

Reproductive seasonality in the female scimitar-horned oryx (*Oryx dammah*)

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Abstract

Faecal oestrogen and progesterone analyses were used to assess ovarian activity in non-pregnant scimitar-horned oryx (*Oryx dammah*) during a 13-month interval. Mean (\pm SE) luteal phase, interluteal phase and oestrous cycle duration were 18.8 (\pm 0.5), 5.1 (\pm 0.2) and 23.8 (\pm 1.3) days, respectively. All females exhibited a synchronized anovulatory period that ranged from 36–95 days during spring. Short ovarian cycles (10.6 (\pm 0.8) days) were observed intermittently throughout the year and before the spontaneous resumption of oestrous cyclicity. Perioovulatory peaks in oestrogen concentrations were detected for 42.5% (31/73) of ovarian cycles. A parallel analysis of reproductive data from the North American studbook (1985–1994) revealed that captive-held scimitar-horned oryx gave birth throughout the year. Sex ratio at birth was male-biased (54.4%), and 19.1% of all calves failed to survive to 6 months of age (220 out of 1149 births). Only 0.7% of births resulted in twins. Median interbirth interval was 277 days, and 75% of these intervals were less than 332 days. Interbirth interval was extended ($P < 0.05$) if parturition occurred from January through May. In summary, the scimitar-horned oryx is a seasonally polyoestrous species that experiences a distinct anovulatory period during spring in north-east America.

INTRODUCTION

The critically endangered scimitar-horned oryx (*Oryx dammah*) is an African antelope in the Hippotraginae subfamily of the family Bovidae. Historically this species inhabited the Sahel, the semi-arid transition zone south of the Sahara, and the northern edge of the Sahara (Newby, 1988). Despite being well adapted to the harsh, arid environment, numbers of wild oryx have declined markedly during this century (Happold, 1966; Newby, 1988). By 1996, the only viable populations of scimitar-horned oryx in their native range were believed to exist as vagrants in the Ouadi Rimé–Ouadi Achime Faunal Reserve in Chad (East, 1996) and as a reintroduced group in the Bou-Hedma National Park in Tunisia (Gordon, 1991).

Endocrine profiles obtained from urine (Lostkutoff, Ott & Lasley, 1983), faeces (Shaw *et al.*, 1995) and blood samples (Morrow & Monfort, 1995; Bowen & Barrell, 1996; Morrow, 1997) during natural and artificially induced ovarian cycles have provided useful infor-

mation on progesterone secretion during the ovarian cycle of the scimitar-horned oryx. However, there has been no investigation of oestrogen profiles or the circannual reproductive-endocrine patterns in female oryx. Additionally, knowledge of the basic reproductive biology (birth patterns, sex ratios, calf mortality, sexual maturity and interbirth interval) has been limited to a few observations. For example, scimitar-horned oryx in the wild reportedly experience a seasonal calving pattern (Brocklehurst, 1931; Edmond-Blanc, 1955; Gillet, 1966; Newby, 1975). In contrast, scimitar-horned oryx held in captivity appear to calve throughout the year (Zuckerman, 1953; Knowles & Oliver, 1975; Kirkwood, Gaskin & Markham, 1987; Gill & Cave-Browne, 1988; Nishiki, 1992).

The present study was designed to establish basic reproductive-endocrine norms and to characterize the incidence of seasonal breeding in zoo-maintained scimitar-horned oryx. Two parallel studies were conducted. One involved a prospective characterization of circannual reproductive-endocrine patterns (including oestrogen profiles) in non-pregnant scimitar-horned oryx using non-invasive faecal steroid monitoring. The other involved a detailed retrospective analysis of reproductive traits of captive scimitar-horned oryx using information

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contained in the *North American regional studbook* (Rost, 1989, 1994). Records were used to identify birth patterns, sex ratios, calf mortality, incidence of twinning, age at first parturition and interbirth intervals.

