

Dendrolimus pini (Pine Tree Lappet Moth) Degree-Day Model Documentation

Len Coop May 20, 2016 vers. 1.0 (OSU IPPC; for APHIS PPQ CPHST)

Sources and Data:

(Note significant data used in final model highlighted in Salmon color)

1. NAPPFAST Model Documentation Sept 2012

Tlow 3C Tupper 30C (optim. Temp 20C)

– this Tlow is dubious based on studies available below

2. PPQ Dendrolimus book

Larvae begin diapause beginning 3rd instar; 4th or 5th instars are OW stage (Heitland 2002)

Larval photoperiodic threshold is 12 hrs daylength or less for 38 days; diapause inhibited at more than 17 hrs. (Geispits etal 1972)

Larvae pupate after 7 or 8 instars

Pupation starts in late spring (May-June and will last 4-5 weeks (Melis 1940)

2 gens/yr in italy otherwise 1-3 years per gen.

Mated females live 7-10 days; unmated 17-20 days; adults do not feed

If 1 gen/yr pupal devel 15 days vs 22 days w/1 gen/2 yr

If 1 gen/yr females dont fly vs do fly w/1 gen/2 yr

Egg devel opt 24C and 80-85% humid, range 14 to 31 C (Kojima 1933)

Temps below 8.5 and above 33.5C result in 100% mortality

Eggs: 10 days at 31.5C to 48 days at 11.5C; 11 days at 24C and 80% RH

Larvae: temp-devel results not mentioned for larvae

Pupae: normal pupation still occurs at 7C; 95 days at 12 C to 14 days at 32C, 25 days at 24C (Kojima 1933, Winokur 1991)

In native range in Europe and Asia, flight normally starts in June and July (Lesniak 1976, Varga 1966)

Flight is conditional: if OW as 4/5th instars, flight mainly in July (univoltine)

If OW as 2/3rd instars (winter 1) then as 5/6th instars (winter 2), flight May-June (2 yrs/generation)

Pg 94: flight normally between June and August

Estimated Adult Female Pre-OV + ca. 40% OV from above (very rough estimate): 8 days at 70 F or 21 C = $8 * (21 - 7.22) =$

110 DD (Tlow=7.22C)

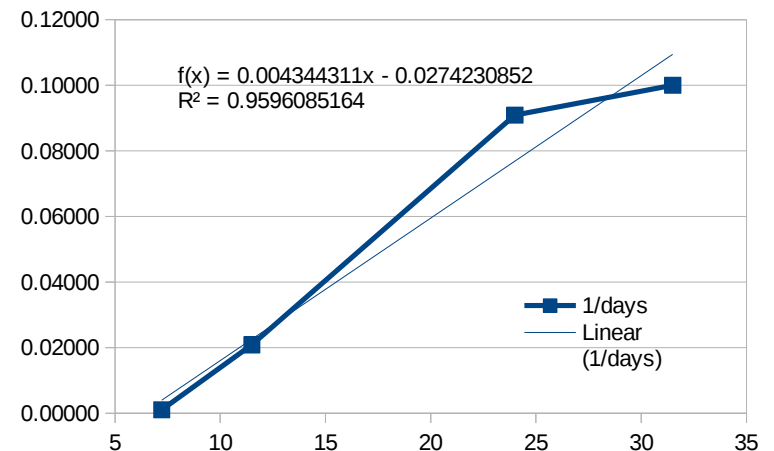
X-intercept regression analyses for eggs based on above reports and 7.22 Tlow

Eggs

Temp C	1/days	days
7.22	0.00100	1000
11.5	0.02083	48
24	0.09091	11
31.5	0.10000	10
Slope (b)	0.00434	
intercept (a)	-0.02742	
R2	0.95961	
1/slope	230.2 (DD req.)	
-a/B	6.3 (x-intercept)	

result: incomplete data set; could not force x-intercept to 7.22 (6.3 is close though)

