

Isopleth Model

Cooperators monitored phenology on reference prairies scattered throughout the tallgrass region, noting the dates which marked the beginning and end of both fall and spring windows (table 1; fig. 1). The resulting data consisted of (X,Y,Z) triplicates, where X = Easting, Y = Northing, and Z = date in Julian format. These data were used to create smoothed response surfaces from which fall- and spring- start and end dates could be extracted. We used SAS PROC G3GRID (SAS 2008) with smoothing parameter set to 1.0 to perform a smoothed spline interpolation of the observed data (table 2). The generated surface can be visualized as one that would be formed if a stiff but flexible, thin metal plate was forced through, or near the observed data points (fig. 2 and fig. 3). By increasing the smoothing parameter, one can create increasingly smooth response surfaces that trade closeness to the original data points for smoothness. We had an a priori belief that changes in phenology across space would be smooth and monotonic; thus we chose a smoothing value (1.0) that gave results with this characteristic. From the smooth surface, we extract fall and spring window start and end dates based on the Easting and Northing of each station (fig. 4; table 3).

Table 1: Reference prairie data points for spring start and end dates during management year 2011. [Easting and Northings are in UTM zone 14]

Reference prairie	Easting	Northing	Spring start	Spring end
Glacial Ridge	714482.51	5286797.86	6/1/2011	6/14/2011
Madison	651197.67	4874276.09	5/27/2011	6/9/2011
Sand Lake	483130.99	5029293.50	5/30/2011	6/9/2011
Chase Lake	481508.58	5220236.44	5/28/2011	6/17/2011
Pembina County	604370.87	5404162.38	6/2/2011	6/20/2011
Tewaukon	605625.78	5107080.54	5/30/2011	6/7/2011
Oakville Prairie	621768.80	5308417.63	6/2/2011	6/16/2011
Morris WMD	740725.16	5052686.43	5/9/2011	6/4/2011

