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# Lunar Effect on Thoroughbred Mare Fertility: An Analysis of 14 Years of Data, 1986–1999

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## Abstract

It became possible to access the yearly studbooks of a major UK Thoroughbred stud-farm. By comparing these with subsequent published records of horse-breeding, one could compare the coverings between mares and stallions with the outcome as to whether or not a registered conception occurred. The coverings went on seven days a week with no interruption, over the breeding months of early spring and summer, and so offered an opportunity to test hypotheses concerning the lunar phase cycle. Since the studbooks began, vets have been able to detect the onset of estrus every three weeks, so that the covering dates give a fairly unerring record of mare estrus. Two logically distinct parameters were here tested: the extent to which the onset of estrus was related to the lunar month, and then whether the proportion of successful coverings varied with the lunar month.

A total of 14 successive years of studbook data was recorded and tested in this manner, partly to average out irregularities in lunar angular speed resulting from the apogee-perigee cycle (linked to the 9-year apse cycle) and partly to be able to investigate whether the 18.6-year nutation cycle would affect the way in which the lunar-month cycle worked. This notion came from geomagnetic surveys, which have showed a sizeable modulation of the geomagnetic field with the synodic cycle, with the modulation of this by the lunar-node cycle. The notion of an influence of the synodic cycle being modulated by the 18-year nutation cycle is supported by the present enquiry. One could choose to view this as, effectively, a 9-year cycle, insofar as no distinction was here made between the two lunar nodes. The method employed five successive lunar-days (one-sixth of the lunar month) to investigate the peaks and troughs of the synodic cycle.

## Introduction

Thoroughbred mares cycle to their three-week estrus period, over the several months of the modern mating-season in spring and early summer, and so one could view it

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as unlikely that any four-week lunar-monthly cycle in their fertility would exist. One finds little by way of folklore on the subject, although in the second century AD Claudius Ptolemy writing in Alexandria averred:

> [farmers] notice the aspects of the Moon, when full, in order to direct the copulation of their herds and flocks . . . and there is not an individual who considers these general precautions as impossible or unprofitable (Ptolemy, 1980).

A discussion by Cloudesley-Thompson of evidence for animal response to the lunar-month cycle emphasized the effect of nocturnal moonlight in the setting of biological clocks (Cloudesley-Thompson, 1980; Endres & Schad, 2002). The testing of a lunar hypothesis is feasible using mare Thoroughbreds, due to the completeness of their breeding records.

The studbooks at a major horse-breeding stable at Newmarket have been compiled yearly since 1986. The modern method of mare covering was established in the early 1980s, whereby a stallion is put together with a mare once the arrival of its estrus has been reliably diagnosed, normally by a hormonal assay; so that coverings of the mare in a studfarm only happen during the estrus period (Rossdale, 1993). Covering dates from the studbook were correlated with the *Return of Mares* as published by Wetherby's the following year, to ascertain which mares conceived and whether conception and/or a live foal was subsequently delivered 11 months later; and also with *The General Stud Book*, which is published less frequently (the former groups data by stallion, the latter by mare). Thoroughbred racehorses are the only animal for which complete and reliable records exist in this manner, of both conception and birth; the reliability being such that a mere 7% of the cases are 'no-returns,' where no outcome is recorded as to whether conception occurred: usually because the pregnant mare went abroad. The present survey is concerned with whether registered conceptions occurred on the studfarm, and not with whether or not a livebirth subsequently transpired.

A pilot study co-authored by the present writer examined nine years' of data 1986–94 (Kollerstrom & Power, 2000), and found peaks centred on the day after Full Moon both for total coverings (+7%) and in successful coverings, as resulted in conception (+15%). Fertility was defined *as the proportion of coverings which led to conception*, and averaged 41%. This ratio tended to peak around the Full Moon each month and to decrease around the first quarter a week earlier. This effect of the 29.5 day lunar cycle upon fertility was examined for mares under 13 years.

