**An Upper Palaeolithic proto-writing system and phenological calendar. Supplementary information.**

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# *Our database*

We compiled our database (spreadsheets 1 and 2) from the literature. For *general works on Upper Palaeolithic art* we consulted Piette 1907; Graziosi 1960; Kozlowski 1992; Guthrie 2005; Clottes 2008; Cook 2013; Bahn 2016. For *non-figurative signs* see, for example, Leroi- Gourhan 1979; Sauvet 1987; Sauvet and Sauvet 1979; Chollot-Varagnac 1980; Villaverde-Bonilla 1994; Bahn and Pettitt 2009; von Petzinger 2009; Cleyet-Merle et al. 2014; d’Errico et al. 2017. For *interpretations of Palaeolithic art as astronomical phenomena* we consulted Hayden and Villeneuve 2011; Jègues-Wolkiewiez 2005; Müller-Beck 2001; Rappenglück 1999; 2003; 2008. Schmidt-Kaler 2008; Sweatman and Coombs 2018.

*Association of signs with animal depictions*: Sauvet and Sauvet (1979) noted that a repeated theme in Palaeolithic imagery was that of an animal in association with sequences of dots/lines, spanning the Aurignacian to the Magdalenian, i.e. period of our database. Guthrie (2005, 152–209) noted the association of ‘mysterious’ red dots with animals, e.g. in Chauvet Cave, where a horse has three red dots below its muzzle, although he concluded that the dots depict blood splatters from either a real or totemistic hunt, a hypothesis which obviously cannot be tested. Though the occurrence of dots/lines with animals has often been noted by Sauvet (1987), Guthrie (2005), and Leroi-Gourhan (1979 343–66), amongst others, it has never, to our knowledge, been proposed that the dots/ lines with animals are numbers, with the exception of Marshack’s observation that there were three and six ‘sky arcs’ on a salmonid plaquette at Labastide (Marshack 1991, 232). Other than Marshack, to our knowledge it has not previously been proposed that they are in fact numbers.

For information on *archaic writing systems* we consulted: Driver 1948; Bottéro 1992; Bottéro et al. 2000, Glassner 2003; Robinson 2016; Woods 2010 in additions to references cited in the main text. We follow the definition of Robinson 2016 for ‘Proto-writing’, which ‘consists of visible marks communicating limited information’. Pictographic-logographic writing is independent of language: Writing about Sumer and adjacent regions, for example, Bottéro (1992), defined pictograms as ‘2-dimensional semi-standardized representations of real world objects’ noting that ‘[pictographic-logographic writing] was independent from any spoken language, and the signs were legible whatever the language of the interpreter’.

Upper Palaeolithic *archaeozoological data* (including seasonality) was taken from: Delpech 1983; Gordon 1988; Martin 1999; Rendu 2007; Bignon-Lau 2008; Kuntz 2011; Goutas & Laccarièrre 2012 in addition to references cited in the main text. In Germany, reaction to changes in the season is referred to as *zugunruhe* for birds (‘migration anxiety/restlessness’). We hypothesise that spring, therefore, with its obvious return of warmth, green, light, plant and animal life would, therefore, be a logical starting point for a hunter-gatherer calendar, especially one dependent on the world returning to fruitfulness after the barren Pleistocene winter. For ichthyological data see Le Gall, 1981; 1984a,b; 1992; 1999. The times for the behaviours indicated in **Table 1** of the main paperare based on both contemporary and archaeozoological data (Delpech 1983; Gordon 1988; Martin 1999; Rendu 2007; Bignon-Lau 2008; Kuntz 2011, Goutas & Laccarièrre 2013). For the purposes of comparison the data for contemporary animal behaviours, which are based on a modern calendar commencing on January 1, have been adjusted to be in approximate accordance with a Palaeolithic calendar hypothetically commencing in late Spring, so that mating for Bison, which would happen in August or Month 8 in a modern calendar commencing January 1, would be given the approximate Palaeolithic calendar time of Month 4. The comparison of the modern and Palaeolithic calendars is only approximate since the modern calendar has a fixed and invariable start date of January 1 and the Palaeolithic calendar has a local variable start date based on a local meteorological event such as the melting of river ice, first appearance of migrating birds, etc. The approximate start of the Palaeolithic calendar is arrived at by analysing the peaks observed in the data, observing the intervals between the data and the intervals in important animal behaviours, comparing peaks between the different prey species, and working back to determine the approximate start of the Palaeolithic calendar year. We estimate that the approximate difference between the Palaeolithic start of the calendar and our modern calendar is ~3.7–4 months.