D. pini eggs (reported in PPQ Dendrolimus book)



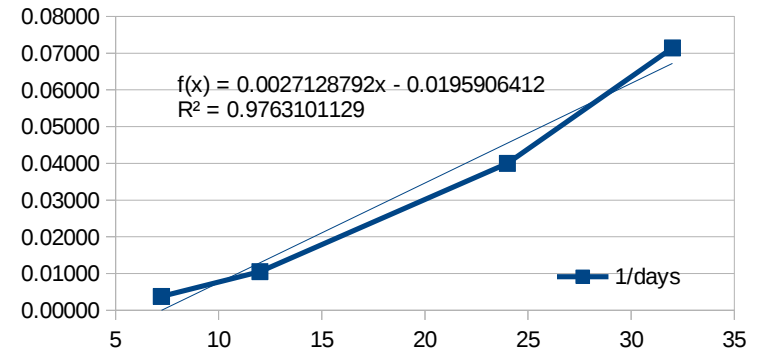
X-intercept regression analyses for pupae based on above reports and 7.22 Tlow

Pupae

Temp C	1/days	days	
7.22	0.00375	267	
12	0.01053	95	
24	0.04000	25	
32	0.07143	14	
Slope (b)	0.00271		
intercept (a)	-0.01959		
R2	0.97631		
1/slope	369 (DD req.)		
-a/B	7.22 (x-intercept)		

result: incomplete data set; fairly good fit; 369 DD best fits with emergence reported Sweden 2012

D. pini Pupae (reported in PPQ Dendrolimus book)



3. Kojima 1934 and Schwerdtfeger 1963, 1977 – graph of egg development

Eggs Focus on Prokhonov 1908: [Fig 2.18 (1)]

Temp C	1/days	days	
10	0.00010	10000.000	
14	0.02700	37.037	
18	0.05700	17.544	
22	0.08300	12.048	
26	0.11500	8.696	
30	0.14000	7.143	
slope (b)	0.00707		
intercept (a)	-0.07101		
R2=	0.9993		
1/slope =	141		
X-intercept=	-b/A	10.0	

Focus on Schwerdtfeger 1963: [Fig 2.18 (3)]

Temp C	1/days	days	
7.22	0.000	3000	
10	0.014	71	
14	0.039	26	
18	0.060	17	
22	0.081	12	
26	0.104	10	
slope (b)	0.0055		
intercept (a)	-0.0398		
R2=	0.9992		
1/slope =	181 (DD C)		
-b/A	7.21 (Tlow)		

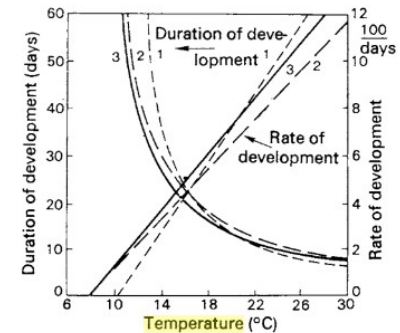
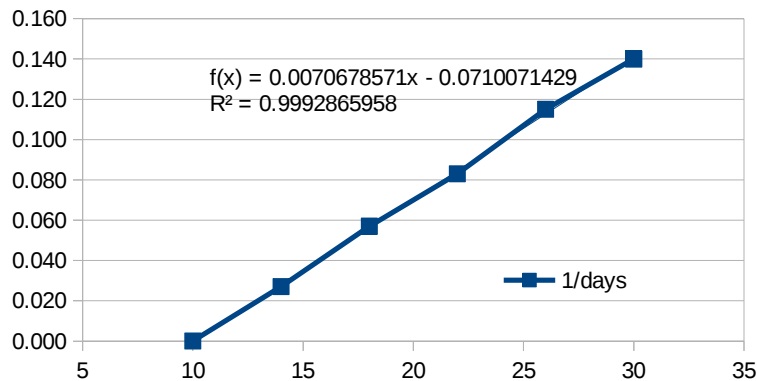


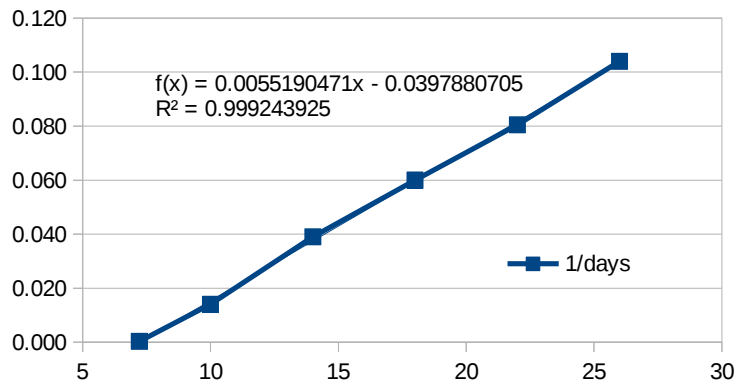
Fig. 2.18 Length and rate of development of eggs of *Dendrolimus pini* (L.) in dependence on temperature (after Schwerdtfeger, 1977): 1 — according to Prokhonov, 1908, 2 — according to Kojima, 1934, 3 — according to Schwerdtfeger, 1963

