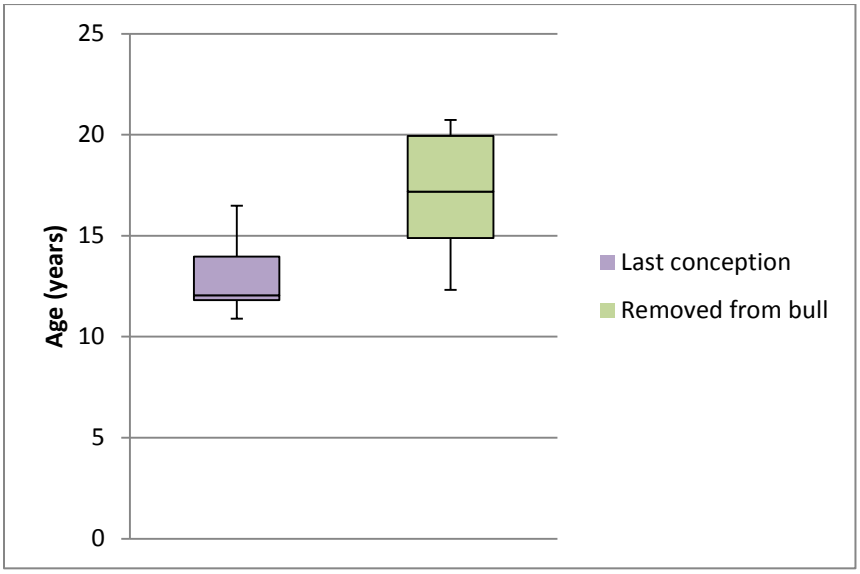

Figure 3. The typical age of a female's last conception is 13.00±0.78 years. The average age when females were removed from the herd bull and put into a bachelorette herd was 17.13±1.27 years.

The reproductive lifespan of 13 females was calculated at 5.54±1.30 years between first and last calving. The minimum lifespan was 1 year, the maximum was 15 years, and the range was 14 years (Figure 4). Eight of these cases had a reproductive lifespan of less than five years, four had a lifespan between 9 and 10 years, and the remaining outlier case has a reproductive lifespan of 15 years.

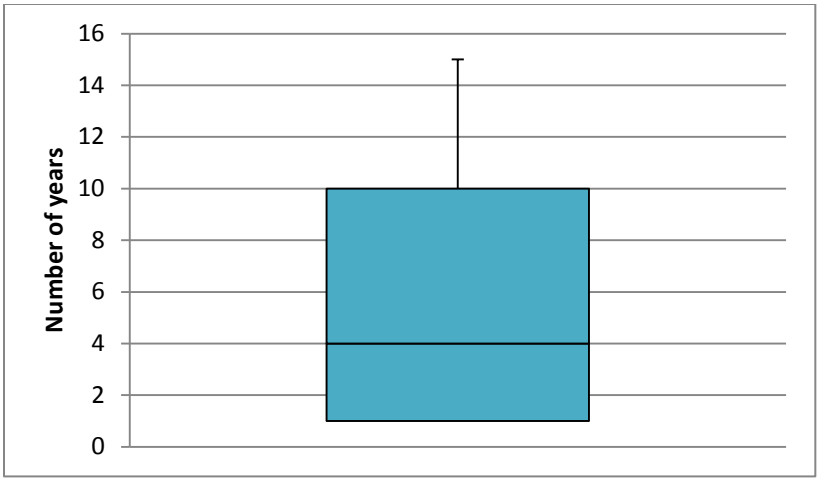

Figure 4. The average reproductive lifespan of 13 female scimitar-horned oryx is 5.54±1.30 years.

The effect of age on female reproductive success

The reproductive success of 100 females in a breeding herd (including those who were both with and without a bull for a period of time) was broken down based on age in order to determine the effect that age has on female fertility. For all age categories 1-15 there was a higher breeding success rate than a breeding failure rate; however, the opposite was true for ages 16-20 (Figure 5). It was determined that age has a significant effect on reproductive success ($G^2 = 17.41$, df = 5, p = 0.01) due to the higher probability of breeding failure in the oldest age class of 16-20 years (z = +3.58).

