# Biological aspects for forecasting of the cabbage stem flea beetle, *Psylliodes chrysocephala* L.

An industrial PhD project
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# The cabbage stem flea beetle, *Psylliodes chrysocephala*

4 – 5 mm

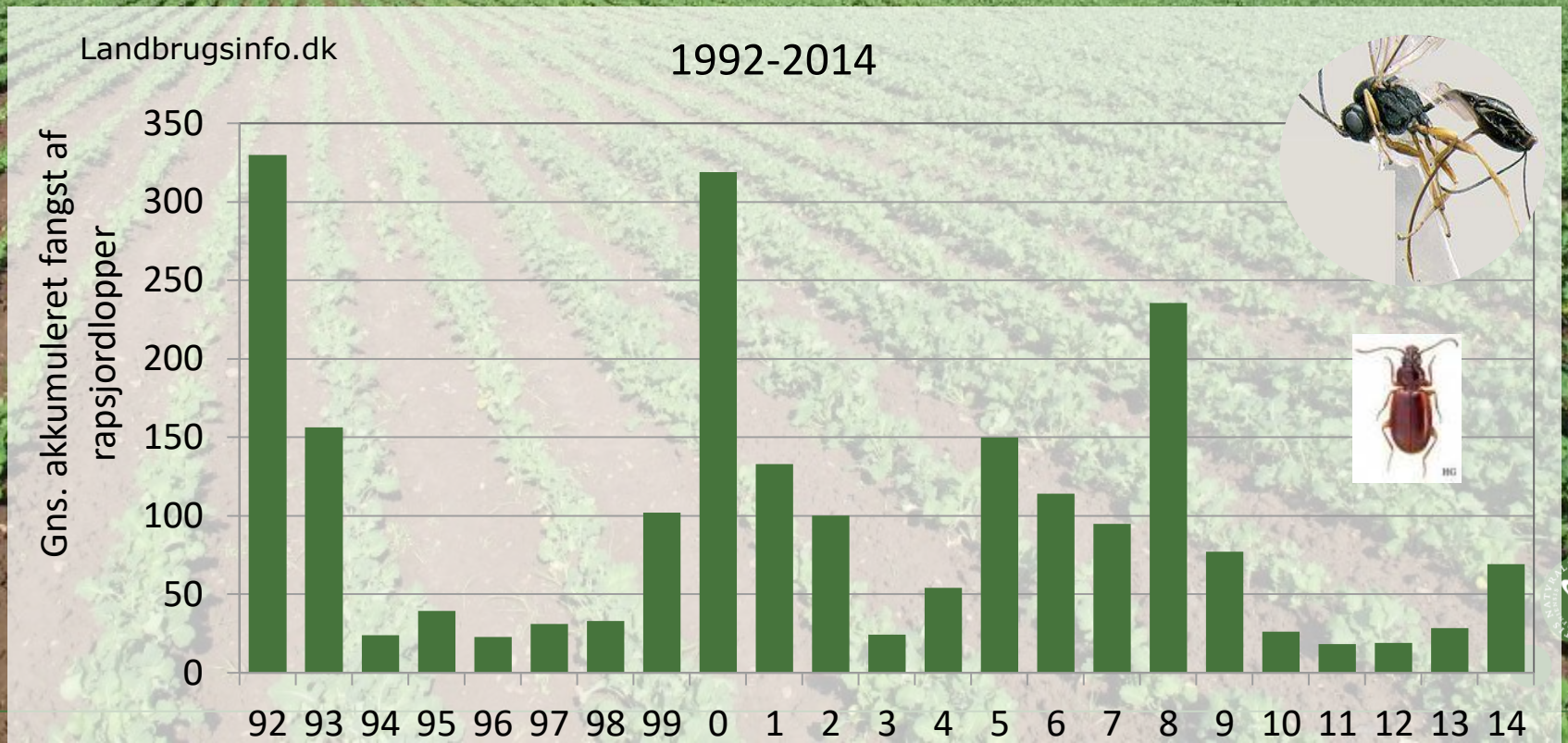
1.2 – 8 mm

# A pest in winter oilseed rape

**A cyclic behaviour?**

Weather?

Natural enemies?