Based on these works, could use for eggs: Tlow=10 C, 141 Dds, or 7.22 C, 181 Dds (use the latter)

Eggs Dev based on Prokhonov 1908



Egg Dev based on Schwerdtfeger 1963



4. CPHST Pest Datasheet Sept 2012

Egg Incub 14-25 days, mortal at or above 32C

OW when daylength 12 hours – larvae move to forest floor to OW in forest litter within 1 m of host tree.

Diapause induced by temps below 5C

Diapause terminated when litter temps reach 3C.

In lab 9hr or less daylight induce diapause for 20-35 days in all instars

Diapause (both sensitivity and response) induced for all larval instars 1962 Ann Rev Entomol

5. Regener and Ratzeburg (from N Hampshire Agric Exp Sta. Sci Contrib. 1910. Pg. 121)

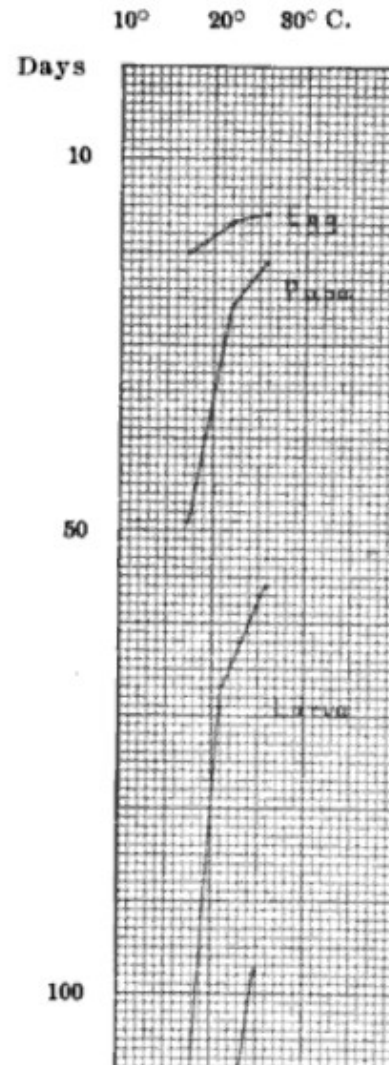
April, '10] SANDERSON: TEMPERATURE AND INSECT GROWTH

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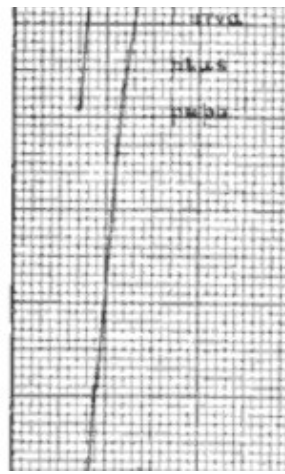
normal conditions, record of which we have, have been maintained. In exact work to determine the effect of temperature the moisture conditions should be constant, as with many species the moisture influence is as much or more important than that of temperature in determining the optimum for development.

Similar observations on the time of hatching of the eggs of *Malacosoma americana*, the time of emergence of the caterpillars of the brown-tail moth from their winter nests, the hatching of eggs of the gypsy moth, and the pupal stage of *Samia cecropia*, *Papilio asterias* and *Epargyreus tityrus*, have been or are now being made, but cannot be summarized at present.

Other data is at hand, however, showing the same facts. Thus Kerschbaumer (15) has given data from which the curve for the life cycle of *Culex pipiens* as influenced by temperature has been plotted