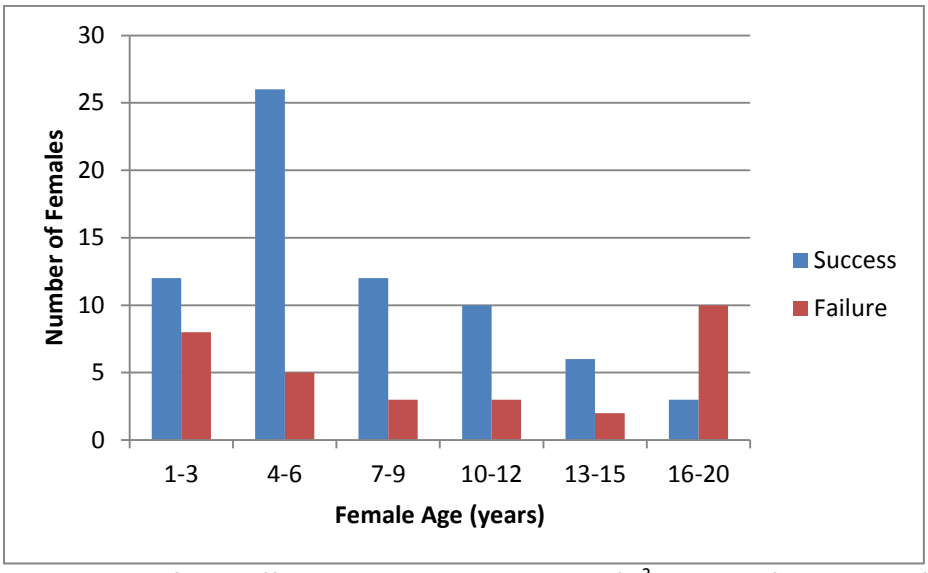

Figure 5. Female age has a significant effect on reproductive success ($G^2 = 17.41$, df = 5, p= 0.01). Females between the ages of 16 and 20 are more likely to experience breeding failure (z = +3.58).

Percentage of breeding success

Figure 6 displays the percentage of the herd that reproduced from 2011-2014. The lowest year for reproductive success was 2013 with a reproduction rate of 73%, where eight of eleven females gave birth to a calf. Conversely, in 2011 and 2012, 100% of the females reproduced with eight calves produced each year.

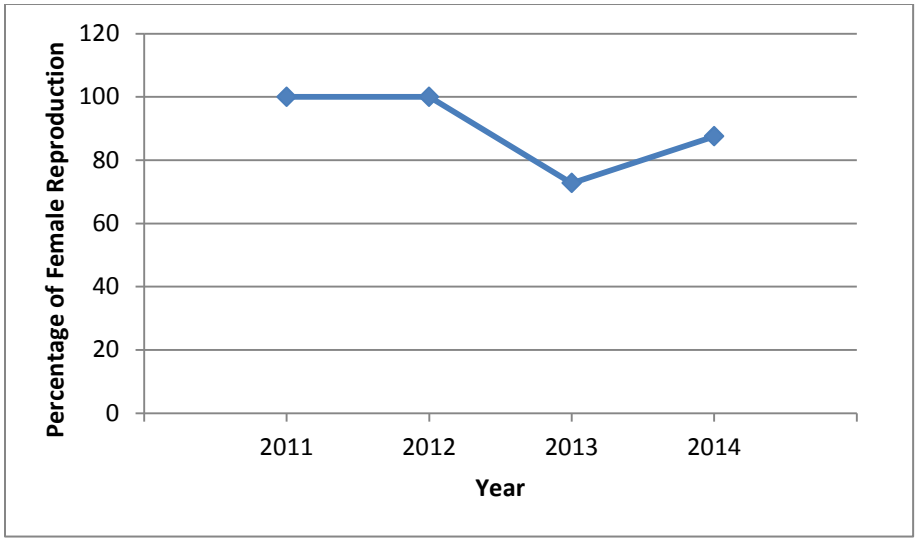

Figure 6. The percentage of the herd that reproduced from 2011-2014. The lowest percent of herd reproduction was seen in 2013 with 73% and the highest was seen in 2011-2012 with 100% of mature females reproducing in both years.

DISCUSSION

The effect of nonbreeding herds on female fertility

The amount of time that the bull was absent from the herd had a significant effect on the likelihood of breeding success. The higher probability of reproductive success when the bull was only separated from the herd for 1-2 years prior, compared to the lower probability of success if the bull was absent for 3-4 years prior, suggests that females become less fertile when they are separated from a bull and kept from breeding for a period of time. Although there was insufficient data to draw any conclusions on the cases that were separated from a bull for more than 4 years, by looking at Figure 1, it seems that the trend holds and that breeding failure is more likely than breeding success for these individuals.