MATERIALS AND METHODS

Animals

Female scimitar-horned oryx (captive-born, 6–10 years of age; 159.5 (\pm 3.6) kg (mean \pm SE) liveweight) were used to study endocrine patterns in the prospective study. Oryx were maintained at the National Zoological Park's Conservation and Research Center (CRC) near Front Royal, VA, USA (38 °53' N, 78 °9' W) and were not on public exhibit. The six females were non-pregnant and maintained together in a 0.2 hectare pasture with natural shade and access to a barn (22 m²). The barn was bedded with straw in cooler months and heated by overhead, electric radiant heat panels set at 18 °C. Oryx had access to fresh water, mineral block, pasture and good quality meadow hay *ad libitum*, and were supplemented with a 12.5% protein concentrate (Washington National Zoo Herbivore Maintenance Pellet, Agway Inc., Syracuse, NY, USA). Females had olfactory and visual exposure to an 8-year old vasectomized male housed in an adjacent enclosure. Colour plastic eartags and variations in horn morphology individually identified oryx. The Institutional Animal Care and Use Committee of the CRC National Zoological Park approved the research proposal.

Faecal sample collection and steroid extraction

After defaecation and positive animal identification, a subset of pelleted faeces (10–12 g wet weight) was collected from the substrate and stored without preservative at –20 °C until processed. Samples were collected from individual females two to five times per week for 13 months beginning in July.

Faecal steroids were extracted from 25 mg of dried, pulverised faeces using a technique adapted from Wasser *et al.* (1994) and previously described and validated for oryx faeces (Morrow & Monfort, 1998). Final hormone concentrations were corrected for individual procedural losses and expressed as ng (oestrogens) or μ g (progesterins) per gram of dry faeces.

Radioimmunoassays

All assays were previously validated by demonstrating (i) parallelism between serial dilutions of oryx faecal extract and the standard curve and (ii) recovery of exogenous hormone added to oryx faecal extract (Morrow & Monfort, 1998).

Oestrogen excretion was measured in duplicate 250 μ l samples of faecal extract (diluted 1:80 in steroid diluent) using the ImmuChem™ Total Estrogens Kit (ICN Biomedical Inc., Costa Meca, CA, USA). Assay sensitivity was 1.25 pg/tube and inter- and intra-assay

coefficients of variation for oryx control samples were 7.8 and 11.4%, respectively.

Progesterin excretion was measured in duplicate 100 μ l samples of faecal extract (diluted 1:500 in phosphate buffered saline, pH 7.4) using a progesterone radioimmunoassay (RIA) developed by Brown *et al.* (1994) and modified for scimitar-horned oryx faecal extracts (Morrow & Monfort, 1998). Assay sensitivity was 3.0 pg/ml and inter- and intra-assay coefficients of variation for scimitar-horned oryx control samples were 13.8 and 15.6%, respectively.

Reproductive records

Birth dates of captive scimitar-horned oryx born in North American institutions from January 1985 to February 1994 were obtained from the *North American regional studbook* (Rost, 1989, 1994). Surveys to determine the management of breeding herds were distributed to 46 North American institutions reporting births in the 1989 studbook.

Data analysis

Standard descriptive statistics, including mean and standard error (SE) were used to evaluate data. Faecal steroid concentrations were considered above baseline when they exceeded 2.0 (oestrogens) or 1.5 (progesterins) standard deviations above the mean value for that animal (Graham *et al.*, 1995). Ovarian cycle duration was calculated as the interval between successive nadirs in progesterin excretion. Day 0 of the cycle was defined as the first day progesterin concentrations returned to baseline.

Calculations of sex ratio at birth, calf mortality and incidence of twinning were generated from all birth records contained in the North American studbook during the 9-year period. Of the 46 surveys distributed to institutions, 25 (54%) were returned with information (see Acknowledgements). Of the respondents, 17 institutions had allowed unrestricted breeding of scimitar-horned oryx for part or all of the 9-year period. Calculations of the monthly distribution of births, age at first parturition and interbirth interval were limited to those institutions with unregulated breeding. Because duration of gestation in this species is ~250 days (Gill & Cave-Browne, 1988; Nishiki, 1992; Morrow, 1997), conception dates were calculated by subtracting 250 days from birth dates.