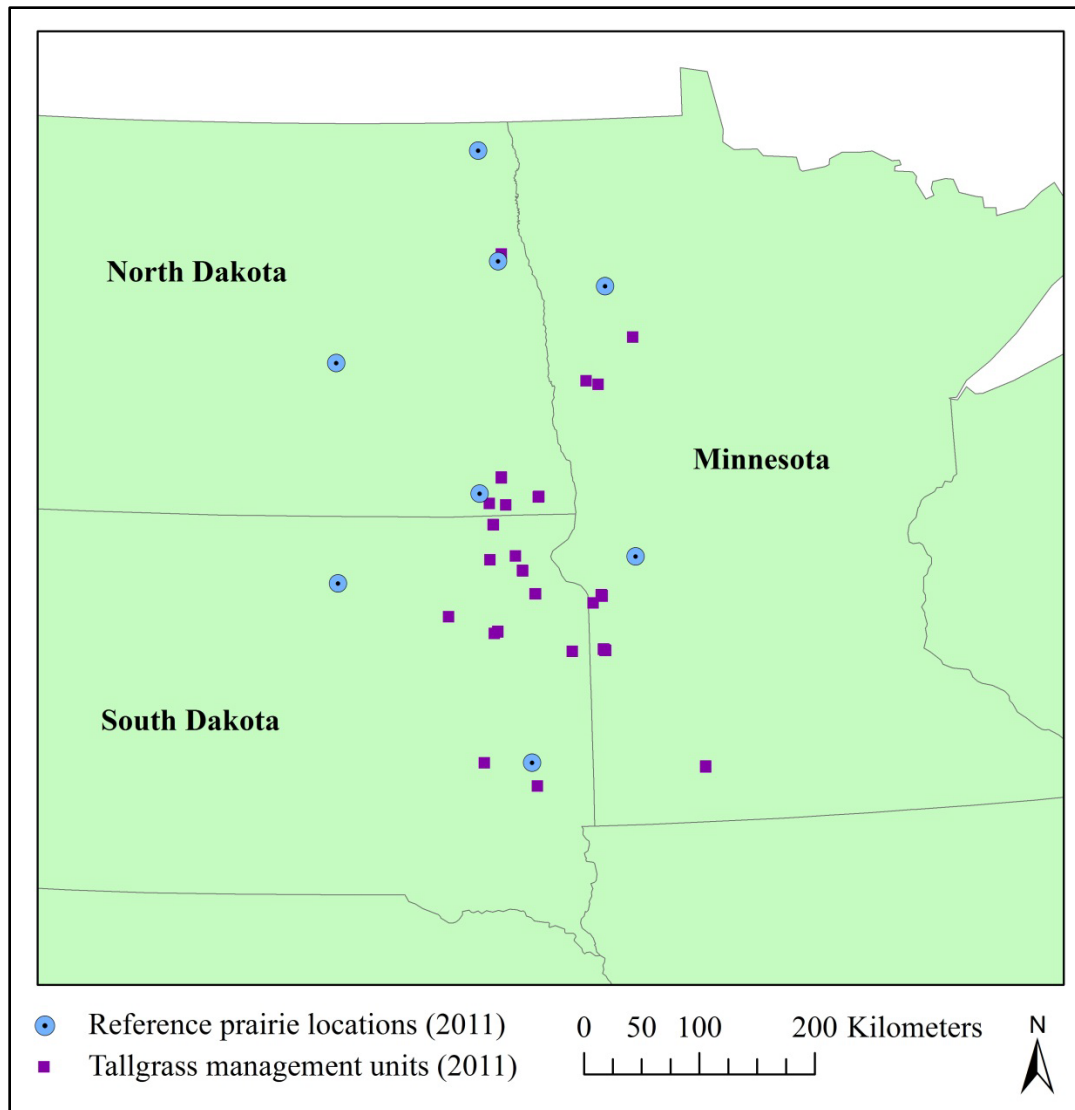


Figure 1. Location of the reference prairie sites monitored for phenology during 2011 and the tallgrass management units enrolled in the Native Prairie Adaptive Management initiative in 2011.

Table 2: Code used in SAS to create the interpolated surface