That pilot study utilised the method of lunar-day numbers (LDNs), whereby noon of 'day one' follows immediately after New Moon (i.e., 0° Sun-Moon angle). That puts the Full Moon around day 14–15. The latter can vary by several days as the Moon's speed varies with the position of perigee (nearest monthly approach of the Moon). The scores for mare converings were grouped by these 29 days, then scores for each sequence of five days centred on the day after Full Moon were summed. Another 5 years of data from the same studfarm have since been collected, to test these findings.

The Earth's geomagnetic field has been shown to respond to the synodic lunar cycle, with a peak at Full Moon or just after, and a minimum a week or so before, in the first lunar quarter (Bell & Defouw, 1964; Stolov & Cameron, 1964). It has further been shown that this response is greatly modulated by the lunar latitude of syzygy (Bell & Defouw, 1966) (i.e., the line or axis connecting the Full and New Moon positions). Modulations in the geo-magnetic field therefore offer a valuable analogy and even to some degree an explanation for comparable modulations found in mare fertility, in relation to the synodic month. As one review of the evidence for GMF modulation by the synodic month put it: ‘It is reasonable to suppose that lunar modulation effects are more likely to occur, or will be more pronounced, when the moon is near the plane of the ecliptic’ (Schneider, 1967).

The Moon swings some five degrees either side of the ecliptic each month, crossing at the nodes, so the lunar nodes are where ecliptic lunar orbit plane intersect. Their position defines the latitude of the Moon, and they revolve against the stars once per 18.6 years. The Sun’s motion against the lunar nodes (Fig. 1) produces the two ‘eclipse seasons’ of the year. What we may call ‘low node’ syzygies happen during or near to these eclipse seasons, with Sun-node angle between 0–45° (Fig. 3): these are Full and New Moons of low latitude, c. 0–2° from the ecliptic. During the rest of the year, when the Sun is at 45–135° from the node axis, ‘high node’ Full and New moons occur, which can be up to five or six degrees away from the ecliptic.

Reviewing evidence for possible lunar cycle effects upon man, Smith and Best argued, somewhat by analogy with the above, that the celestial latitude of syzygy was a key to how strong or weak lunar influence was perceived to be (Smith & Best, 1989). We here endeavour to test this hypothesis. It may here be relevant that researches on biological and climatological effects of the 18.6-year nutation cycle have been published by Currie et al. (Currie & Hameed, 1986; Currie, 1987; Currie, Wyatt & O’Brian, 1993). The 9.3-year nodal half-cycle has sometimes turned out to be dominant in these studies, implying a symmetry between the two nodes. The present enquiry is concerned with the modulation of the synodic cycle by the nutation cycle, in a way that does not distinguish between north and south nodes, and in that sense uses a 9.3-year modulation of the lunar month. Fourteen years of consecutive data should, therefore, suffice for an initial study.

## Method

Two methods for mapping this data onto the lunar month were used. Firstly, the data was plotted by Sun-Moon angle at noon of covering date, putting Full and New moons at 180° and 0°. Each covering was scored 1 or 0 according to whether or not conception occurred, and a moving average expressing the mean value as a percentage was then drawn through the points. Its size was arbitrarily adjusted to some 10% of the data used, so that it spanned 36° of Sun-Moon angle. The larger its span, the more smoothed-out will the curve appear. Thus fertility values were plotted as $100 \times \{\text{conceptions/coverings}\}$ over the designated range.

Secondly, the LDN method was used to divide up the data. Statistically this method is preferred, because each of the 29 lunar-days has an equal expected frequency. One counts from the New Moon position each month, discarding a half-day’s data as the month has 29.5 days. The problem with this method is that its Full Moon day-number will vary by several days depending on the Moon's varying angular velocity, which varies with the location of perigee (its nearest monthly approach to Earth): the Moon there moves almost 30% faster than it does at apogee (its furthest distance). This is one reason for conducting such an enquiry over at least nine years, because this is the period of rotation of the apse line (the line joining mean apogee and perigee positions), and so the inequalities thereby generated will tend to even out. To assign LDNs, the data was first sorted into a chronological sequence by date, having found the Sun-Moon angle for noon of each covering day: the counting of days began anew each time that angle jumped back from 360 to zero, that is, at the New Moon position. These two different methods, one mapping by time and the other by space, should give similar results.