These results seem to agree with those published by Penfold *et al* (2013) regarding reproductive changes that negatively impact fertility of canids, elephants, white rhinos, bats, wildebeest, stingrays, and some felid species. Both in this study and the results seen in the Penfold article, it appears that if females don't use their reproductive system for long enough they are likely to "lose it" or lose the ability to use it again. Lindburg and Durrant (1998) showed that if domestic hoofstock females are kept open (not pregnant) for extended periods of time they are more likely to have issues resuming or beginning breeding and to encounter reproductive problems such as dystocia and stillbirths. For example, oryx ISIS #111 conceived for the first time when she was almost 3 years old. However, after her first birth she was not exposed to a bull for seven years and then her first calving event after the seven year gap was a stillbirth. In fact, two of her next three calving events resulted in stillbirths.

The implications of this decreased fertility is that if the females are not exposed to a male for long enough they will become infertile and the population will become unsustainable (Penfold *et al* 2013). The results

suggest that female fertility will not be negatively impacted if a female is not exposed to a bull for 1-2 years. This means that if the population is growing too quickly and there is a need to cut down on the number of births, or if there is an accident and the bull were to die prematurely, there is enough time to take 1-2 years off from breeding before the females' fertility is affected. However, once females are not exposed to a bull for 3 years or longer, that is when they begin losing their fertility. This loss of fertility should be included in demographic models projecting the results of management scenarios designed to maintain sustainable herds.

Although the data from this one herd strongly suggests that female fertility declined when a bull was absent from the herd for longer than two years, age is a potential confounding factor that affected this analysis. For example, females in the category "without the bull for 1-2 years" showed an average age of 4 years, while the females that were "without a bull for 3-4 years" averaged 10 years of age. This introduces age as a confounding variable for our results. It is hard to say that if the females in both categories had been the same age if the original results would have been so clear cut; however, since we know that age affects female fertility (Figure 5), we must remember this when considering the results.

Female reproductive lifespan

Age of first conception at Fossil Rim on average was 3 years. This average includes females that were not exposed to bulls until they were several years old and also females that were exposed to a bull from birth until their first conception. Considering only females that were always exposed to a bull, average age of first conception dropped to 1.3 years (Figure 2). This suggests that in the ISIS records the average age of first reproduction may be biased to be high due to the number of cases of females that are not with a male during their first year. For example, a female that is 7 years old and has never been exposed to a male may still be capable of conceiving, although this is less likely.

For females held continuously with a bull, the average age of sexual maturity is 1.3 years with a range of 1 to 1.6 years. This means that herds should be managed so yearling females are not bred by their father or close relatives. It should be noted that the case of a female that conceived at 1.6 years old might have already been in estrous previously, but the infertility might have been for other reasons, such as (1) the bull did not breed her, (2) she did not conceive, or (3) there was fetal loss.

The average age of last conception at Fossil Rim Wildlife Center was 12-13 years. The calculated average of 12 years includes an outlier case, a female that conceived at 7 years, gave birth, and then was euthanized a month later for medical reasons unrelated to the calving. Excluding that outlier, average age of last conception was 13 years with a maximum of 16.5 years (Figure 3). This suggests that fertility begins to decline after 13 years. Females were removed from the breeding herd on the average at 17 years (Figure 3). On average the females were left in the breeding herd for 4 years after their last conception, giving them plenty of time to conceive again if physiologically capable. This suggests the age of the last conception is not biased by removal of females from a breeding herd. These results will prove beneficial for management purposes because once females exceed 13 years of age they can be removed from the herd knowing that they are not likely to conceive again. An advantage of removing these post-prime females might be an increase in the percentage of pregnant females in the herd if the bull attends older infertile females and misses inseminating younger, fertile females.

Although the data suggests that removing females at the age of 13 is the best option to increase reproductive success, we should also consider the behavioral benefits of keeping elder females in with the herd. According to Newby (1974), older females are leaders in scimitar-horned oryx herds, and they may serve an important role in herd movement and cohesion. Under some conditions, males may also appear to be leaders, so this topic needs to be further investigated (Kranz and Ralls, 1979). It has also been suggested that older females help raise the offspring of younger females, possibly increasing survival of the first calf of their daughters. With the multiple roles that older females may hold in each herd it is up to the herd managers to consider the costs and benefits of keeping them with the herd past their prime breeding age.