*Further discussion of issues relating to signs and the function of artificial memory systems*

*Dots/lines as numbers*: In the view of Tang et al. (2008), subitization (the mental processing of quantity/numbers under 4 common to most animals) was followed by numerosity, a uniquely *Homo sapiens* ability, which is the use of numbers over 4, processed in a different part of the brain to the numbers under 4. The use of numbers over 4 generally involves using some kind of aid, either pointing with a finger or counting off on fingers. Initially, and to this day, humans used fingers and other body parts, counting off on our fingers and establishing one-to-one correspondence between the objects being counted and our fingers. This system is limited to about 20, more if the system in a particular culture uses other body parts such as the head, elbows, etc. (Overmann 2013; Wynn 2016) In the view of Overmann, d’Errico, Henshilwood and others, strung beads from Blombos Cave, South Africa (~77,000 BP), engraved and notched artefacts from the African Middle Stone Age, and notched and engraved artefacts from the European Upper Palaeolithic served the purpose of ‘material scaffolding’, replacing fingers as a counting mechanism. Such scaffolding enabled the use and recording of numbers much larger than the number of available body parts, and allowed the permanent recording of numbers in a material form (Henshilwood et al. 2004; d’Errico et al. 2005; Overmann 2013; Wynn 2016). To this day we use ‘scaffolding’ in the form of fingers, calculators, abaci, pencil and paper, Excel spreadsheets, lines scratched on a prison wall, etc.. Only very rare individuals can use large numbers without some kind of written or material aid. Though this ‘scaffolding’ onto objects other than body parts allowed much greater use of numbers to develop, it had the same disadvantage that using body parts had, in that *what* was being notated was only available through oral information, not written information. This may be a result of the system developing from the use of using body parts, which relied on oral information to understand the meaning of the number of body parts enumerated. The end result is that the meaning of these notated objects is presumably only available to the limited number of people who had access to the necessary oral information.

*‘Signs’ as decoration*: there has been a recent tendency to generalise that Upper Palaeolithic ‘art’ was primarily aesthetic in drive, but with strong cultural, shamanistic, and spiritual content that expressed strong spiritual ties between Upper-Palaeolithic hunter-gatherers and nature. Paillet (2014) referred to the signs in the caves as ‘symbolic ornament’. Jean Clottes (1996) also believes that the primary function of the caves and their art is spiritual and shamanistic; Lise Auriére, Carole Fritz, and other recent scholars refer to the marks on portable objects as ‘decoration’ or ‘ornament’ (Fritz 1991), an integral part of the artistic essence of the images (Aurière et al. 2013). More recently, von Petzinger (2009) created a partial systematic database of painted parietal signs, although she advanced no interpretation of the meaning of any specific examples. Although believing that the signs possibly constitute writing—because of their consistency of form over ~30,000 years and be- cause they frequently appear together in regular associations—she suggests that their meaning is primarily ‘abstract’ and ‘symbolic’ and may prove impossible to re-read. To date, therefore, there have been no generally accepted suggestions as to what any of the signs mean or in what wider information system they functioned.

*Engraved plaquettes:* One of the most notable aspects of portable art is that engraved stone plaquettes were often over-engraved or -painted, and then broken, burnt, or otherwise reused before being discarded (Sieveking, 1987a, b; Tosello, 2003; Gaussein, 2012; Rivero, 2014). The destruction of plaquettes would run counter to our hypothesis if the creation of an artistic plaquette *was an end in itself*. If, however, they were instead a means of keeping records of observed animal behaviour such as birth, mating, migration, etc. that could otherwise vary somewhat from year to year, then it would be natural to discard or destroy through redeployment a plaquette that had been over- written several times in order to make sure that information remained legible and current. While we do not wish to deny any aesthetic or pedagogic function of the image of the animals themselves, we are stressing that it was the *written* information that was critical to the unit’s importance. Once this information was no longer current, or couldn’t be read legibly, the object lost its ethological value and was repurposed or discarded.