In order to examine the possible relevance of lunar nodes, all mares of 13 years or older were excluded from the survey, to create a more uniform population. Race-horse mare fertility peaks around 6–7 years, and declines fairly rapidly after 12 years of age, as well as which older mares are mated somewhat later in the season, as could further complicate any observed lunar-monthly patterns. Thus, from an initial group of 4,891 coverings, the no-return cases were excluded to give 4,557 coverings, then excluding older mares left a group of 3,428 coverings, which took place between 1,656 mating-pairs (1986–99).

## Lunar nodes

Twice a year the sun draws near to one of the lunar nodes (or, it appears to owing to the Earth's motion), when the 'eclipse seasons' happen. A 45° sun-node angle (Fig. 1) was here used to distinguish whether the Sun was near to or far from one of these nodes. The data was thereby divided into two roughly equal halves according to the Sun-lunar node angle: sorting the data by the angle 0–180° between the Sun and a lunar node, in celestial longitude, and separating out according to its magnitude.

Then, the two groups thus obtained were plotted by Sun-Moon angle, centred on Full Moon. Summarising this four-stage process: first, 'no-return' coverings were excluded, losing 7% of the data, then mares over twelve years were excluded, losing another 22%; then the data was sorted by Sun-node angle to divide it into two roughly equal parts; and, lastly, each of the two groups thereby generated was sorted by Sun-Moon angle at covering date. Suitable moving-averages were put through the data and plotted. The last step was repeated using the 29 LDN totals for comparison, and tables were generated from these totals, taking four unit groups of five consecutive 'lunar-days' centred on the days after Full Moon, New Moon and quarters. Both total coverings and the 'fertility' ratio were estimated within each of these groups. For comparison, five days correspond to some sixty degrees of Sun-Moon angle.

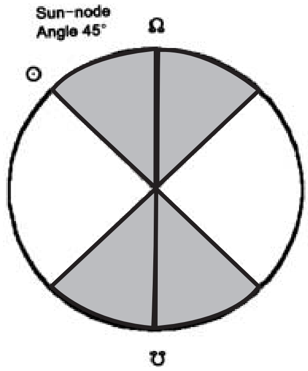


*Figure 1.* Lunar node axis on ecliptic, showing the 5° tilt of the lunar-orbit plane, and the equal 45° divisions of Sun-node angle in the ecliptic here used.

## Results

### General

Seventy-eight percent of mares were covered during the three months March–May. There were on average 2.1 coverings per mare each season and 10% of the mares used were barren. Mares aged 5 to 7 years had a mean fertility of 44% whereas for those aged 14–20 years (excluded from the present survey) it was 35%. On average this studfarm had 165 mating-pairs per season, however this number shrunk somewhat over the years of the survey, with the last 3 years (97–99) having 31% less than the first 3. The mean fertility, however, did not change: it was 41.3% for the first 3 years and 41.4% for the last 3, which is reassuring for the present enquiry. There were 11% less mare coverings at weekends, overall, than on weekdays. The ratio of livebirths to deadbirths (abortions, slipped foal, etc.) was about 10 : 1, no linkage of which was found to the lunar month.

### Lunar month

The frequency of mare coverings over the 14 years, plotted around the lunar month, is shown in Figure 2. This indicates that mare estrus, as indicated by the covering dates, tended to a fairly sharp minimum around the first quarter, then peaked around the Full Moon and for about a week afterwards. What we have defined as fertility (conceptions per covering, %) as a function of the lunar month is shown in Figure 3. This shows a more notable peak around and just after the Full Moon. The two graphs depict distinct biological functions: the three-weekly arrival of estrus, and then the likelihood that a covering performed during the days of estrus will be successful, i.e. lead to conception. Table 1 shows these two functions, over four groups of five