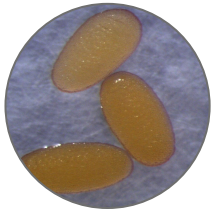


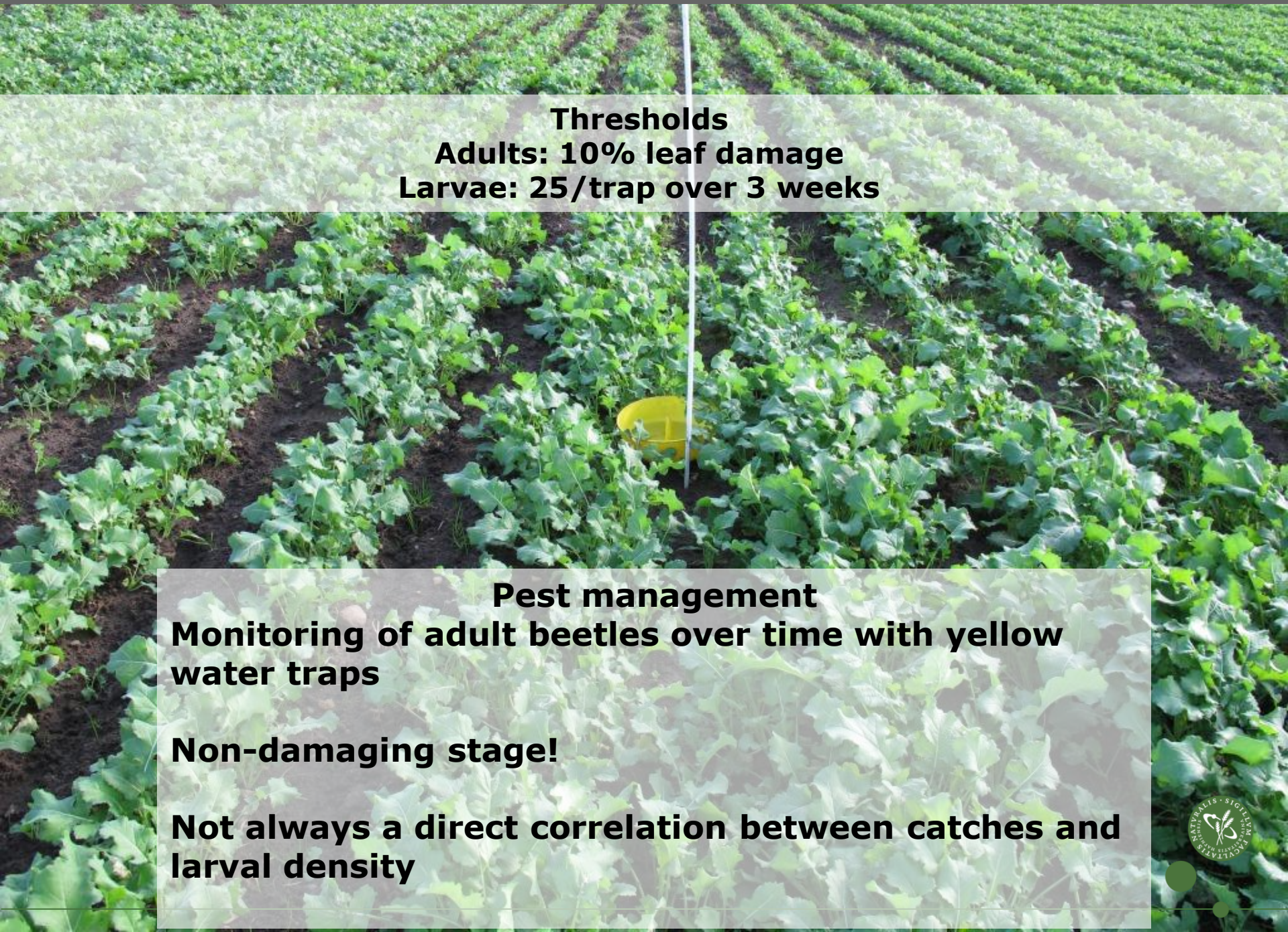
New generation

$L_1$ $L_2$ $L_3$

Diapause

aug sep okt nov dec jan feb mar apr maj jun jul





## Thresholds
**Adults: 10% leaf damage**
**Larvae: 25/trap over 3 weeks**

## Pest management
**Monitoring of adult beetles over time with yellow water traps**

**Non-damaging stage!**

**Not always a direct correlation between catches and larval density**

## Trap catch to damage 5 – 7 months

**Leaf mining**

**Increased risk of plant mortality during winter**

$L_1$ $L_2$ $L_3$

**Main flight period**

aug sep okt nov dec jan feb mar apr maj jun jul

**Damage visible as reduced or stunted growth**

**Monitoring with yellow water traps** → **Start of invasion**

**Study 2**

**Temperature effect on:**

- **Egg-laying**