RESULTS

Endocrine profiles

Each of the six females exhibited cyclic progesterin excretion assumed to represent luteal activity (Fig. 1). The ovarian cycle consisted of two phases. The luteal phase was 18.8 (\pm 0.5) days duration (range, 16–23 days) and characterized by a sustained increase in progesterin concentrations from nadir (5.0 (\pm 0.5) μ g/g) to peak concentrations (36.9 (\pm 1.9) μ g/g) between days 10–19,

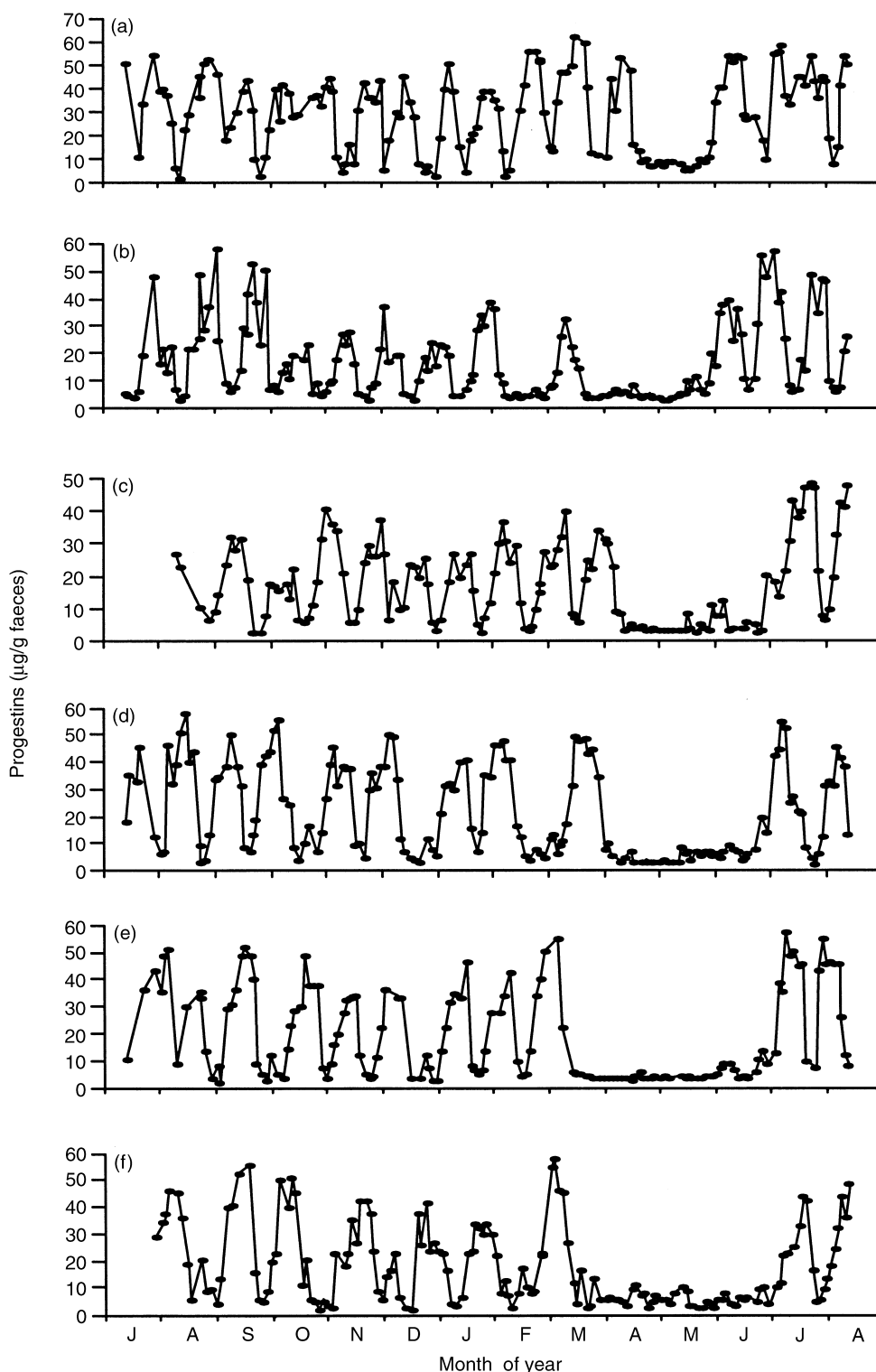


Fig. 1. Faecal progesterin concentrations (●) in six non-pregnant, scimitar-horned oryx during a 13-month period. (a) animal no. 1272; (b) no. 1815; (c) no. 1537; (d) no. 1710; (e) no. 1280; (f) no. 1261.

followed by declining progesterin concentrations indicative of luteolysis (days 19–24). The interluteal follicular phase was $5.1 (\pm 0.2)$ days duration (range, 3–8 days) and was characterized by nadir concentrations of progesterins.