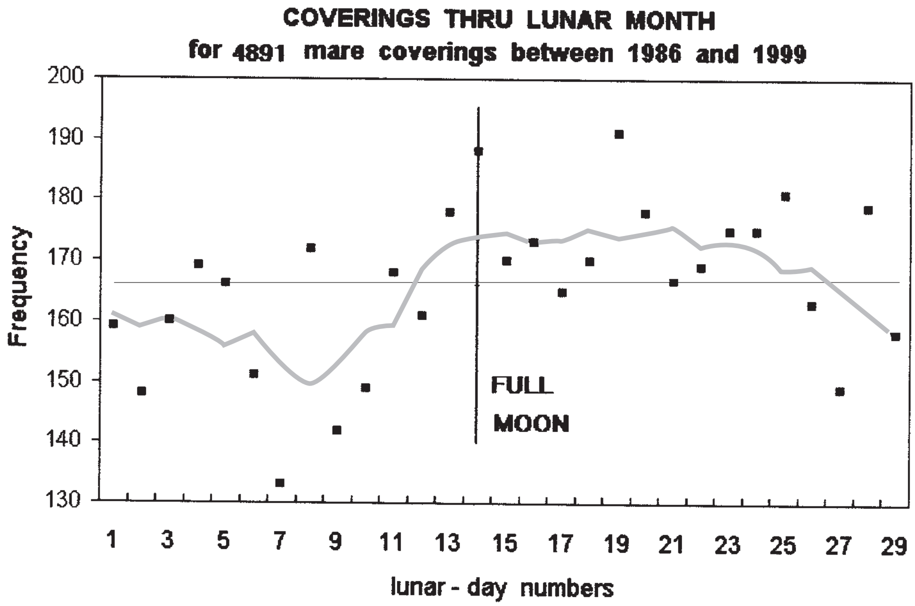


*Figure 2.* Mare coverings per lunar day (New Moon = day 1) summed over 1986–99, with a five-point moving average shown as a continuous line.

consecutive LDNs around the lunar month (i.e., using 20 out of the total of 29): coverings expressed as a total sum and fertility as a percentage ratio.

Both of these graphs (Figs. 2 and 3) show a differential between the minimum at first-quarter and the maximum at Full Moon. Mare fertility averaged around 40%, and using the groups of five lunar-day numbers (Table 1), this was found to increase by 3.8% over the Full as compared to the New moon period; while a larger swing of 5.3% happened from the First Quarter to the Full. For comparison, Figure 3 shows a swing in some eight percent overall, over a period of just over one week in the lunar month (NB. the ‘no-return’ coverings, included in Figure 2, were excluded from Figure 3, so the latter has a smaller database).

## ‘High-node’ moons

For this further study, mares over 12 years were excluded. Then, excluding that half of the data having syzygy at low celestial latitude, Figure 4 plots mare fertility within the lunar month: here the swing around Full Moon appears as 10–12%, within less than a week. This suggests an effect of comparable magnitude or possibly even larger to the difference due to age: as we saw, between peak-fertility mares and those older

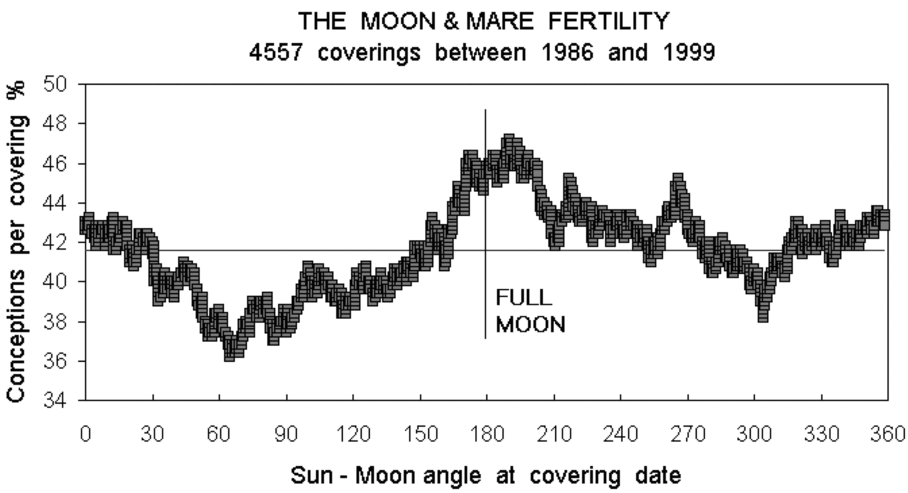


*Figure 3.* Percent fertility in the lunar month using Sun-Moon angle at noon of covering date (New Moon = 0°), plotting a 550-point moving average, covering 11% of the data: each of the 4557 points here plotted thus represents an average value (100 × No. conceptions / No. coverings), where separate points are 1 or 0 according to whether conception took place; each value spanning about 40° of Sun-Moon angle (This angle moves 13° a day).