```

proc g3grid data=work2 out=grid;
  grid x1*y1=spring_start spring_end /
    axis1=-8.02 to -5.95 by .010
    axis2=4.85 to 5.35 by .010
  spline
  smooth=1.0;
run;
quit;

```

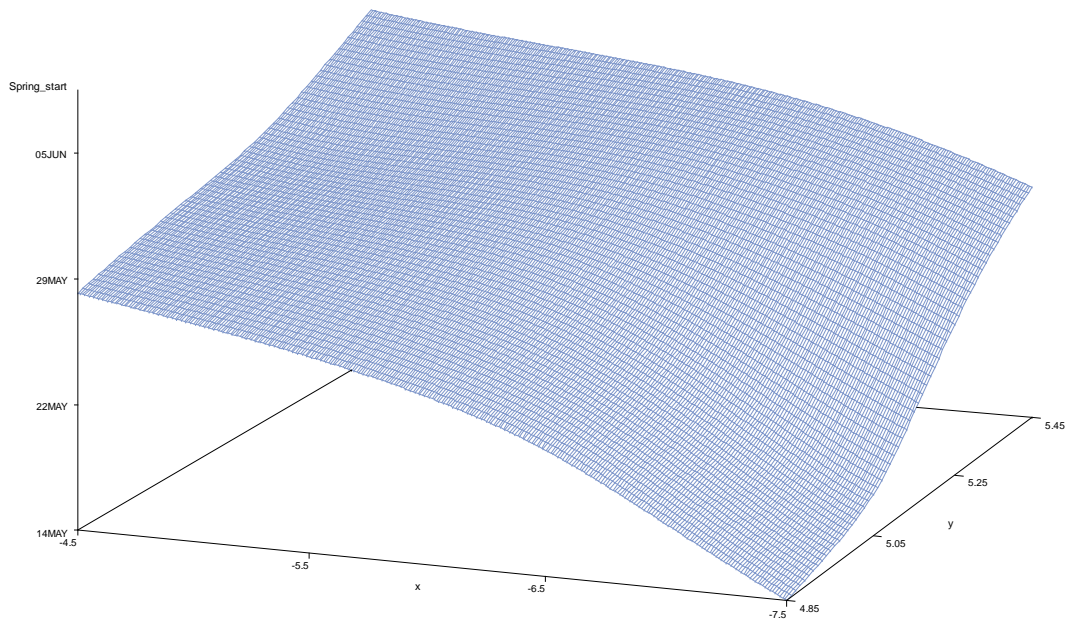
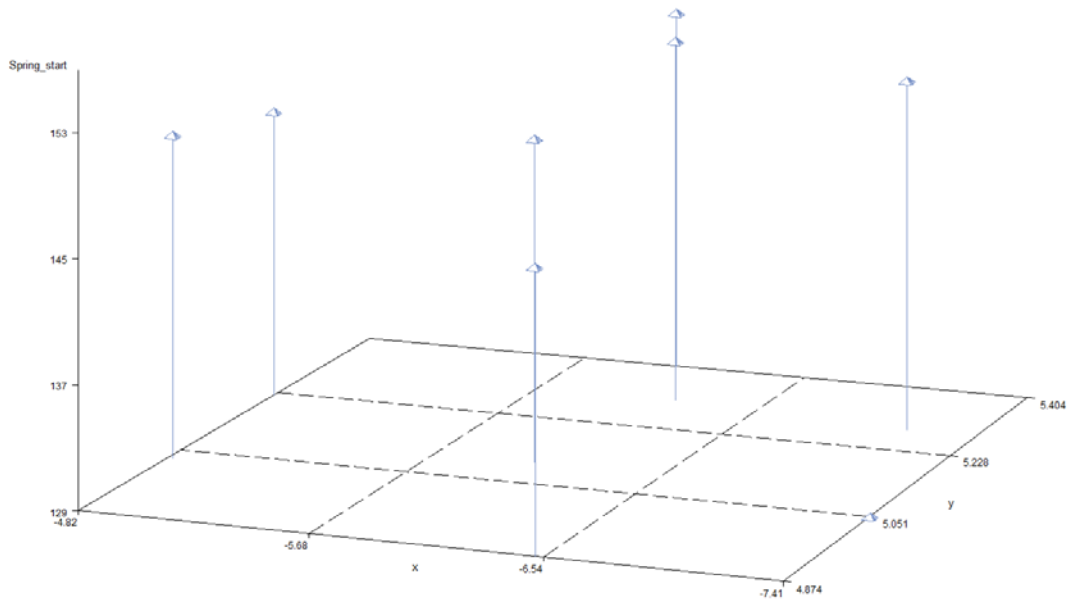