All females exhibited a synchronized anovulatory period that ranged in length from 36–95 days (73.3

± 8.1) days) from March through June (Fig. 1). Table 1 presents the individual ovarian cycle lengths, dates and duration of anovulatory periods for the six females. The overall mean ovarian cycle length for 73 cycles was $23.8 (\pm 1.3)$ days (range, 8–45 days). The frequency distribution of ovarian cycle length is presented in Fig. 2. Short duration cycles generally consisted of transitory

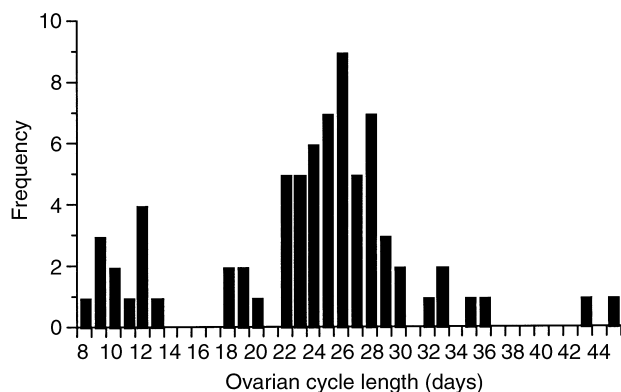


Fig. 2. Frequency distribution of ovarian cycle length for 73 cycles from six scimitar-horned oryx.

increases in progestin concentrations ($2.7\text{--}22.7\ \mu\text{g/g}$) that lasted $10.6 (\pm 0.8)$ days (range, 8–13 days; $n = 12$). Excluding cycles ± 2 standard deviations from the mean resulted in a mean ovarian cycle length of $24.8 (\pm 1.3)$ days (range, 17–30 days; $n = 52$).

Elevated oestrogen concentrations were detected in 111 faecal samples and were classified into three categories based on corresponding progestin concentrations: (i) periovulatory oestrogen peaks consisted of an elevated concentration within 3 days of day 0 (day 0 defined as the first day that progestin concentration returned to baseline); (ii) luteal phase increases in oestrogen; and (iii) elevated oestrogen concentration during the period of anovulation. Periovulatory oestrogen peaks were detected for 31/73 (42.5%) ovarian cycles. Figure 3 presents the periovulatory peak in a composite graph of mean faecal oestrogen and progestin concentrations for 19 ovarian cycles that had elevated faecal oestrogens on day 0 of the ovarian cycle. Luteal phase elevations in oestrogens were detected in 55 faecal samples. Elevated oestrogen concentrations were detected in 25 samples during the anovulatory period.

Birth records

Analysis of a seasonal birth peak was based on 497 births to dams known to have had unrestricted breeding opportunities. Scimitar-horned oryx calves were born in each month of the year (Fig. 4). Frequency of births varied