*Table 1.* Mare fertility vs Lunar month for four sets of five consecutive 'lunar days' centred on the day after FM, NM & quarters; for 2,160 mating-pairs, 4,557 coverings and 1,896 conceptions.

| Total | Coverings | Concep$^n$ | Fert$^y$. |
|---|---|---|---|
| 1st Quart. | 717 | 285 | 39.8 |
| Full M.: | 819 | 369 | 45.1% |
| 3rd Quart. | 802 | 331 | 41.3% |
| New M.: | 739 | 307 | 41.5% |
| Excess FM/NM: | 11% | 20% | |
| Excess FM/1stQ. | 14% | 29% | |

(For the 369 FM conceptions, expect 321, $X^2 = 7$, $p < 0.01$).

there was a mean difference in fertility of 9%. While the effect of the Full Moon appeared strongly in the 'high node' half of the data, when the Moon was furthest from the ecliptic, it appeared as entirely absent from the 'low node' half (Fig. 5). Figures 3, 4 and 5 have been plotted over the same (y-scale) range of fertility values

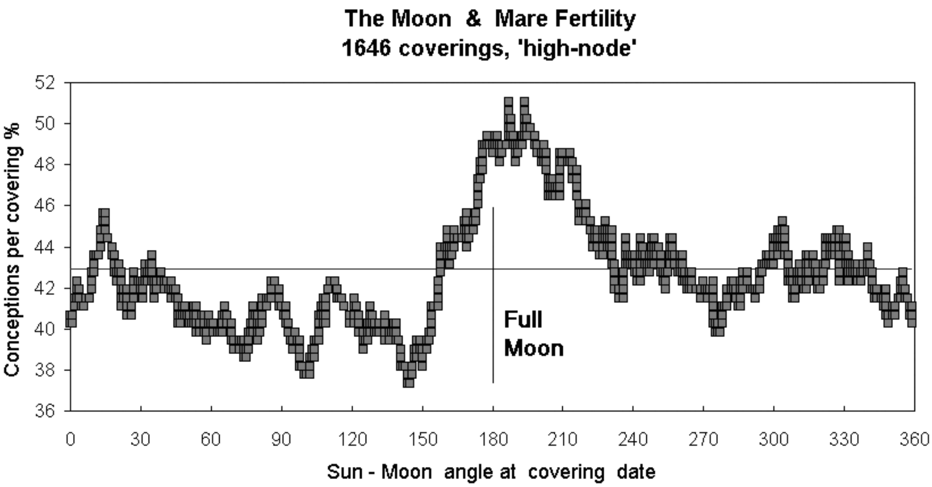


*Figure 4.* Mare Fertility in lunar month, 'high node' As for (2), but excluding over-twelve year mares, and plotting covering dates for Sun >45° from nodal axis.

to facilitate comparison. Figure 3 used a 550-point moving average spanning 11% of the total data, while the smaller samples in Figures 4 and 5 have a 240-point moving average which spanned slightly more, c. 13% of the total (The mean fertility values in Figs. 4 and 5 are elevated as compared with Figure 3, due to the exclusion of older mares).

Comparing the total number of conceptions that resulted from the coverings made over the five LDN groups (Table 1): their overall increase from First Quarter to Full Moon was 29%. Table 2, selecting only the 'high node' half of the data, shows how this ratio then increased up to 41%, while it reduced to a mere 14% for the 'low-node' group (Table 3), with its syzygies near to the ecliptic. Figures 3–5 illustrate the data sets used in, respectively, Tables 1–3.