Figure 2: *A*, Reference prairie data points for spring start date during the 2011 management year. *B*, Generated surface based on the available data points and a smoothing value of 1.0.

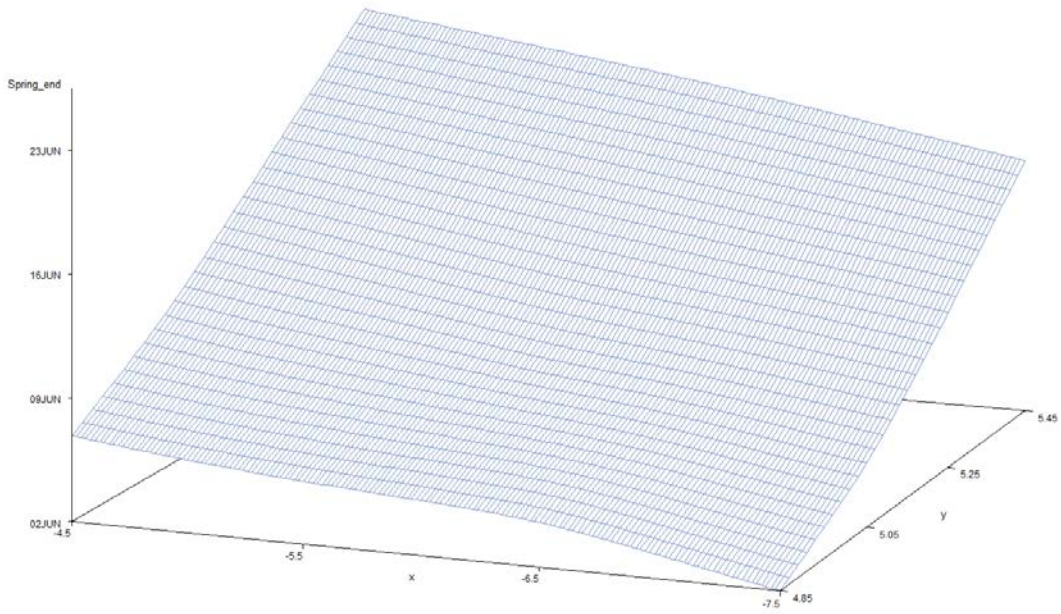
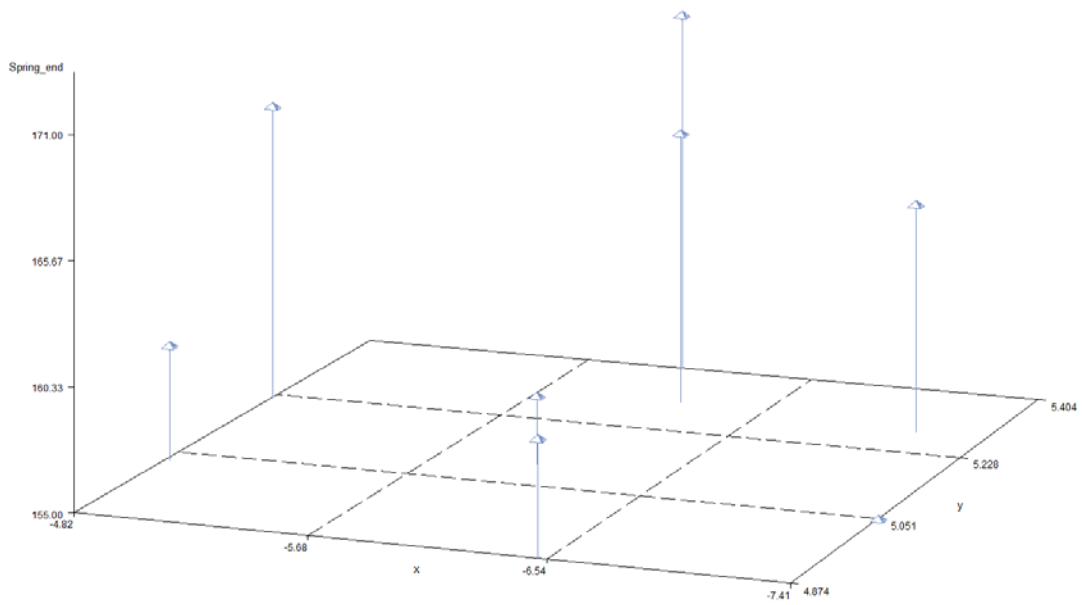


Figure 3: A, Reference prairie data points for spring end date during the 2011 management year. B, Generated surface based on the available data points and a smoothing value of 1.0.