- **Egg development**

→ **Risk assessment in the autumn**

aug sep okt nov dec jan feb mar apr maj jun jul

**Study 3**

**Winter survival of larvae**

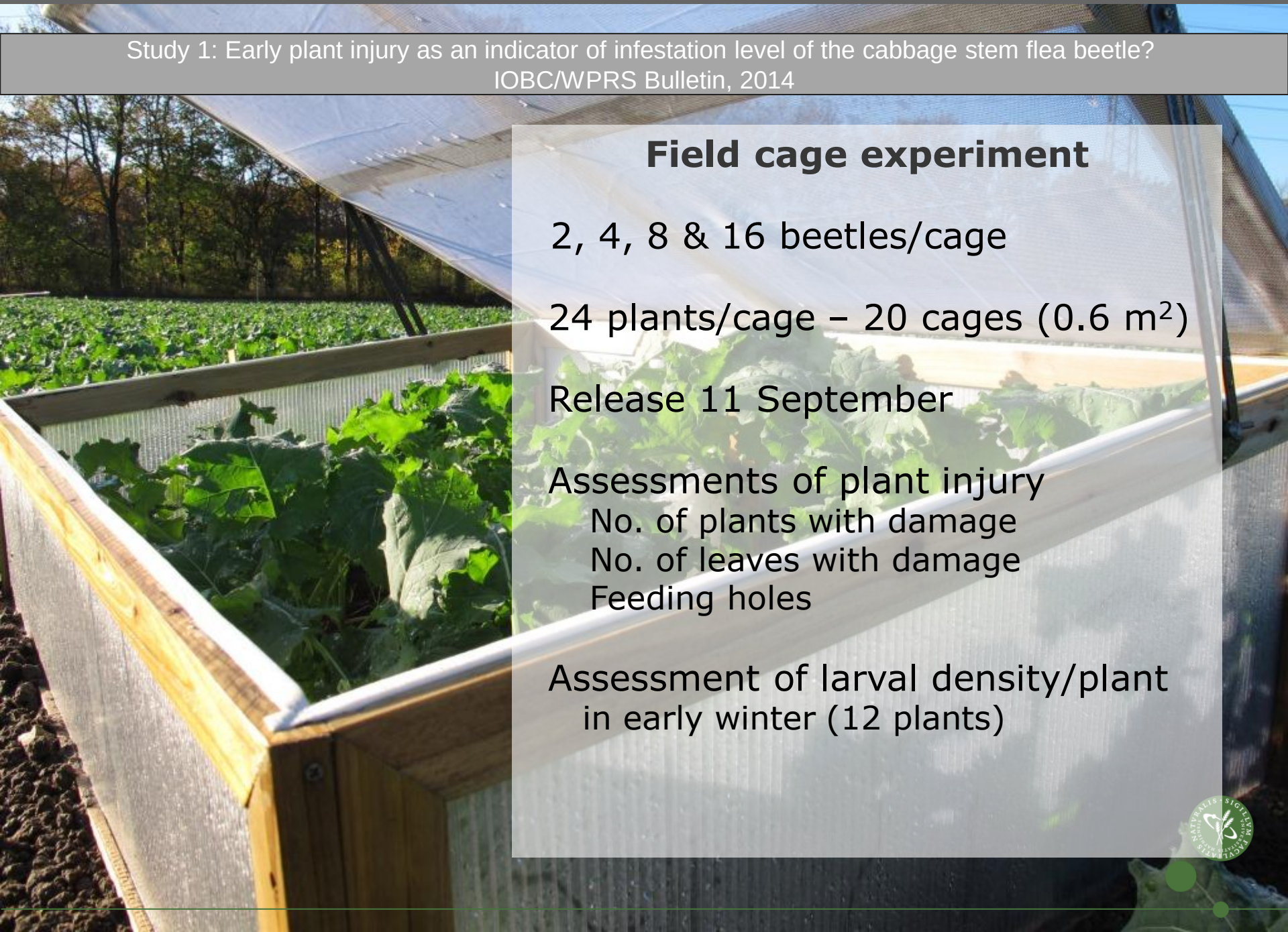
→ **Risk assessment in spring**

**Study 1**

**Correlation between feeding and beetle density**

→ **Number of beetles on a rough scale?**

Study 1: Early plant injury as an indicator of infestation level of the cabbage stem flea beetle?
IOBC/WPRS Bulletin, 2014



## Field cage experiment

2, 4, 8 & 16 beetles/cage

24 plants/cage – 20 cages (0.6 $m^2$)

Release 11 September

Assessments of plant injury
- No. of plants with damage
- No. of leaves with damage
- Feeding holes