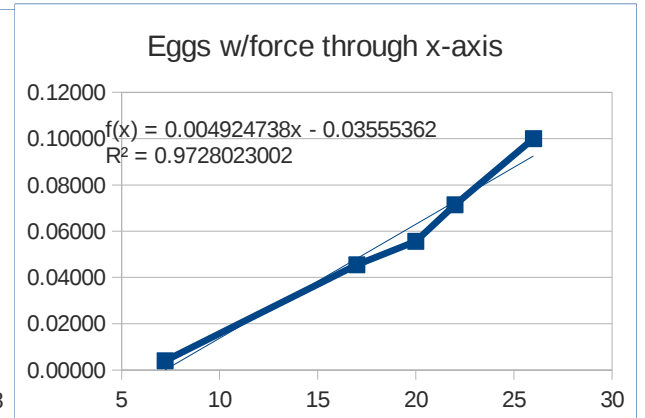
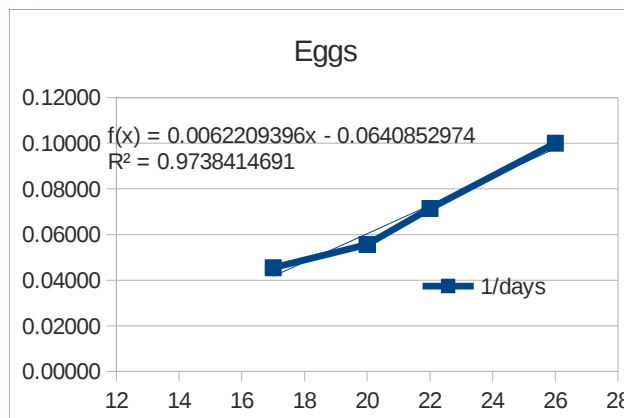


(figure 12), and Regener (21) and Ratzeburg (20) have shown the same for the different stages of *Dendrolimus pini*, shown in figure 13. One of the most careful studies of the relation of both temperature and moisture to the development of an insect is a recent one of Hennings (9) with *Tomicus typographus* Linn. Hennings reared all stages and secured the complete life cycle of this species at four



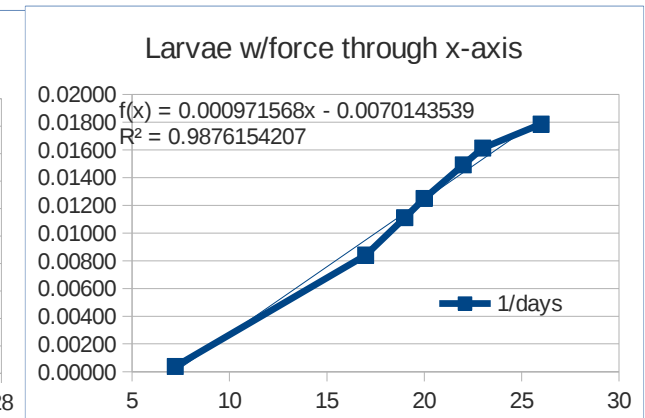
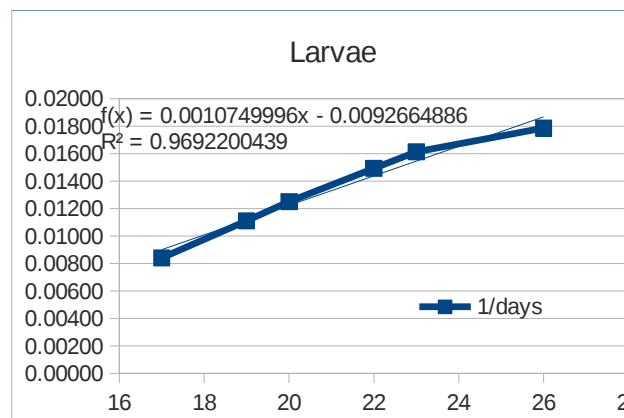
From above figure (with forcing through proposed Tlow of 7.22 C):
X-intercept regression analyses:

Egg	Temp C	1/days	Days
	7.22	0.00395	253
	17	0.04545	22
	20	0.05556	18
	22	0.07143	14
	26	0.10000	10
	slope	0.00492	
	intercept	-0.03555	
	R2	0.97280	
	1/slope	203	
	-a/B	7.22	