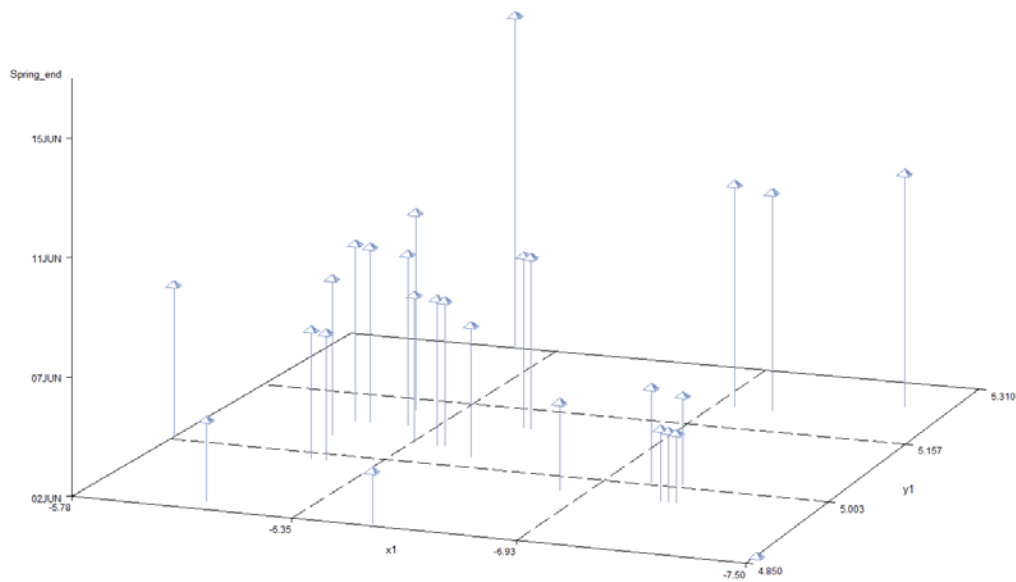
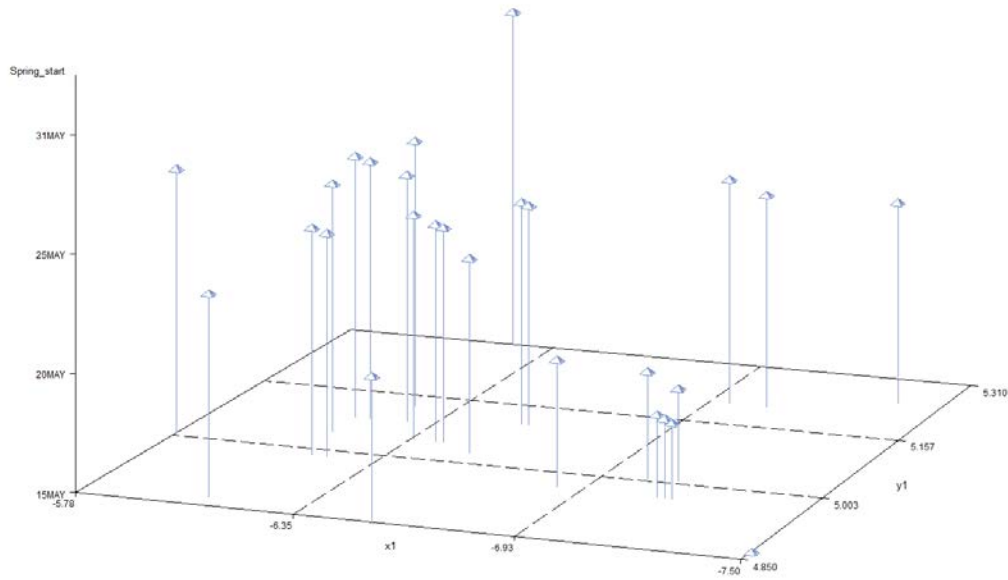


Figure 4: *A*, Extracted spring window start dates and *B*, extracted spring window end dates for the tallgrass management units in management year 2011, based on the reference data (table 1), the generated surfaces for the spring window start and end dates (fig. 2 and fig. 3), and the locations of the tallgrass units.

Table 3: Extracted spring window start and end dates for the tallgrass management units in management year 2011, based on the reference data (table 1), the generated surfaces for the spring window start and end dates (fig. 2 and fig. 3, respectively), and the locations of the tallgrass units.

[Eastings and Northings are in UTM zone 14]