Assessment of larval density/plant
in early winter (12 plants)

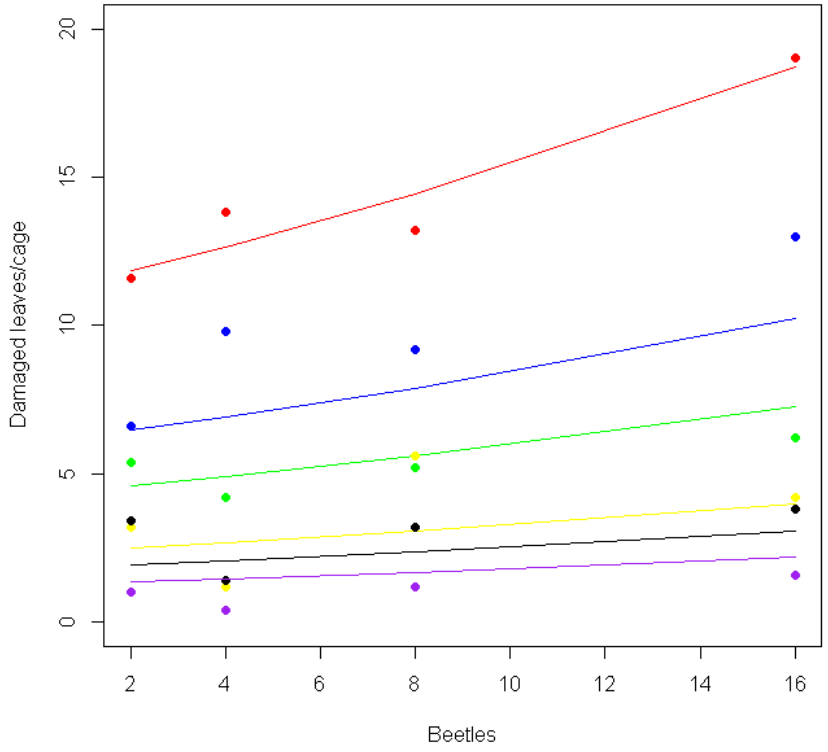
Study 1: Early plant injury as an indicator of infestation level of the cabbage stem flea beetle?

Number of plants with damage
Number of ”feeding holes”

No effect of beetle density

Number of leaves with damage - a significant but small effect of beetle density

## Low feeding!




Assessment dates
- 14 september
- 18 september
- 21 september
- 28 September
- 2 October
- 9. October

Significant correlation between beetle and larval density/plant

## Low larval density!

| Beetles | Larvae/plant (mean±sd) |
|---|---|
| 2 | 0.15 ± 0.66 |
| 4 | 0.38 ± 0.99 |
| 8 | 0.87 ± 1.59 |
| 16 | 1.42 ± 1.90 |