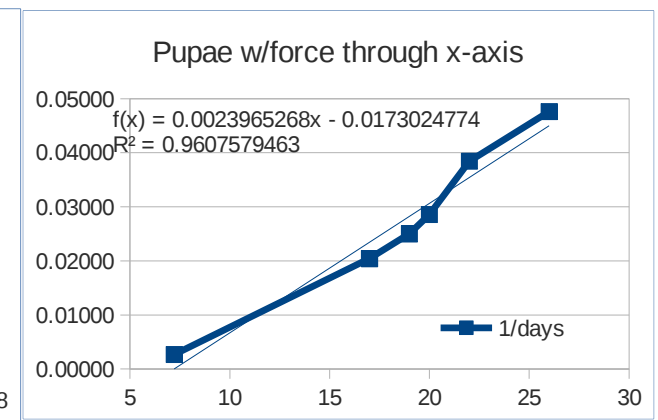
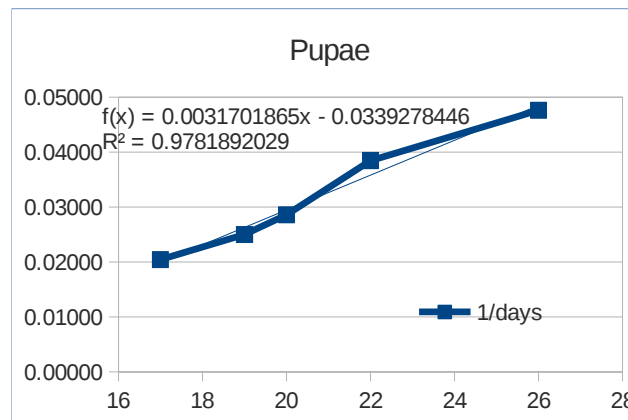
Notes: similar to earlier examined studies; use those numbers

Larvae	Temp C	1/days	Days
	7.22	0.00038	2650
	17	0.00840	119
	19	0.01111	90
	20	0.01250	80
	22	0.01493	67
	23	0.01613	62
	26	0.01786	56
	slope	0.00097	
	intercept	-0.00701	
	R2	0.98762	
	1/slope	1029	
	-a/B	7.22	



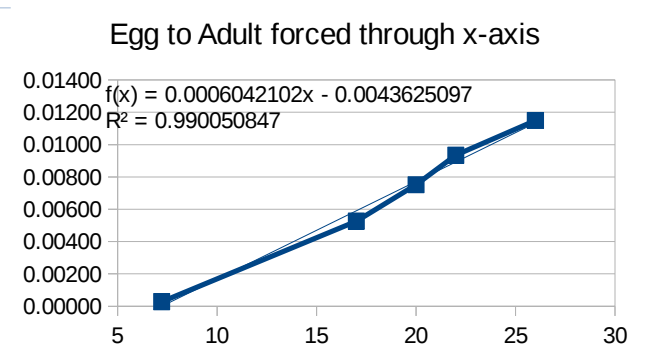
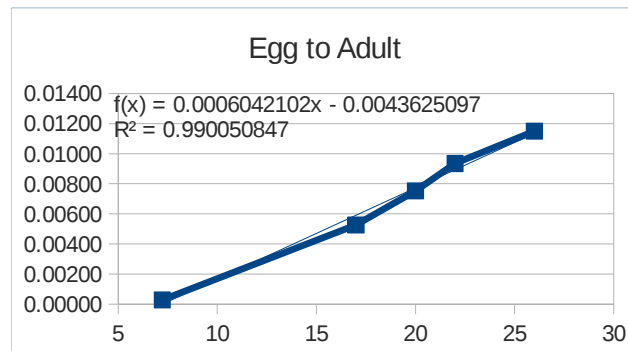
Notes: best avail. Data for larvae; Tlower of 7.22 seems to be a good fit.

Pupae	Temp C	1/days	Days
	7.22	0.00267	375
	17	0.02041	49
	19	0.02500	40
	20	0.02857	35
	22	0.03846	26
	26	0.04762	21
slope		0.00240	
intercept		-0.01730	
R2		0.96076	
1/slope		417	
-a/B		7.22	



Egg through Pupae

Temp C	1/days	Days
7.22	0.00029	3500
17	0.00526	190
20	0.00752	133
22	0.00935	107
26	0.01149	87
slope	0.00060	
intercept	-0.00436	
R2	0.99005	
1/slope	1655	
-a/B	7.22	



Summary from all highlighted data above:

	Egg	Larvae	Pupae	Egg-Pupae	sum	Regression
DDs		181	1029	369	1579	1655 Dds
Tlow		7.22	7.22	7.22	7.22	7.22

From these results: estimate Egg to Adult Devel: Tlow 7.22 C, 1579 DD

6. Meshkova, V. ca. 2004. Dependency of outbreaks distrib. From insects-defoliators seasonal development (Ukraine): Proceedings: Ecology, Survey and Management of Forest Insects GTR-NE-311

"the interval between dates of air temperature transition over 5 and 10C with *D. pini*...i tis during this period that larvae initiate feeding after hibernation. ...transition below 5 and 0 in autumn is also reliable. This is during the period when winter diapause of *D. pini* caterpillers begins.