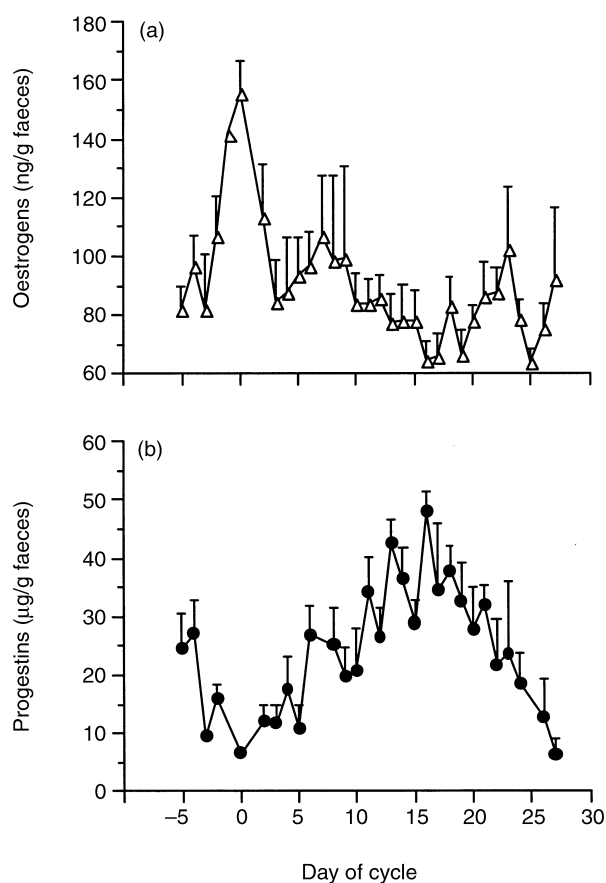


Fig. 3. Mean (\pm SE) concentrations of (a) faecal oestrogen (Δ) and (b) progestin (\bullet) for 19 ovarian cycles in scimitar-horned oryx where the periovulatory oestrogen peak corresponded with the progestin nadir (day 0 of cycle).

from month to month, with fewer than the average number of births per month (41.1) occurring from June through December (range, 22–41) compared with January through May (range, 46–66).

Sex ratio, calf mortality and twinning

The *North American regional studbooks* for the scimitar-horned oryx reported 1149 calves born from January 1985 to February 1994. Of the 1129 calves for which gender was reported, 614 (54.4%) were male and 515

Table 1. Ovarian cycle length, dates and duration of anovulatory periods in six scimitar-horned oryx by age and parity (number of offspring) on the basis of faecal progestin concentration.

Id	Age (year)	Parity	Ovarian cycle (days)	Mean length (days \pm SE)	Anovulatory period	
					Dates	Days
1272	10	4	20, 43, 45, 26, 19, 26, 22, 26, 25, 24, 32, 36	28.7 ± 2.6	23 Apr–29 May	36
1815	6	2	28, 29, 22, 23, 26, 25, 27, 29, 19, 24, 24, 22	24.8 ± 0.9	22 Mar–27 May	66
1537	8	2	24, 28, 28, 18, 26, 25, 27, 25, 27, 11, 33	24.7 ± 1.8	13 Apr–27 June	75
1710	7	2	22, 27, 27, 10, 26, 22, 9, 23, 26, 9, 30, 35	22.2 ± 2.6	6 Apr–19 June	74
1280	10	3	28, 23, 26, 9, 24, 23, 23, 12, 25, 24, 30, 12, 33, 18	22.1 ± 1.9	17 Mar–19 June	94
1261	10	4	8, 29, 28, 25, 12, 28, 28, 13, 25, 12, 10, 26	20.3 ± 2.5	22 Mar–25 June	95
Overall mean \pm SE				23.8 ± 1.3		73.3 ± 8.1

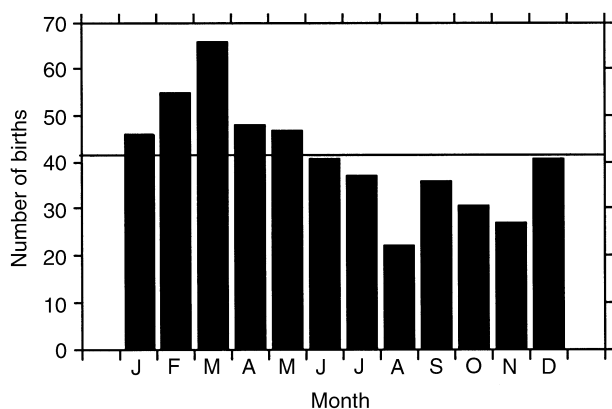


Fig. 4. Frequency of 497 scimitar-horned oryx births by month in North America from January 1985 to February 1994; horizontal line indicates the mean number births per month (41.1).

(45.6%) were female giving a sex ratio of 1:0.84 males to females which differed significantly from 1:1 ($\chi^2 = 8.68$, $P < 0.005$).

Overall mortality (number of calves dying by 6 months of age divided by the number born) was 19.1% (220 out of 1149). Most calf mortality (178 out of 220; 80.9%) occurred in the first 30 days of life (perinatal period). Mortality was significantly higher ($P < 0.05$) for males (120 out of 220; 54.5%) than females (89 out of 220; 40.4%) resulting in a sex ratio of 1:0.86 males to females at 6 months of age.

