

Model for *Galerucella californiensis* phenology (biocontrol agent for purple loosestrife)

Len Coop, OSU IPPC for implementation at <http://uspest.org/wea>

Version 1.0 – Mar. 15, 2013

Notes: estimated values w/blue-gray background
important results for implementation w/salmon background

Sources:

1. McAvoy, T.J. and L.T. Kok. 2004. Temperature dependent development and survival of two sympatric species, *Galerucella californiensis* and *G. pusilla*, on purple loosestrife. *BioControl* 49:467-480.
2. McAvoy, T.J., L.T. Kok, and W.T. Mays. 1997. Phenology of an Established Population of *Galerucella californiensis* (L.) and *G. pusilla* (Duft.) (Coleoptera: Chrysomelidae) on Purple Loosestrife, *Lythrum salicaria* L. (Lythraceae), in Southwest Virginia. *Biological Control* 9:106-111.

1.0 Temperature Development Studies to determine Lower Thresholds and DD requirements (X-intercept method)

Temp C	Days						Days			Temp C	E+L+P 1/days
	Egg	L1	L2	L3	Pupa	Female	E+L+P				
12.5	133		9.85	9.43	8.76	38.09	266.68	199.13	12.5	0.0050	
15	17.37		8.23	9.15	8.03	29.32	341.36	72.1	15	0.0139	
20	9.42		5.72	4.91	4.93	16.95	152.95	41.93	20	0.0238	
25	6.54		3.83	3.61	3.33	9.81	73.67	27.12	25	0.0369	
27.5	7.06		2.75	2.78	2.83	8.01	59.43	23.43	27.5	0.0427	
30	5.99		4.29	5.35	--	--	--				
Slope (b)	0.00245										
Intercept (a)	-0.02446										
R-square	0.996										
X-intercept (-a/b)	10.0										
Dds (1/b)	408.9										

1.1 Double check/compare to Source 1 Table 2 Thresh. for E and L

Egg Stage Only

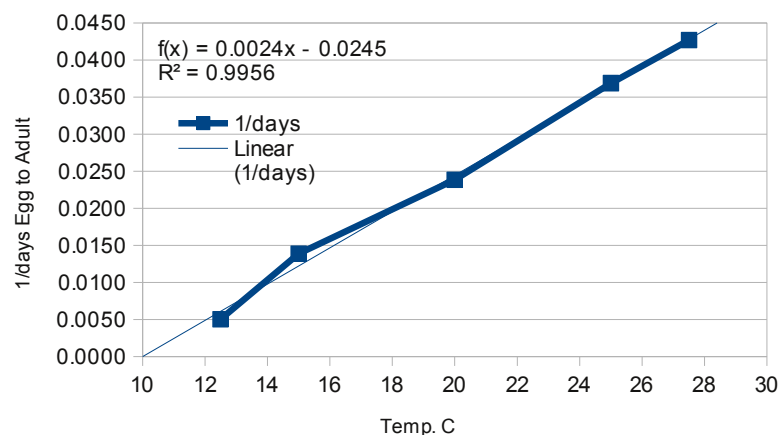
Slope (b)	0.00953
Intercept (a)	-0.08513
R-square	1.000
X-intercept (-a/b)	8.929
Dds (1/b)	104.894

Larval Stage Only

Slope (b)	0.00620
Intercept (a)	-0.05669
R-square	0.977
X-intercept (-a/b)	9.138
Dds (1/b)	161.184

Results: Thresholds from this analysis favors 9.0C; published (Tab. 2) ranges 5.7 to 7.5 as a lower threshold for the two stages; reason is that they included outliers.

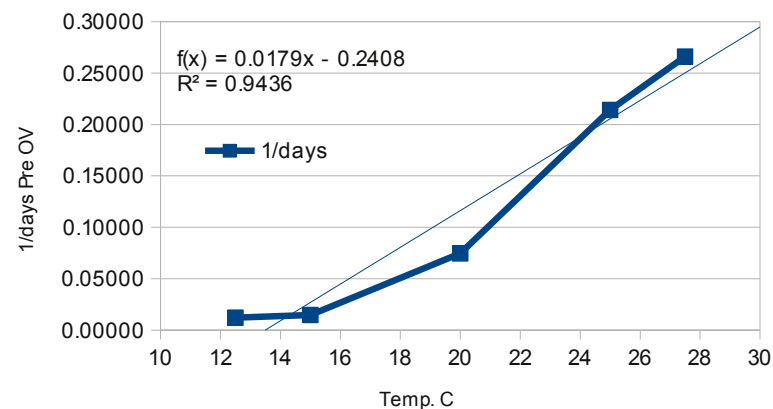
G. californiensis
Temperature Development E+L+P