Complex	Org	Unit	Eastings	Northings	Spring start	Spring end
WINDOM WMD	COTTONWOOD COUNTY WPA	Des Moines River WPA SOUTH	801605.0683	4870624.341	09MAY2011	04JUN2011
WINDOM WMD	COTTONWOOD COUNTY WPA	Des Moines River WPA NORTH	801554.7483	4871464.092	09MAY2011	04JUN2011
DETROIT LAKES WMD	MAHNOMEN COUNTY WPA	Sandy Lake Native	738294.1382	5242691.396	26MAY2011	11JUN2011
MORRIS WMD	LAC QUI PARLE COUNTY WPA	Florida Creek C	715018.5201	4971609.118	13MAY2011	04JUN2011
MORRIS WMD	LAC QUI PARLE COUNTY WPA	Florida Creek B	714446.3366	4971521.494	13MAY2011	04JUN2011
MORRIS WMD	LAC QUI PARLE COUNTY WPA	Florida Creek A	714127.5546	4971995.175	13MAY2011	04JUN2011
MORRIS WMD	LAC QUI PARLE COUNTY WPA	Freeland B	713161.3778	4972710.905	13MAY2011	05JUN2011
MORRIS WMD	LAC QUI PARLE COUNTY WPA	Freeland A	712897.0354	4972636.329	13MAY2011	05JUN2011
MORRIS WMD	BIG STONE COUNTY WPA	Hillman B	711938.3043	5019021.018	13MAY2011	04JUN2011
MORRIS WMD	BIG STONE COUNTY WPA	Hillman D	711758.3608	5018368.374	13MAY2011	04JUN2011
MORRIS WMD	BIG STONE COUNTY WPA	Hillman C	711107.6492	5018447.834	14MAY2011	04JUN2011
MORRIS WMD	BIG STONE COUNTY WPA	Hillman A	711058.9605	5019828.595	14MAY2011	04JUN2011
DETROIT LAKES WMD	CLAY COUNTY WPA OF MINNESOTA	Hoykens WPA North	708191.5886	5201793.121	25MAY2011	09JUN2011
BIG STONE NWR	BIG STONE NWR	Laskowske	703861.6407	5012729.271	15MAY2011	05JUN2011
DETROIT LAKES WMD	CLAY COUNTY WPA OF MINNESOTA	Jarvis WPA	697841.0794	5204893.701	26MAY2011	09JUN2011
MADISON WMD	DEUEL COUNTY WPA	Miller	685940.7423	4970720.707	19MAY2011	06JUN2011
TEWAUKON WMD	RICHLAND COUNTY WPA	Hartleben Unit A	657109.3671	5104779.35	25MAY2011	06JUN2011
TEWAUKON WMD	RICHLAND COUNTY WPA	Hartleben Unit B	656756.9087	5104396.84	25MAY2011	06JUN2011
TEWAUKON WMD	RICHLAND COUNTY WPA	Hartleben Unit C	656412.1488	5104383.247	25MAY2011	06JUN2011
MADISON WMD	MINNEHAHA COUNTY WPA	Buffalo Lake 80	655627.8068	4854273.721	26MAY2011	09JUN2011
WAUBAYNWR COMPLEX	ROBERTS COUNTY WPA	Berward Paddock 4	654085.7667	5020629.403	24MAY2011	06JUN2011
WAUBAYNWR COMPLEX	ROBERTS COUNTY WPA	Berward Paddock 5	653711.0517	5020606.428	24MAY2011	06JUN2011
WAUBAYNWR COMPLEX	ROBERTS COUNTY WPA	Wike Paddock 2	643029.7937	5040426.741	26MAY2011	06JUN2011
WAUBAYNWR COMPLEX	ROBERTS COUNTY WPA	Wike Paddock 1	642664.7395	5040830.095	26MAY2011	06JUN2011
WAUBAYNWR COMPLEX	MARSHALL COUNTY WPA	Buffalo Lake	636644.6315	5053333.114	26MAY2011	06JUN2011
TEWAUKON WMD	SARGENT COUNTY WPA	Krause	628202.3659	5097445.881	28MAY2011	06JUN2011
DEVILS LAKE WMD	GRAND FORKS COUNTY WPA	Mekinock	624583.7228	5314619.728	02JUN2011	16JUN2011
TEWAUKON WMD	SARGENT COUNTY WPA	Gainor Unit B	624458.8838	5120961.716	29MAY2011	07JUN2011
TEWAUKON WMD	SARGENT COUNTY WPA	Gainor Unit A	624405.1432	5121704.907	29MAY2011	07JUN2011
WAUBAYNWR COMPLEX	CODINGTON COUNTY WPA	Roe E	621465.6145	4987910	28MAY2011	06JUN2011
WAUBAYNWR COMPLEX	CODINGTON COUNTY WPA	Roe F	621451.2223	4987487.433	28MAY2011	07JUN2011
WAUBAYNWR COMPLEX	CLARK COUNTY WPA	Wamer Lake Paddock 5	618269.7587	4986231.256	29MAY2011	07JUN2011

Complex	Org	Unit	Easting	Northing	Spring start	Spring end
WAUBAYNWR COMPLEX	MARSHALL COUNTY WPA	Buss Paddock 2	617711.1227	5080304.196	29MAY2011	06JUN2011
WAUBAYNWR COMPLEX	MARSHALL COUNTY WPA	Buss Paddock 1	617318.1328	5080342.604	29MAY2011	06JUN2011
WAUBAYNWR COMPLEX	MARSHALL COUNTY WPA	Jensen East	614613.4223	5050046.912	29MAY2011	06JUN2011
TEWAUKON WMD	TEWAUKON NWR	Tewaukon NWR	614141.7174	5098774.319	29MAY2011	06JUN2011
MADISON WMD	MINER COUNTY WPA	Hepner WPA	609793.0884	4874088.275	30MAY2011	08JUN2011
SAND LAKE COMPLEX	SPINK COUNTY WPA	Sanderson	578855.8814	5000819.838	30MAY2011	06JUN2011

Literature Cited

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