Of the 1149 calves born, there were eight sets of twins yielding a twinning incidence of 0.7%. Five out of the eight sets of twins (62.5%) consisted of a male and female calf (i.e. fraternal twins). The sex ratio was 1:0.78 (nine males, seven females) which did not differ from 1:1 ($\chi^2 = 0.25$, $P > 0.05$). Mortality rate of twin calves was 56.3% (9 out of 16 calves), and all nine were still-born or died on the day of birth.

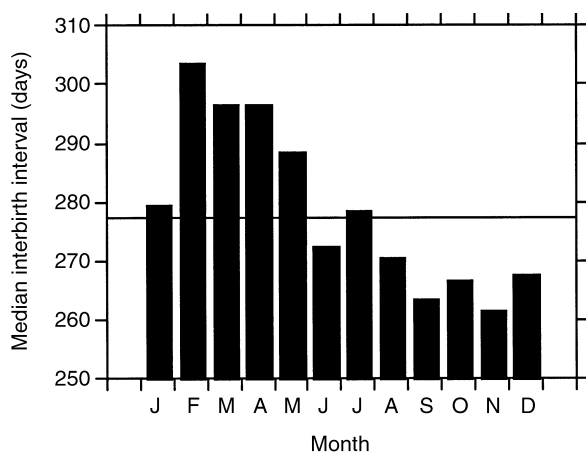


Fig. 5. Median interval (days) to the next birth by month of current birth. Calculated from 231 interbirth intervals in the scimitar-horned oryx. The horizontal line indicates the overall median interbirth interval (277 days). Gestation interval in this species is ~250 days.

Interbirth interval

Interbirth interval was defined as the number of days between consecutive births. A total of 231 interbirth intervals were calculated for 95 females. Intervals less than 207 days ($n = 6$; 17, 85, 166, 180, 202, 206 days) were excluded from the analysis because they were presumed to have reflected recording errors. The median interbirth interval was 277 days (range, 241–705 days), with 75% of intervals being less than 332 days (10.9 months). It was common for an individual female to give birth twice in a 12-month period, and the data suggested a 40 week (10 month) periodicity in consecutive births. However, the interbirth interval varied with month of birth, with the next interbirth interval being longer if the calf was born in the months from January through May (median ≥ 280 days) and shorter if the calf was born from August through December (median ≤ 271 days) (Fig. 5).

Age at parturition

The average age of 53 primiparous scimitar-horned oryx at the time of their first parturition was 27.8 (± 0.1) months (range, 19.1–46.7 months). Most females (44 out of 53; 83.0%) had a first calf before 32 months of age. Thus, average age at first conception was calculated from records as 19.6 (± 0.9) months (range, 10.9–38.5 months).

The oldest scimitar-horned oryx to have given birth to a healthy calf was a 21.9-year old female (Studbook no. 80) at Omaha's Henry Doorly Zoo, NE, USA. This individual was zoo-born from founders wild-caught in Chad and produced 17 calves in the period from 1974 to 1992 (ISIS/ARKS specimen report; C. Socha, pers. comm.).

DISCUSSION

Extensive endocrine monitoring, combined with a retrospective examination of reproductive records, demonstrated that the scimitar-horned oryx was a seasonally polyoestrous, spontaneously ovulating species. Our evaluation of faecal steroid metabolites over 13 months clearly revealed, for the first time, a distinctive spring anovulatory period for scimitar-horned oryx in north-east America. Results further demonstrated the wealth of information available in zoo-maintained studbooks that allowed the evaluation of reproductive life-history strategies in an endangered species.

To our knowledge, the detection of periovulatory faecal oestrogen peaks in ungulates has been reported only for the horse (Barkhuff, Carpenter & Kirkpatrick, 1993). We have recently reported elevated oestrogen concentrations in the scimitar-horned oryx corresponding to the presence of a large antral ovarian follicle (> 10 mm diameter) and after spontaneous luteolysis (Morrow & Monfort, 1998). Elevated oestrogen concentrations observed in the present study during the periovulatory period and also during the luteal phase suggested that

daily faecal oestrogen monitoring may be useful for monitoring follicular activity in this species.