Interpretation: including photoperiod (threshold 12:12 L:D) would be a good way to terminate and then initiate diapause in spring and fall; but finding an appropriate Tlow that tends to correspond with non-diapause activity could work well also. Thus 7.22C may fit these analyses of spring and fall activity.

Two *D. pini* gens per year occur in the South, only one gen. In the North of Ukraine

In outbreak years, first gen. Cocoons were formed before June 17 in 88.2% of cases; majority of first gen. Larvae complete feeding before the solstice (June 21)

Late level. Larvae may go through a summer diapause and then will coincide with larvae from the summer generation.

7. Pest Alert (UK Forestry Commission) – Pine Tree Lappet Moth (2009) – possibly established near Inverness, Scotland

Adult moths emerge between late June and mid August and live for 9-10 days.

Eggs hatch after 16-25 days during August and Sept.

Larvae begin feeding on edges of pine needles. Autumn feeding lasts for 2-3 moults until the first frost, when larvae migrate down the tree to OW beneath the litter at the litter/mineral soil interface, usually very close to the tree trunk.

This devel. Stage ends in early spring, when soil temps reach 4-5C. The larvae then return to the pine canopy and feed on old needles.

Pupae devel occurs in May-June and lasts 4-5 weeks.

8. Grodner, J. and R. Zander. 2010. Sex pheromone of the pine tree lappet moth *D. pini* and its use in attractant based monitoring system.

Pestycydy/Pesticides 1-4,43-49

D. pini males were trapped 5 July to 13 August 2010. In the Slawa Slaska Forest District (Zielona Gora) Poland

Nearest German data found:	Date	DDs
3376	07/06/10	580 approx first flight (according to data)
Muncheberg (E of Berlin)	08/14/10	1091 approx end of flight (accord. To data)

(modify Jun and July with data from Leszno, Poland; Climate diffs between Berlin and Poznan Poland are small)

wea file:

SLAWA210.txt **NOTES: Corresponds pretty well with the model at least for beginning of flight**

9. Priesner, E et al. 1984. Identification and field evaluation of a sex pheromone of the European Pine Moth. *Z. Naturforsch* 39c:1192-1195

D. pini flight season usually begins in central Europe in early July – beginning of 1983 flight season was apparently missed, but the mid-July peak was covered.

Seewiesen	06/25/82	06/29/82	07/06/82	07/13/82	07/20/82	07/27/82	08/03/82	08/10/82	08/17/82
(sw of Munich) Germany		3.8	19.1	37.4	22.9	12.2	1.5	3.1	0
sta. Numbers 3379,3385									

Best Match →	1982 SEEWIES1 Germany	Date	DDs
	Station code 3379	06/25/82	574 approx first flight (model)
	wea file:	07/18/82	866 approx first egg hatch (model)
	SEEWIES182.txt	07/17/82	862 approx peak flight (accord. To data)
		08/14/82	1211 approx end of flight (accord. To data)

seems a poor mat (leave out of average below)	1982 SEEWIES2 Germany	Date	DDs
	Station code 3385	07/06/82	574 approx first flight (model)
	in Munich	07/30/82	866 approx first egg hatch (model)
	at Nymphenburg	07/17/82	728 approx peak flight (accord. To data)
	wea file:	08/14/82	1047 approx end of flight (accord. To data)
	SEEWIES282.txt		

Breisach,	07/04/83	07/12/83	07/19/83	07/26/83	08/02/83	08/09/83	08/16/83
(w of Freiburg, s of Strasbourg) Ge		19.6	39.2	28.3	9.3	1	2.6
station codes 1443,1447,1451							

	1983 BREISACH1 Germany	Date	DDs
	Station code 1443	06/14/83	574 approx first flight (model)
	wea file:	07/09/83	866 approx first egg hatch (model)
	BREISACH183.txt	07/21/83	1073 approx peak flight (accord. To data)
		08/18/83	1483 approx end of flight (accord. To data)

1983 BREISACH2 Germany	Date	DDs
Station code 1447	06/14/83	574 approx first flight (model)
wea file:	07/11/83	866 approx first egg hatch (model)
BREISACH283.txt	07/21/83	1026 approx peak flight (accord. To data)
	08/18/83	1417 approx end of flight (accord. To data)

Average DDs for Events based on flight data from 8 & 9 above:

987 approx peak flight (accord. To data)
1370 approx end of flight (accord. To data)

10. Ostrauskas, H. and P. Ivinskis. 2011. Moths Caught in pheromone traps during search for *Dendrolimus pini* and *D. sibiricus* (Lep: Lasiocampidae) in Lithuania. Acta Zool. Lithuanica 21:238-243.