*Numerosity:* Overmann posited that the acquisition of numerosity, and thus the quantification of time, would lead to development of more accurate notational systems of the year. In her view stellar observations—heliacal risings, etc.— would require detailed observations over years from a constant location to become precise and would probably not be used in an early calendar (Overmann 2013; Kelley and Malone 2005; Wynn et al. 2016)). She posits that noting the position where the sun rises or sets on the horizon would be an aid in gauging the advance of the seasons, but the moon, in her view, was the obvious candidate for a more precise time quantification system. She suggests that the recurrence of the complete cycle of the moon’s phases, and the recurrence of the four individual phases of the moon, would provide a framework, aided by material scaffolding, for quantifying time. A longer lunar cycle of ~29 days could be accurately subdivided into four lunar phases of ~7 days. The cycle is short, repeats regularly, is clearly visible, and the progression of time is accurately marked in an easily observable and predictable cycle, the four phases of the moon (Jègues-Wolkiewiez 2005). References for innate number sense: Flegg 1984; Dehaene 1997; Dehaene et al. 1993; Newcombe 2002; Fias & Fischer 2005.

*Lunar calendars:* Marshack (1991) suggested that Upper Palaeolithic groups used lunar (as opposed to solar) calendars, dividing each lunar cycle into four phases of seven days each—New Moon, First Quarter, Full Moon, and Last Quarter Moon. It is likely that the New Moon was identified with the First Lunar Crescent (as it was in many ancient calendars), since a New Moon is not visible except at a solar eclipse (Neugebauer 1975). Marshack expanded on this theory, using notched bâtons and engraved stone plaquettes from Le Placard, Grotte du Thaïs and other caves, suggesting that the patterns of dots on these artefacts corresponded numerically with a four-week lunar month based on the four major phases of the moon, and postulating that the patterns of engraved dots/lines/cupules represented the moon as it went through these from First Crescent to Full. Overmann and Wynn also posit that the observation and use of a lunar-phase calendar would be a logical use of the acquired use of ordinality (Jègues-Wolkiewiez 2005; De Smedt et al. 2011; Overmann 2013; Wynn et al. 2016).

Recent analysis of the Abri Blanchard artefact by Jègues-Wolkiewiez (Jègues-Wolkiewiez 2005; Overmann 2016) would indicate that the Upper-Palaeolithic people not only carefully observed the moon but conducted this observation over long periods and then recorded their observations in permanent form— ‘material scaffolding’ (d’Errico et al. 1994; Overmann 2013, 2016). This is a conclusion reached by Marshack, amongst others. The sophistication of the Abri Blanchard artefact would be compatible with the use of a detailed lunar calendar, and given its sophistication, is presumably a *terminus ante quem* for the innovation. Carefully noting the moon and then recording their observations would also suggest that the recording of facts about their environment in material form was practised in the Upper Palaeolithic. Presumably the critical factors in their environment would be the progression of the seasons, the behaviour of animals, and the cycle of plants, upon which they depended for food. Using their acquired skill in numerosity and ordinality to make these systems more efficient, productive, and reliable, would be logical. What is interesting about the Abri Blanchard artefact is that Jègues-Wolkiewiez could only establish that the pattern on the artefact was the moon’s analemma and phases by visually comparing the pattern of the data on the artefact with the pattern of data compiled from the French Bureau of Longitudes. There does not appear to be a sign on the artefact that would indicate ‘Moon’ and thus instantly convey its meaning. Presumably Jègues-Wolkiewiez could only determine that the information recorded was about the moon because the analemma of the moon is so distinctive, presumably unique. In this sense the Abri Blanchard artefact is functioning in the same way as the notched batons and stones, utilizing ‘Material Scaffolding’, in that it records numerical information but does not specify what the information is about. This is an important point, and we will return to it later, but it would indicate that the system of notation used in the Abri Blanchard artefact had not yet evolved to where it would/could indicate what the notational information was about, though the Venuses from Laussel (~22,000 BP) and Dolní Vestonice (~29,000 BP) combine both sign (<Y>) and meaning (female image), and are of roughly similar age.

*Calibrating the lunar calendar with the start of* bonne saison: Marshack demonstrated that the lunar calendars keep count of all 29/30 days in a lunar month and that the four main phases of the moon—New Moon (First Crescent), First Quarter, Full Moon, and Last Quarter—were accurately recorded (Marshack 1991). This being so, then it may be that when *Bonne Saison* commenced the main phase of the moon was noted and all subsequent months began with that phase—for example, if *Bonne Saison* fell on the First Quarter Moon, then the recording of all subsequent months would begin with the First Quarter Moon. De Smedt and others note the precision with which hunter-gatherers note the progression of the lunar phases (2011). This would be easy to observe and would allow a synchronisation of the lunar calendar and the *Bonne Saison* within an accuracy of approximately three days (the transition between phases of the moon is gradual and it may have been necessary to wait for two or three days before a phase of the moon was clearly visible). Marshack (1991) notes the recurrence of units of seven dots/lines/cupules (corresponding in his model to weeks or phases of the moon) in the portable works he believes are calendars. In his annotation, he doesn’t indicate if he thinks that the lunar calendars commenced with the same or differing phases of the moon; we posit that as the four lunar phases proceed in regular units of ~seven it is possible that months in different years could begin with different phases of the moon. Hence the system of calculating intervals from the start of *Bonne Saison* could operate with great precision. It may well be, therefore, that the primary reconciliation of different time systems in the Palaeolithic calendar was not between the solar year and the lunar month, but between the beginning of *Bonne Saison* and the recording of the corresponding lunar phase, and that this happened at the beginning of the year rather than at its end.