The scimitar-horned oryx had a 23.8 (\pm 1.3) day ovarian cycle calculated from more than 70 individual cycles. These data confirm previous reports calculated from behavioural observations (Durrant, 1983; Bowen & Barrell, 1996), plasma progesterone profiles (Morrow & Monfort, 1995; Bowen & Barrell, 1996), urinary pregnanediol-3 α -glucuronide patterns (Loskutoff *et al.*, 1983) and faecal steroid metabolites (Shaw *et al.*, 1995). These previous estimates were based on a limited number of ovarian cycles (maximum of four continuous cycles). The ovarian cycle of the scimitar-horned oryx was similar to that reported for Arabian oryx (*Oryx leucoryx*) (22 (\pm 3.6) days, range, 19–23; Vié, 1996) and sable antelope (*Hippotragus niger*) (24.2 (\pm 0.9) days; Thompson, Mashburn & Monfort, 1998) but shorter than the 32.3 (\pm 1.7) day cycle reported for addax (*Addax nasomaculatus*) (Asa *et al.*, 1996).

Previous studies of scimitar-horned oryx had not revealed short ovarian cycles of 8–12 days duration or the spring anovulatory period. Short luteal cycles (~7 days) preceded 74% of postpartum oestrous cycles in Arabian oryx and were also evident between other cycles (Sempéré *et al.*, 1996). Abbreviated ovarian cycles usually occur prior to the first oestrus of the breeding season and/or before the resumption of oestrous cycles in the postpartum female. Progesterone secreted during these short cycles presumably primes the hypothalamic–pituitary axis to facilitate the initiation of regular ovarian cycles (Legan *et al.*, 1985).

Interestingly, the analysis of monthly birth records only could have led to the conclusion that female scimitar-horned oryx were not seasonally polyoestrous (Fig. 4). However, endocrine monitoring revealed that scimitar-horned oryx at CRC experienced a seasonal anovulatory interval that was loosely synchronized among females and occurred between the northern hemisphere spring equinox (March 21) and summer solstice (June 21), a period of increasing daylength. Unpublished birth records for the CRC oryx herd from 1975–1978, when breeding was not regulated, indicated that most births (13 out of 16; 81%) occurred from March through August, suggesting that most females conceived from June through November. Anovulatory periods have been observed in addax in a study conducted from late autumn to early spring in North America; but, did not appear to be synchronized among herd mates or with respect to season (Asa *et al.*, 1996). Sable antelope maintained at CRC under the same conditions as the scimitar-horned oryx, do not experience a seasonal anovulatory period (Thompson *et al.*, 1998). Such observations emphasize the likelihood of significant differences in reproductive physiology among species of Hippotraginae antelope.

Based on North American studbook birth records, scimitar-horned oryx females that gave birth from January through May (winter/spring) experienced an interbirth interval longer than those females that gave birth from August through December (summer/autumn).

Thus, females calving in months when daylength was increasing (January through May) may not have: (i) experienced postpartum oestrus and ovulation; or (ii) conceived as readily as females that calved when daylight was decreasing. Furthermore, fewer calves were born in North America from June through December (i.e. conception from September through April). Scimitar-horned oryx females respond poorly to superovulatory hormone treatments given from February to April (Pope *et al.*, 1991; Schiewe *et al.*, 1991) which also supports the concept that ovarian function and/or sensitivity are compromised during periods of increasing photoperiod in North America. Whereas photoperiod is a common environmental cue in temperate regions to time breeding events in seasonally reproductive species, it is generally accepted that variations in temperature, rainfall and hence food availability provide the proximate cues for regulating reproduction in species living in arid habitats. In particular, nutritional status in wild oryx is likely to be variable and may affect reproductive capability. However it is unlikely that the anovulatory periods observed in this study were due to nutritional status because the oryx at CRC are on a managed nutrition programme and the anovulatory period occurred in the Spring. Sicard *et al.* (1988) demonstrated that six out of seven Sahelian rodent species retain photoresponsiveness even though daylength varies by less than 2 hours (14 °N latitude). Thus, photoperiod may remain as an important modulator of reproductive seasonality in the scimitar-horned oryx.