The average reproductive duration of 13 females was 5.5 years (Figure 4); however, multiple factors may have influenced this average. Eight of these cases had a reproductive duration of less than five years, with

four reproducing in only one year. Two of these individuals were sold at the age of 7 and may have continued to reproduce at the facility where they were moved. The other two females that had a reproductive duration of only one year gave birth early in their life and then were separated from a bull for a long period of time. Once they were exposed to a bull again they were either too old to reproduce or had become infertile from the long amount of time they had been separated from the bull. For our purposes, these cases do not hold much weight in determining the theoretical female reproductive lifespan because outside factors may have played a greater role than physiological limitations on their inability to reproduce. The remaining individuals all began reproducing early in life. The five individuals that had a reproductive duration of greater than five years, all experienced some period of time without a bull in the herd. This means that none of the females gave birth consistently for the entire reproductive period of their lifespan and there was at least a 2-3 year gap when they did not reproduce. For this reason, we cannot draw any conclusions about the lifetime reproductive success of a female if she were to be bred consistently each year. From this dataset, we cannot determine if breeding and calving each year with no breaks would increase or decrease the post-prime decline in fertility.

Although we were somewhat unsuccessful calculating the reproductive lifespans of individual scimitar-horned oryx at Fossil Rim Wildlife Center, we can confidently report a theoretical reproductive lifespan by analyzing the average age of first reproduction and the average age of last reproduction. Since the average first reproduction (when always exposed to a bull) was 1.3 years (with a minimum of 1 year) and the average age of last reproduction was 13 years (with a maximum of 16.5 years), theoretically the female scimitar-horned oryx reproductive lifespan should be about 12 years with prime fertility between 2 to 13 years and declining fertility thereafter up to 17 years.

The effect of age on female reproductive success

Based on cases from 100 females in a breeding herd, age has a significant effect on reproductive success. Females 16-20 years old have a higher probability of breeding failure (Figure 5). Conversely, for all the younger age categories (>1 to 15 years), reproductive success was more likely than reproductive failure (Figure 5). The peak of female fertility was between the ages of 4-6 where there was an 84% reproductive success rate. Although females in the 13-15 age category had a positive reproductive success rate, it should be noted that of the six breeding successes, three of the cases were for females that were 13 years old. While there were not enough cases to determine statistical significance, it appears that the age-related decline in fertility begins in the age range of 13-15 years.

Percentage of breeding success

For many years the scimitar-horned oryx population at Fossil Rim Wildlife Center was spread out into several different herds across multiple pastures making it difficult to draw conclusions about the reproductive success of the herd as a whole. However, since 2011, there has been only one herd, located in the Front Pasture, and detailed records have been kept for each member of the herd. Having the herd all in one place and knowing exactly who was a member made it possible to determine the percentage of the herd that reproduced from year to year. While the data from the 2011 to 2014 breeding season is accurate and complete, there is also a significant amount of incomplete information from years prior. This information includes calves that were born and some females that were kept together, but does not take into account the herd as a whole. The information shows that there were some females that calved and some that didn't, but there were also additional females in the herd and it is not known whether or not they reproduced. The inability to use cases with incomplete information shows the importance of keeping accurate records, not only for individuals, but for the group as a whole. The herd history database developed for this project should be maintained (Appendix 2).

During the period with accurate records, the percentage of females that reproduced ranged from 73% in 2013 to 100% in 2011 and 2012 (Figure 6). In 2008, the herd bull died shortly after being rotated out of the front pasture with the herd. After his death a new bull was not put in with the herd until December of 2010, meaning that the females were not exposed to a bull for over two years. However, 100% of the females were bred and

successfully calved in 2011 and also in 2012. This supports the hypothesis that female fertility is not likely to decline if a bull is not present with the herd for only 1-2 years (Figure 1).

CONCLUSIONS

The length of time that a scimitar-horned oryx bull was absent from the Fossil Rim herd has had a significant effect on the likelihood of breeding success, possibly confounded by age of the females. Although the absence of a bull for 3-4 years reduced fertility in older females (average age of 10 years), the absence of a bull for 1-2 years did not reduce fertility in younger females (average age of 4 years). These results suggest that a time window of 1-2 years is safe to rest females from breeding. Managers may use this information to adjust herd production rates to meet their goals of maintaining genetic diversity and demographic sustainability.

For the purpose of demographic modeling, the average age of first conception for female scimitar-horned oryx in the Fossil Rim herd has been 1.31±0.22 years, and the earliest recorded conception age was 1.05 years. The average age of last conception was 13.00±0.78 years, with a maximum age of 16.49 years. The significant effect of female age on reproductive success was due to a declining fertility in the age class of 16-20 years. Although insignificant due to small sample size, the declining trend in fertility appeared to start in the age class of 13-15 years. The peak of reproductive success was in the age class of 4-6 years. As these data were confounded by removal of a breeding bull from the herd and incomplete records, they should be considered specific to the management conditions of the Fossil Rim herd, not necessarily generalizable to other herds. In the future, accurate data need to be kept on herd history (group composition) as well as individual history.