*Further details of statistical methods:* We want to know whether the number or ordinal position of marks associated with depictions of particular species correspond to the months in which those species engage in specific behaviours (mating, birth, spring and autumn migration). To conduct this analysis, we organise our data so that there are separate records for each of 13 months for each species. In each record there are variables corresponding to birth, mating, spring and autumn migrations. These variables have a value of 1 if the species engages in that behaviour in that month and a value of 0 if they do not. So, for example, ‘birth’ would have a value of 1 for month the ‘Auroch: Month 2’ record, but a value of 0 for ‘mating’ (Aurochsen give birth in month 2, but do not mate until month 4). In addition to the variables indicating whether behaviours do, or do not, take place in a specific month we also have variables indicating the number of times we observe numbers or ordinal positions of marks associated with that species that correspond to the numerical value of that month. So, for ‘Auroch: Month 2’ we have variables that indicate the number of times we observe sequences of 2 dots or lines, the number of times we observe a <Y> symbol in position 2 of a <Y> containing sequence, and the number of times we observe sequences a <Y> containing sequence of length 2.

Given this way or organising the data we can test whether a particular behaviour has more marks with values (number or position) corresponding to the month of the year in months when the behaviour takes place than in months where the behaviour is absent. We could either test whether number or position predicts the occurrence of a behaviour or vice versa. We can also test whether adding additional predictors significantly improves our prediction compared to using a single predictor (so, for example, does the combination of number of dots and lines together with position of <Y> in <Y> sequences predict birth month better than number of dots and lines alone). We could couch our predictions in either direction (using number or position of marks to predict the presence of a behaviour or using the presence of a behaviour to predict number or position of marks).

As we are particularly concerned about correlations between the position of <Y>s and the total number of marks in <Y> containing sequences confusing our interpretation of results it makes sense to test how well using number or position of marks predicts the presence of a behaviour. By testing the relationship in this direction, we can see whether adding number of marks in a <Y> sequence significantly improves predictions over and above predictions based on <Y> positions alone. We could either start by including all of our predictor variables in a prediction and then removing them one by one, or by starting with single predictors and then testing the effects of adding additional predictors. As we have a clear question regarding the effects of combining number and position in <Y> sequences, and it makes little sense to imagine artists in the upper Palaeolithic using combinations of values to convey simple information, we adopt the latter approach – starting with single predictors and testing the effect of adding additional ones. When we use more than one predictor, we do not include an interaction term as it is unrealistic to think that Palaeolithic artists may have used multiplications of values to represent the timing of behaviours.

In our tests we are using frequencies of number or position of marks to predict presence or absence of a behaviour. We use the statistical procedure of logistic regression when assessing predictions of the values of a binary (yes/no) variable. In the statistical package R we use the procedure ‘glm’ with a binomial family link function, in this case the logistic function to conduct logistic regressions. We test whether our data conform to the mathematical assumptions of logistic regression using the R package ‘DHARMa’ which provides us with tests of deviation, dispersion, and occurrence of outliers for the procedure Note when exploring the data using binary variables to predict frequencies of number or positions of marks with a different method, Poisson regression, the data almost invariably violated the assumption of that test - an additional reason to use logistic regression to predict binary outcomes.

**Predicting species’ birth months.**

All tests of the relationships between variables were conducted using a generalised linear model with a Binomial family link function (logit). All comparisons between models suing different numbers of predictors were conducted using anova with a chi-square test.