The shortest interbirth interval recorded from the studbook data was 241 days, and 75% of the interbirth intervals were less than 332 days. Similar interbirth intervals have been reported in the scimitar-horned oryx (Newby, 1975; Nishiki, 1992) and other Hippotraginae species (Joubert, 1971; Sekulic, 1978; Wachter, 1988; Stanley Price, 1989; Sempéré *et al.*, 1996). Based on this information and a gestation interval of ~250 days, it appears that the scimitar-horned oryx experiences oestrus and ovulation soon after parturition, with the majority of conceptions occurring within the next 3 months. Postpartum oestrus has been suspected to occur in captive (Knowles & Oliver, 1975; Nishiki, 1992), reintroduced (Gordon, 1991) and wild (Newby, 1975) scimitar-horned oryx. Gillet (1966) and Newby (1988) concluded that wild scimitar-horned oryx in Chad could breed continuously under favourable climatic and nutritional conditions with a marked birth peak every 8–10 months, but that the pattern was disrupted in years of drought. An 8–11 month reproductive periodicity was confirmed by our retrospective analysis of captive births in North America. Assuming that a postpartum oestrus and mating are common in this species, then it was not unexpected that under the constant nutritional conditions typical of zoos, scimitar-horned oryx calves can be born every month of the year.

A high priority for the future is to determine if a similar pattern of seasonal anovulation occurs in other scimitar-horned oryx populations and to determine the evolutionary implications of such a life-history strategy.

The reintroduced population in the Bou-Hedma National Park in Tunisia (33 °N latitude) is of particular interest because the founding individuals were captive born at Marwell or Edinburgh Zoological Parks (United Kingdom, 51 and 55 °N latitude, respectively), but now are living on the northern limit of the native range for the species. Thus, a comparison of the reproductive traits of captive scimitar-horned oryx and free-ranging oryx in Tunisia would be of scientific interest.

Although sex ratios in captive scimitar-horned oryx have been reported to be nearly 1:1, evaluated populations never exceeded 65 individuals (Yoffe, 1980; Gill & Cave-Browne, 1988; Nishiki, 1992). In contrast, our analysis of 1129 births suggested that sex ratios in zoo-maintained oryx in North America were male-biased. A predominantly male sex ratio has been observed in several ungulate species (for a review, see Hoefs & Nowlan, 1994). The 19.1% calf mortality rate in the North American population was similar to the incidence of mortality reported for other Hippotraginae species (7.5–28.0% for Arabian oryx, Stanley Price, 1989; Vié, 1996, and 17.8% for fringe eared oryx, King & Heath, 1975).

Twin births are uncommon in both the scimitar-horned oryx (0.7%) and addax (0.4%, Densmore & Kraemer, 1986). It has been speculated that the low frequency of twinning in Hippotraginae antelope may reflect anatomical limitations imposed by a duplex uterus and bifurcated cervix that are characteristic of the subfamily (Hradecky, 1982; Mossman, 1989), including the scimitar-horned oryx (Pope *et al.*, 1991; Schiewe *et al.*, 1991; Morrow, 1997). If two embryos were competing for space in the same uterine horn, the complete division of uterine horns would prevent expansion of foetal membranes into the opposite horn.

Age of sexual maturity (from studbook data) fell within the range of 10–39 months, an interval previously proposed by others (Newby, 1975; Durrant, 1983; Gill & Cave-Browne, 1988; Nishiki, 1992). Although no comparative data exist for wild oryx, our analysis indicated that captive individuals had the capability to remain reproductively competent beyond 20 years of age. Overall, zoo-maintained scimitar-horned oryx have high reproductive potential due to the combination of low calf mortality, adult longevity and an 8–11 month interbirth interval.

Due to the lack of viable, wild populations, the maintenance of genetic diversity in the scimitar-horned oryx, and perhaps species survival itself, is inextricably linked to *ex situ* breeding programmes. Efficiency of such programmes potentially could be increased by applying advances in reproductive technology, such as synchronization of ovulation, semen cryopreservation and artificial insemination. These approaches are particularly attractive for moving germ plasm among geographically dispersed individuals or populations and for overcoming occasional cases of mating incompatibility in genetically paired animals. However, detailed knowledge about the fundamentals of reproductive biology, including the life history information generated in this paper, is an essen-

tial prerequisite to successfully applying assisted breeding (Wildt *et al.*, 1992). We are particularly strong advocates for using non-invasive hormone monitoring as a means of safely and effectively understanding basic reproductive mechanisms in timorous species such as the oryx. For example, our hormonal results implied that little or no effort should be made to breed scimitar-horned oryx in spring in North America. Finally, this study has re-confirmed the value of studbooks as a source of useful scientific information for researchers and genetic managers of endangered species.

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