Additional data should be collected at Fossil Rim Wildlife Center and collaborating institutions to develop demographic models to aid in projecting the results of alternative management scenarios (e.g. resting females from reproduction). These studies should be expanded to include other African antelope species, to determine whether the same factors that affect scimitar-horned oryx fertility also affect other antelope species. In addition, to better understand scimitar-horned oryx fertility a study is needed to assess how male age and experience affects the conception rate of females. Now that we have an appreciation for the reproductive period in the lifespan of females and the effects of removing a breeding bull, it would be beneficial to understand the effect of experience and the prime reproductive age of males.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1. A portion of the scimitar-horned oryx herd database for Fossil Rim Wildlife Center. This database includes information for all 235 of the tagged scimitar that have been on property at Fossil Rim since 1983. Additional columns that are not shown include name, tattoo, sire tag number, sire studbook number, dam tag number, dam studbook number, date of departure, date of death, and comments.

Tag Number	ISIS	Studbook #	Transponder #	Sex	Date of Birth	Date of Arrival	Sire ISIS	Dam ISIS
2Y/202Y/146R	104	1062	00-001F-054B	Female	4-Apr-83	18-May-84		
228Y/50R/28Y	105	1609	7F7E602C67	Male	20-Feb-87	12-May-88		
75R/609B/141R/375Y	106	1910	00-001C -4C6F	Female	28-May-89	28-May-89	105	103
58B/463B	107	1743	7F7E60287D	Male	1-Jan-88	25-May-89	1371	197
57B	108	1726	7F7E60256E	Male	10-Nov-87	25-May-89	1371	123
66R/28W	109	1271	7F7E601D4C	Male	14-Jun-84	9-Aug-89		
61W/143R/27Y	110	1706	7F7E60293C	Female	15-Sep-87	11-May-90	619	3319
188Y/155G/29Y	111	1707	7F7E603012	Female	19-Sep-87	11-May-90	619	672
153G/108O/30Y	112	1709	7F7E601E72	Female	21-Sep-87	11-May-90	619	3258

Appendix 2. Herd history database for the scimitar-horned oryx at Fossil Rim Wildlife Center. This database includes only those animals with ISIS numbers and shows which animals were on property at any date between 1983 and today, which females were part of the herd, and whether or not a breeding bull was present. Only a portion of the complete database is shown below.

ISIS ID	101	102	103	104	105	106	107	108
TAG ID	375	330Y	350Y/145R	146R/2Y	228Y	609B/141R/375Y/75R	58B	57B
SEX	Female	Female	Female	Female	Male	Female	Male	Male
DOB	1979	1978	1977	1983	1987	1989	1988	1987
DATE								
29-Jan-83								
5-Jul-83		SSP	SSP					
20-May-84				SSP				
1-Jan-85								
1-Jan-86								
1-Jan-87								
16-Dec-87			65G					
13-Jan-88		66G						
2-Feb-88				69G				
12-May-88					SSP			
25-May-89							pens	pens
28-May-89			106		106	SSP		
8-Jun-89								SP
9-Aug-89								
9-Sep-89								
1-Nov-89				119	119			
28-Nov-89		120			120			

Immature	Females not capable of breeding - immature (1 year and younger)
Bachelorette herd	Females Open-No intact male present.
Birth	Live calves born.
Stillborn	Complications with pregnancy (still born)
Open	Females at Fossil Rim capable of breeding
Immature/ Vasectomized	Males not capable of breeding at Fossil Rim (immature (2 years and younger), vasectomized, or hormone inhibitor implanted)
Bachelor	Males capable of breeding at Fossil Rim but unable to breed due to location (no access to females)
Intact	Mature males at Fossil Rim capable of breeding and located in a pasture with females

Appendix 3. The yearly reproductive status of female scimitar-horned oryx at Fossil Rim Wildlife Center from 1983 to 2014. This spreadsheet includes only females with ISIS numbers. It includes a number of cases, where each case represents a single breeding year for one female. Also included in the spreadsheet is the reproductive status of the female over the course of the previous three years. "Year -1" refers to the previous year, "year-2" refers to the individuals' social group 2 years before "this year". Only a portion of the complete database is shown below.