1995 Berlin **data in Fig. 1 – moths caught by light traps in Sarkiske 1995**

Climate average

1-2 deg C warmer avg. Tmax and ca same Tmin for months of Mar-July

vs. Vilnius Lithuania (data adjusted for climate differences)

SARKISK95.txt	Date	DDs	DDs (not adjusted for climate diffs Berlin vs. Lithuania)
SARKNA95.txt (not adj.)	06/15/95	334	359 approx first flight (accord. To data)
	07/12/95	621	649 approx peak flight (accord. To data)
	07/30/95	861	893 approx end of flight (accord. To data)

NOTES: this report indicates flight can occur earlier than model predicts by ca. 200-300 Dds;

This pattern essentially shows that larvae have completed feeding and development by winter and only need to complete the pupal stage in the spring

11. Bjorkman et al 2013. A rare event - an isolated outbreak of the pine tree lappet moth in Stockholm archipelago (Sweden). Ent. Tidskr. 134:1-6.

Female lays 15-350 eggs on branches and stems in July. Eggs hatch after 2-3 weeks. Larvae develop through 6 instars and may be completed after 1 or 2 hibernations. In Oct half-grown larvae hibernate in soil. Post 2nd-hibern. Larvae will pupate in May or early June. In southern Sweden the larvae develop into adults already in the second summer and emerge in July.

2012 STCKHLM Sweden	Date	DDs	event
	07/05/12	391	approx first flight (accord. To data)
	07/30/12	655	approx end of flight (accord. To data)
	09/18/12	1099	numerous small larvae present (accord. To data)
	07/24/12	574	approx first flight (model)
	08/19/12	866	approx first egg hatch (model)
	10/18/12	1175	larvae seek OW hibernacula (model)
2012 SVENSKA Sweden	07/05/12	258	approx first flight (accord. To data)
	07/30/12	505	approx end of flight (accord. To data)
	09/18/12	954	numerous small larvae present (accord. To data)
	08/06/12	574	approx first flight (model)
	09/05/12	866	approx first egg hatch (model)
NA		1175	larvae seek OW hibernacula (model)

NOTES: like in Lithuania, fewer Dds required before flight, so treat as a Northern/cold site that may have 3 yrs/generation

Average DDs for Events based on 10 & 11 above:

Note: these cases seem to support a 2-3 yr/generation model whereby mature larvae/prepupae OW
363 approx first flight (accord. To data)
758 approx end of flight (accord. To data)

Summary of Phenology Model for *Dendrolimus pini* (Pine Tree Lappet Moth):

Start Date: January 1st

Calc Method: Single Sine

	<u>Deg. C</u>	<u>Deg. F</u>
Tlower:	7.22	45
Tupper:	30	86

Primary Events

	<u>DD C</u>	<u>DD F</u>
OW late instar Larvae-Adult Emerge	574	1034 (est. based on 20% larval+pupal dev.)
Egg	181	326
Larvae	1029	1852
Pupae	369	664
Egg to Adult	1579	2842
Pre-OV+40% OV	110	198 (from #2 above)
Generation Time	1689	3040

Events Table

In northern/colder regions: first adult flight from late instar OW larvae	363	653
1st Gen. Adult Emerg. (most regions)	574	1034
1st Eggs Hatch from spring adult egg laying (most regions)	866	1559
Approx. peak adult flight (most regions; end of flight colder regions)	987	1777
Early-mid larval instars seek hibernacula (if after Oct 1)	1175	2114
Approx. end of adult flight (except colder regions)	1370	2467
Mid-late larval instars seek hibernacula (if after Oct 1)	1483	2670
2nd Gen. Adult Emerg (only in warmest regions)	2263	4074
1st Eggs Hatch from 2nd Gen. adult egg laying (if any)	2555	4599