G. calmariensis
Temp. Level. - Pre OV

1.2 Pre-OV period

Temp C	Days	Temp C	1/days
12.5	82.37	12.5	0.01214
15	68.36	15	0.01463
20	13.4	20	0.07463
25	4.67	25	0.21413
27.5	3.76	27.5	0.26596
Slope (b)		0.01785	
Intercept (a)		-0.24077	
R-square		0.944	
X-intercept (-a/b)		13.49	
Dds (1/b)		56.01	

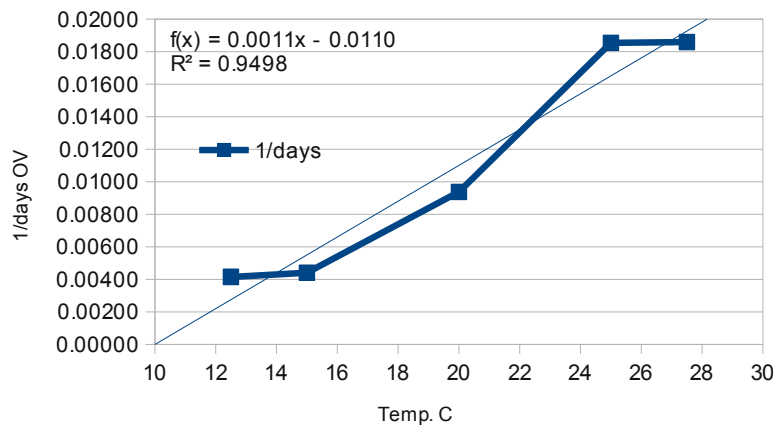


Notes: Temperatures below 15C appear to induce reproductive diapause (McAvoy & Kok 2004); this stage appears to have a significantly higher Tlow than other stages; thus model error may be expected for varying cool climates; and making local validation of the model a very likely necessity

G. calmariensis
Temp. Level. - OV

1.3 OV period

Temp C	Days	Temp C	1/days
12.5	241	12.5	0.00415
15	227.18	15	0.00440
20	106.63	20	0.00938
25	53.93	25	0.01854
27.5	53.81	27.5	0.01858
Slope (b)		0.00110	
Intercept (a)		-0.01102	
R-square		0.950	
X-intercept (-a/b)		10.00	
Dds (1/b)		908.01	



Note 1: OV period at 12.5 (140.68 days) is an outlier; rather than remove it, it was changed to force x-intercept through 10.0 C to comply with threshold derived for other life stages, with good r-sq = 0.95

Note 2: OV period in lab is much longer than noted in field (McAvoy et al 1997; 908 Dds vs 295)

Therefore we estimate that 1/3 of OV period (Lab) is the ENTIRE OV period in field

ca. Field OV period:	1993	1994	1995 AVG	
Dds F (May 1-Jun 10)	562	456	579	532.3
Dds C	312.2	253.3	321.7	295.7

OV period to use in model: $0.3333 \times 908 = 302.6$

Half OV period to use for complete generation time: 151

1.4 Complete Generation (use for peak event to peak event in model)

E+L+P+PreOV+1/2OV

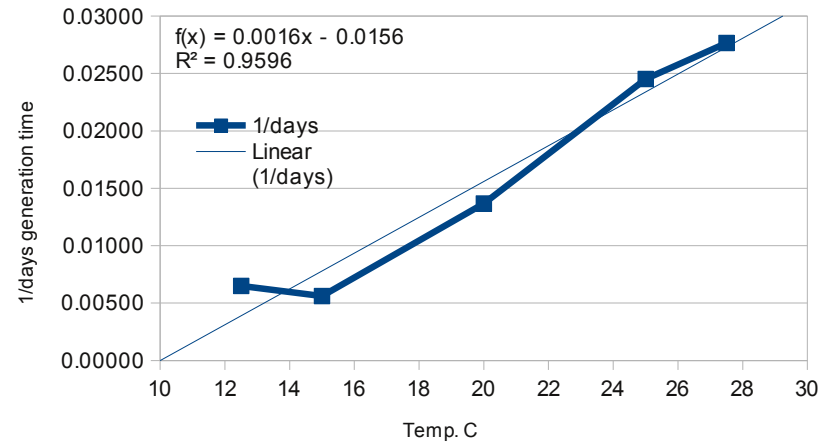
Temp C	Days	Temp C	1/days
12.5	154.00	12.5	0.00649
15	178.32	15	0.00561
20	73.10	20	0.01368
25	40.78	25	0.02452
27.5	36.16	27.5	0.02766
Slope (b)	0.00		
Intercept (a)	-0.02		
R-square	0.960		
X-intercept (-a/b)	10.00 C		
Dds (1/b)	641.54 DD C		

Note: Again, as days to develop for certain life stages (eggs, OV period) were outliers, this number was manipulated to force the x-intercept through the lower threshold of 10.0, which gives a good r-sq = 0.990 fit to the model.