## Discussion

Peaks both in mare coverings (estrus) and in fertility (% successful coverings) tend to synchronise on or just after Full Moon. This effect is asymmetric, with no equal and opposite minimum two weeks later at New Moon; rather, a minimum tends to appear a week earlier, in the first quarter. The magnitude of the peak at or just after Full Moon appears to depend on lunar latitude, with the effect virtually disappearing at the 'low node' periods. This unexpected result could suffice to explain the absence of folk-traditions about mare fertility and the Moon: one might not easily experience this pattern, if it vanished for some months depending upon Sun-node angle. There

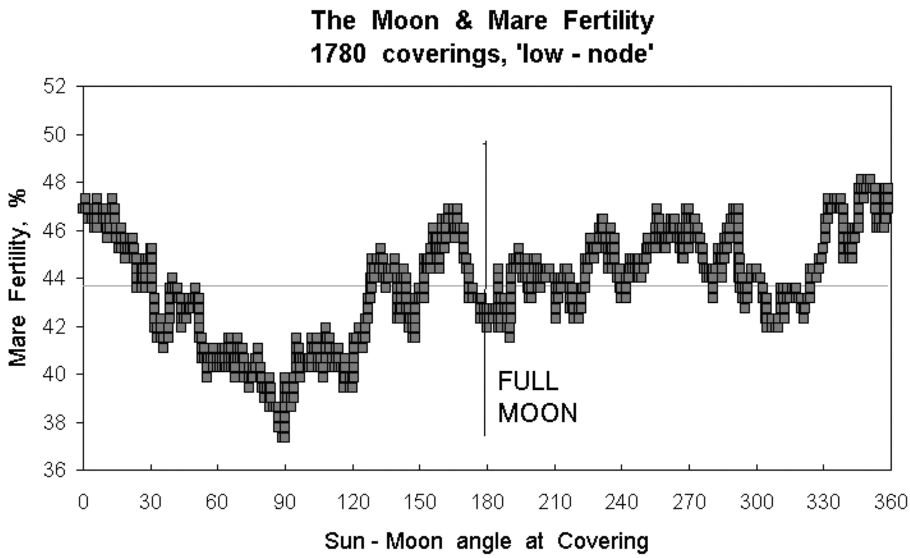


*Figure 5.* Mare fertility in lunar month, 'low node' As for (4), for Sun <45° from nodal axis.

*Table 2.* As in Table 1, but excluding mares over 12 years of age, then excluding that half of the data with Sun-node angle <45°; for 809 mating-pairs, 1647 coverings and 707 conceptions.

| 'High-Node' | Coverings | Concep$^{n}$ | Fert$^{y}$. |
|---|---|---|---|
| 1st Quart. | 243 | 99 | 40.7% |
| Full M: | 296 | 140 | 47.3% |
| 3rd Quart. | 287 | 119 | 41.5% |
| New M.: | 254 | 112 | 44.1% |
| Excess FM/NM | 17% | 25% | |
| Excess FM/1stQ. | 22% | 41% | |

is some analogy with the Moon's effect upon the geomagnetic field, but the nodal effect here described is the converse of that observed for the Earth's geomagnetic field, where surveys found that lunar-month modulation of the GMF was maximal during the 'low-node' (i.e., eclipse season) months.

The effect here described warrants further investigation, and a further set of data from a studfarm of comparable size, over the same 14 years and in the southern hemisphere would be ideal. Modern racehorse-breeding is artifically compressed into a few months of the year, mainly March to May, and this compression can readily induce artefacts in an investigation of lunar cycles, should not enough consecutive

*Table 3.* As in Table 1 but where Sun-node angle <45°; for 847 mating-pairs, 1781 coverings and 778 conceptions, where 'fertility' is the ratio {conceptions / coverings} %.

| Low-Node | Coverings | Concep$^{n}$ | Fert$^{y}$. |
|---|---|---|---|
| 1st Quart. | 286 | 119 | 41.6% |
| Full M.: | 307 | 136 | 44.3% |
| 3rd Quart. | 309 | 137 | 44.3 |
| New M.: | 302 | 132 | 43.7% |
| Excess FM/NM | 1% | 3% | |
| Excess FM/1st q. | 7% | 14% | |

years be taken. The Sun-node angle is related to the seasons because the nodal axis moves quite slowly, and so another data-set with different seasons would be of value in enabling the relevant solar-lunar equations for mare fertility to be correctly ascertained.

I'd be happy to donate the database here used to any university department interested in this subject.

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