CASE (FEMALE/YR)							REPRODUCTIVE STATUS	
CASE#	ID	YR	AGE	This year	year -1	year -2	year -3	comments
102	111	1997	10	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
103	111	1998	11	Stillborn	Bachelorette	Bachelorette	Bachelorette	SSP, calf sire 133
104	111	1999	12	Birth	Stillborn	Bachelorette	Bachelorette	calf sire 133
105	111	2000	13	Stillborn	Birth	Stillborn	Bachelorette	calf sire 133 (twins)
106	111	2001	14	Bachelorette	Stillborn	Birth	Stillborn	
107	111	2002	15	Bachelorette	Bachelorette	Stillborn	Birth	
108	111	2003	16	Bachelorette	Bachelorette	Bachelorette	Stillborn	
109	111	2004	17	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
110	111	2005	18	Open	Bachelorette	Bachelorette	Bachelorette	
111	111	2006	19	Open	Open	Bachelorette	Bachelorette	
112	111	2007	20	Open	Open	Open	Bachelorette	
113	111	2008	21	Bachelorette	Open	Open	Open	RP, death
114	112	1990	3	Bachelorette				SSP
115	112	1991	4	Birth	Bachelorette			*calf sire 108
116	112	1992	5	Bachelorette	Birth	Bachelorette		FP
117	112	1993	6	Bachelorette	Bachelorette	Birth	Bachelorette	
118	112	1994	7	Bachelorette	Bachelorette	Bachelorette	Birth	
119	112	1995	8	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
120	112	1996	9	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
121	112	1997	10	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
122	112	1998	11	Open	Bachelorette	Bachelorette	Bachelorette	SSP
123	112	1999	12	Birth	Open	Bachelorette	Bachelorette	calf sire 133
124	112	2000	13	Birth	Birth	Open	Bachelorette	calf sire 133
125	112	2001	14	Bachelorette	Birth	Birth	Open	
126	112	2002	15	Bachelorette	Bachelorette	Birth	Birth	
127	112	2003	16	Bachelorette	Bachelorette	Bachelorette	Birth	
128	112	2004	17	Bachelorette	Bachelorette	Bachelorette	Bachelorette	
129	112	2005	18	Open	Bachelorette	Bachelorette	Bachelorette	
130	112	2006	19	Open	Open	Bachelorette	Bachelorette	
131	112	2007	20	Open	Open	Open	Bachelorette	
132	112	2008	21	Bachelorette	Open	Open	Open	RP, death

* Represents a female's first calf

Appendix 4. Breeding success and failure for mature female scimitar-horned oryx with ISIS numbers at Fossil Rim Wildlife Center from 1983 to 2014. Only a portion of the complete database is shown below.

CASE	ID	YEAR	AGE	PRIOR YRS ISOLATED FROM MALE	SUCCESS ?	COMMENTS
5	101	1987	8	4	No	
6	101	1988	9	0	No	
7	101	1989	10	0	No	
8	101	1990	11	0	No	
9	101	1991	12	0	No	
18	102	1987	9	4	No	
19	102	1988	10	0	Yes	
20	102	1989	11	0	Yes	
21	102	1990	12	0	Yes	
22	102	1991	13	0	Yes	
31	103	1987	10	4	Yes	
32	103	1988	11	0	No	
33	103	1989	12	0	Yes	
34	103	1990	13	0	Yes	
35	103	1991	14	0	Yes	
46	104	1987	4	3	No	
47	104	1988	5	0	Yes	*
48	104	1989	6	0	Yes	
49	104	1990	7	0	Yes	
50	104	1991	8	0	Yes	
57	104	1998	15	6	Yes	
58	104	1999	16	0	Yes	
59	104	2000	17	0	Yes	
66	106	1991	2	0	Yes	*
82	106	2007	18	14	No	
87	110	1991	4	1	Yes	*
96	111	1991	4	1	Yes	*

* Represents a female's first calf

Appendix 5. Inquiry questions about scimitar-horned oryx reproduction that were identified as relevant to the Ungulate Taxon Advisory Group (H. Haefele, personal communication).

Question Number	Question
1	Is there a statistical difference in reproductive success if a bull was present or absent from the herd for the previous two years?
2	What is the typical age of first reproduction?
3	In what percentage of cases were immature females in bachelorette herds?
4	What is the typical age of last reproduction?
5	What is the reproductive lifespan? (Range between age of first birth and age of last birth)
6	What is the effect of age on female fertility/reproductive success?
7	What is the percentage of the herd that reproduces?