**<Y> position predicting Birth months.**

Birth month was analysed with the independent variable frequency of <Y> position value. Birth month (181 observations) **was** predicted by the <Y> positions, b=0.146, z=2.44, p=0.0146

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of marks in <Y> sequences predicting Birth months.**

Birth month was analysed with the independent variable frequency of number of marks in <Y> sequences. Birth month (181 observations) **was** predicted by the number of marks in <Y> sequences, b=0.128, z=2.64, p=0.00835.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of dots or lines in sequences without a <Y> predicting Birth months.**

Birth month was with the independent variable number of dots or lines in sequences not containing a <Y>. Birth month (181 observations) **was not** predicted by the number of dots or lines in sequences not containing a <Y>., b=0.011, z=-0.393, p=0.695

The data conform to the statistical model (all diagnostic tests non-significant).

**Are <Y> position and number of marks in a <Y> sequence independent?**

We should note that although the number of marks in a <Y> sequences was a more consistent predictor of birth month than <Y> position (p=0.00835 vs. p=0.0146), the relationship between <Y> position and birth month was stronger (i.e. the slope of the estimated relationship was higher) than that for number of marks in a <Y> sequence (b=0.146 vs. b=0.126).

Birth month was analysed with independent variables of both frequency of <Y> position value and frequency of number of marks in <Y> sequences (with no interaction term). Interestingly neither predictor was a significant predictor of birth month Birth month (181 observations) was not predicted by <Y> positions, b=0.456, z=1.875, p=0.061, or the number of marks in a <Y> sequence, b=-0.331, z=-1.40, p=0.161. Note that the slopes of the relationships are in opposite directions for the two predictors and that the consistency of prediction from the position of <Y> approaches significance (p=0.061) whereas that for number of marks is far from significance (p=0.161). We would not expect Palaeolithic artists to use a negative relationship between number of marks and the occurrence of behavioural events. It therefore seems more likely that the position of the <Y> was being used to represent birth month.

The data conform to the statistical model (all diagnostic tests non-significant).

An analysis of the effect of adding frequencies of number of marks in a <Y> sequence to an initial prediction based solely on <Y> position frequencies using the ‘anova’ procedure in R does not show any significant additional predictive power (chi-square(1)=2.451, p=0.117).

We conclude that the ordinal position of <Y> in a sequence denoted the months in which different species gave birth.

**Predicting species’ mating months.**

**<Y> position predicting Mating months.**

Mating month was analysed with the independent variable frequency of <Y> position value. Mating month (181 observations) **was not** predicted by the <Y> positions, b=0.0376, z=1.68, p=0.0934.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of marks in <Y> sequences predicting Mating months.**

Mating month was analysed with the independent variable frequency of number of marks in <Y> sequences. Mating month (181 observations) **was** predicted by the number of marks in <Y> sequences, b=0.0603, z=1.98, p=0.0477.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of dots or lines in sequences without a <Y> predicting Mating months.**

Mating month was analysed with the independent variable number of dots or lines in sequences not containing a <Y>. Birth month (181 observations) **was** predicted by number of dots or lines in sequences not containing a <Y>., b=0.0846, z=3.041, p=0.00236

The data conform to the statistical model (all diagnostic tests non-significant).

**Are < Number of marks in <Y> sequences and number of dots or lines independent?**

We should note that the number of dots or lines was both a stronger and more consistent predictor of mating months than number of marks in a <Y> sequences (slopes 0.0846 vs. 0.0603 and p=0.00236 vs. p=0.0477).

Mating month was analysed with independent variables of both frequency of number of dots or lines and frequency of number of marks in <Y> sequences (with no interaction term). In this combined analysis mating month (155 observations – some images are not associated with both <Y> containing sequences and sequences of dots or lines, hence the reduced number of observations) was predicted by number of dots or lines, b=0.832, z=2.77, p=0.00558, but not by number of marks in a <Y> sequences, b=0.00558, z=0.154, p=0.878).

The data conform to the statistical model (all diagnostic tests non-significant).

An analysis of the effect of adding frequencies of number of marks in a <Y> sequence to an initial prediction based solely on frequencies of numbers of dots and lines using the ‘anova’ procedure in R does not show any significant additional predictive power (chi-square(1)=0.0236, p=0.878).

We conclude that the number of dots and lines in a sequence denoted the months in which different species mated.