Tlow =	10C	Dds
E+L+P+PreOV+1/2 OV		641.54 DD C 1154.8 DD F

Upper Threshold (Thigh): nominally set at 37.8 C = 100 F

G. californiensis Complete Generation Time
Temp. Devel. - Egg + Larvae + Pupae + PreOV + 1/2 OV



2.0 Proportionate Development Times – Major life stages

Temp C	Days Egg	Larvae	Pupae	Pre-OV	1/2OV	Total	
15		17.37	25.41	29.32	68.36	37.86	178.32
20		9.42	15.56	16.95	13.4	17.77	73.10
25		6.54	10.77	9.81	4.67	8.99	40.78
27.5		7.06	8.36	8.01	3.76	8.97	36.16
	Proportion						
15		0.0974	0.1425	0.1644	0.3833	0.2123	1.0000
20		0.1289	0.2129	0.2319	0.1833	0.2431	1.0000
25		0.1604	0.2641	0.2406	0.1145	0.2204	1.0000
27.5		0.1953	0.2312	0.2215	0.1040	0.2480	1.0000
avg		0.1455	0.2127	0.2146	0.1963	0.2310	1
	DD C						
15		62.5	91.4	105.5	245.9	136.2	641.5
20		82.7	136.6	148.8	117.6	156.0	641.5
25		102.9	169.4	154.3	73.5	141.4	641.5
27.5		82.7	132.5	136.2	145.7	144.5	641.5
avg		93.3	136.4	137.7	125.9	148.2	641.5
st dev		16.49	31.98	21.83	73.15	8.36	0.00
CV		17.67	23.44	15.86	58.09	5.64	0.00

2.1 Proportionate Development Times – Larval Instars Only

Temp C	Days L1	L2	L3	Total	
15		8.23	9.15	8.03	25.41
20		5.72	4.91	4.93	15.56
25		3.83	3.61	3.33	10.77
27.5		2.75	2.78	2.83	8.36
	Proportion				
15		0.3239	0.3601	0.3160	1.0000
20		0.3676	0.3156	0.3168	1.0000
25		0.3556	0.3352	0.3092	1.0000
27.5		0.3289	0.3325	0.3385	1.0000
avg		0.3440	0.3358	0.3201	1
	Dds				
15		44.2	49.1	43.1	136.4
20		50.2	43.1	43.2	136.4
25		48.5	45.7	42.2	136.4
27.5		44.9	45.4	46.2	136.4
avg		46.9	45.8	43.7	136.4
st dev		2.48	2.17	1.50	0.00
CV		5.29	4.73	3.44	0.00

3.0 Summary of Development - *Galerucella californiensis*

T _{Low} =	10 C	50 F
Thigh (nominal) =	37.8 C	100 F
<u>Stage</u>	<u>DD C</u>	<u>DD F</u>
Egg	93.3	168
L1	46.9	84
L2	45.8	82
L3	43.7	79
Pupae	137.7	248
Pre-OV period	125.9	227
½ OV period	148.2	267
Egg to 1 st Adult	367.4	661
Egg to 1st OV	493.4	888
Egg to ½ OV (complete Gen Time)	641.5	1155

4.0 Model starting event for *G. californiensis* phenology (use Peak OW gen. adult oviposition):

(McAvoy & Kok 2007 Table 1)	DD C	DD F	DD F	DD F
Field Data	ca. Peak OW Adult Egg-Laying		ca. Peak L2/G1 larvae	ca. Peak 1 st Gen Adults
Coeburn, VA 1993	05/14/93	255.3	459.6	06/08/93 793
cool year				07/08/93 1441 '<-G1 adults in low numbers; not peak
				06/07/93 767
Coeburn, VA 1994	05/10/94	257.6	463.6	07/15/93 1614.4 '<-estimated using model
avg year				
Coeburn, VA 1995	05/05/95	255.8	460.5	05/28/95 773
warm year				06/29/95 1332 '<-G1 adults in low numbers; not peak
				05/28/95 772
Mean Dds Peak Egg-laying		256.2	461.2	07/13/95 1615.3 '<-estimated using model

Note 1: All three years appear useful to estimate peak OW egg-laying, albeit with considerable uncertainty

Note 2: Events beyond this in too low numbers, but 1993 & 1995 somewhat useful for G1 peak larvae

4.1 Est. Dds for OW Adults first eggs = Peak OV – ½ OV period (use DD F):

'=461 – 267 = 194.5

5.0 Final model parameters for *Galerucella californiensis* phenology

Starting date:	Jan 1 (nominal)	
DD Calculation method:	Single sine (nominal)	
Tlow:	10 C	50 F
Thigh (nominal):	37.8 C	100 F
<u>Event</u>	<u>DD C</u>	<u>DD F</u>
First OW Adult egg-laying:	108	195
Peak OW Adult egg-laying:	256	461
Peak G1 Larvae:	419	755
ca. 5% G1 Adults (daylength sens. Stage):	636	1145
Peak G1 Adult egg-laying:	898	1616
Peak G2 Larvae:	1061	1910
ca. 5% G2 Adults (daylength sens. Stage):	1278	2300
Peak G2 Adult egg-laying:	1539	2771