**Predicting species’ Spring Migration months.**

**<Y> position predicting Spring Migration months.**

Spring migration month was analysed with the independent variable frequency of <Y> position value. Spring migration month (181 observations) **was not** predicted by the <Y> positions, b=-0.0520, z=-0.583, p=0.56.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of marks in <Y> sequences predicting Spring Migration months.**

Spring migration month was analysed with the independent variable frequency of number of marks in <Y> sequences. Spring migration month (181 observations) **was not** predicted by the number of marks in <Y> sequences, b=-0.125, z=-0.760, p=0.477.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of dots or lines in sequences without a <Y> predicting Spring Migration months.**

Spring migration month was with the independent variable number of dots or lines in sequences not containing a <Y>. Spring migration month (181 observations) **was not** predicted by number of dots or lines in sequences not containing a <Y>., b=0.0262, z=1.41, p=0.158

The data conform to the statistical model (all diagnostic tests non-significant).

We conclude that there is no evidence that any position or number of marks denote the months in which species migrate in spring.

**Predicting species’ Autumn Migration months.**

**<Y> position predicting Autumn Migration months.**

Autumn migration month was analysed with the independent variable frequency of <Y> position value. Autumn migration month (181 observations) **was not** predicted by the <Y> positions, b=-15.421, z=--0.012, p=0.99.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of marks in <Y> sequences predicting Autumn Migration months.**

Autumn migration month was analysed with the independent variable frequency of number of marks in <Y> sequences. Autumn migration month (181 observations) **was not** predicted by the number of marks in <Y> sequences, b=-0.0503, z=-0.564, p=0.573.

The data conform to the statistical model (all diagnostic tests non-significant).

**Number of dots or lines in sequences without a <Y> predicting Autumn Migration months.**

Autumn migration month was analysed using generalised linear model with a Binomal family link function (logit), with independent variable number of dots or lines in sequences not containing a <Y>. Autumn migration month (181 observations) **was not** predicted by number of dots or lines in sequences not containing a <Y>., b=-0.0672, z=-0.929, p=0.353

The data conform to the statistical model (all diagnostic tests non-significant).

We conclude that there is no evidence that any position or number of marks denote the months in which species migrate in autumn.

Finally, due to the concern that fish might be outliers in terms of their time of spawning (month 6) compared to other species (where birth occurs much earlier in the RBS year), we re-ran all of our analyses on data excluding fish. Removing fish had no meaningful effect on the statistical results or their interpretation. A summary of the results of analyses excluding fish is given in the following table.

**Summaries of Results with Fish Removed**

**Simple Logistic Regression Results**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dependent  Variable | Predictor | b (slope) | z | p >|z| | Significant |
|  |  |  |  |  |  |
| Birth | <Y> Position | 0.167 | 2.54 | 0.011 | \* |
| Birth | N Marks in <Y> | 0.148 | 2.76 | 0.00575 | \* |
| Birth | N Dots or Lines | -0.00361 | -0.127 | 0.899 |  |
|  |  |  |  |  |  |
| Mating | <Y> Position | 0.0334 | 1.51 | 0.132 |  |
| Mating | N Marks in <Y> | 0.0532 | 1.78 | 0.0753 |  |
| Mating | N Dots or Lines | 0.184 | 3.59 | 0.000338 | \* |
|  |  |  |  |  |  |
| Spring Migration | <Y> Position | -0.321 | -0.513 | 0.608 |  |
| Spring Migration | N Marks in <Y> | -0.542 | -0.911 | 0.362 |  |
| Spring Migration | N Dots or Lines | -0.0364 | -0.523 | 0.601 |  |
|  |  |  |  |  |  |
| Autumn Migration | <Y> Position | -15.1 | -0.011 | 0.991 |  |
| Autumn Migration | N Marks in <Y> | -0.0603 | -0.648 | 0.517 |  |
| Autumn Migration | N Dots or Lines | -0.0612 | -0.827 | 0.408 |  |

**Multiple Logistic Regression Results**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dependent  Variable | Predictors | b (slope) | z | p >|z| | Significant |
|  |  |  |  |  |  |
| Birth | <Y> Position | 0.533 | 1.93 | 0.0533 |  |
| N Marks in <Y> | -0.387 | -1.45 | 0.147 |  |
|  |  |  |  |  |  |
| Mating | N Marks in <Y> | -0.0613 | -1.30 | 0.194 |  |
| N Dots or Lines | 0.215 | 3.51 | 0.000477 | \* |

**Model Comparison Results**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Dependent  Variable | Predictors | Chi-squared | p | Significant |
|  |  |  |  |  |
| Birth | <Y> Position vs  <Y> Position + N Marks in <Y> |  |  |  |
| 2.619 | 0.106 |  |
|  |  |  |  |  |
| Mating | N Marks in <Y> vs  N Marks in <Y> + N Dots or Lines |  |  |  |
| 1.643 | 0.200 |  |

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