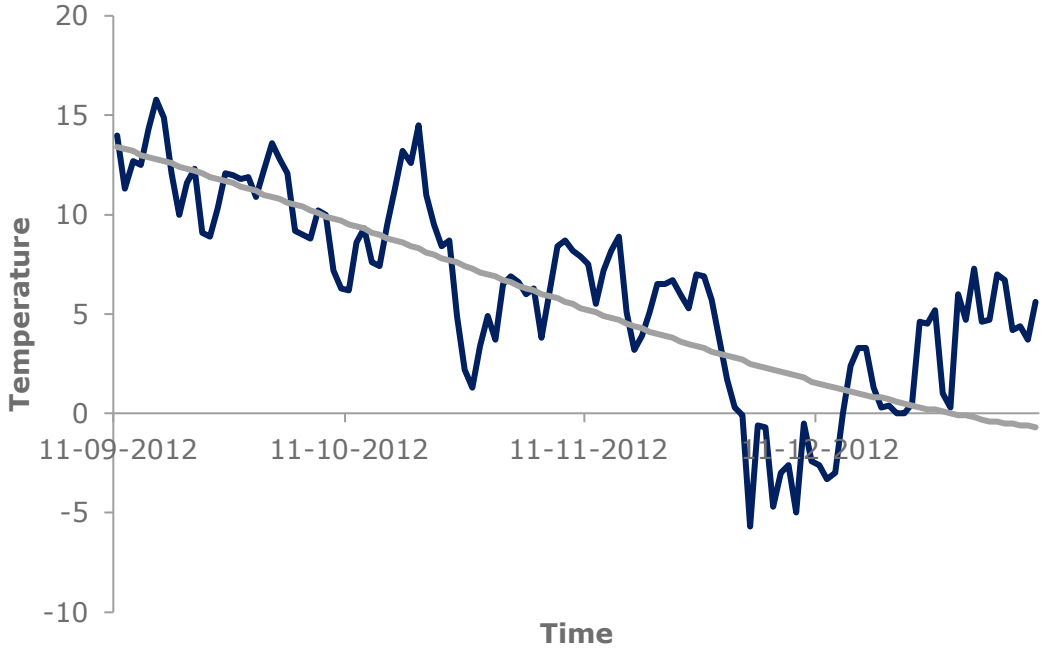
1 female ~ approx. 0.2 larvae/plant

25 females ~ 5 larvae/plant

Study 1: Early plant injury as an indicator of infestation level of the cabbage stem flea beetle?

# Low adult feeding and larval density

## Low insect activity?




Range of beetle density?
1 female ~ approx. 0.2 larvae/plant
25 females ~ 5 larvae/plant
New range 2 - 48 beetles

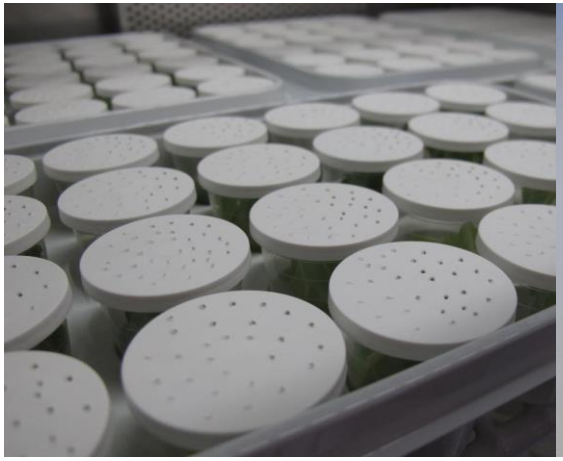
## Study 1: Early plant injury as an indicator of infestation level of the cabbage stem flea beetle?

Assessment of early leaf injury is not a reliable indicator of beetle density

Range of beetle densities: 2 - 48 beetles

## Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle *Psylliodes chrysocephala* Accepted for publication in Journal of Applied Entomology



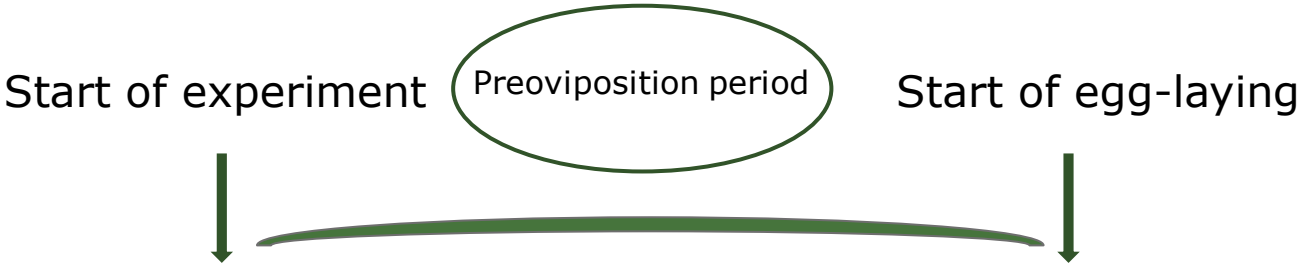



20 beetle pairs at 4, 8, 12, 16 & 20°C

Assessments

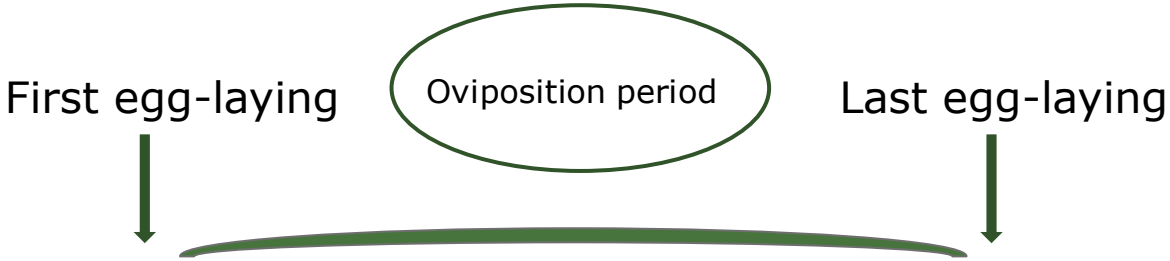
- The preoviposition period
- No. of eggs laid
- The oviposition period
- Female survival time
- Egg development time
- Egg hatching rate

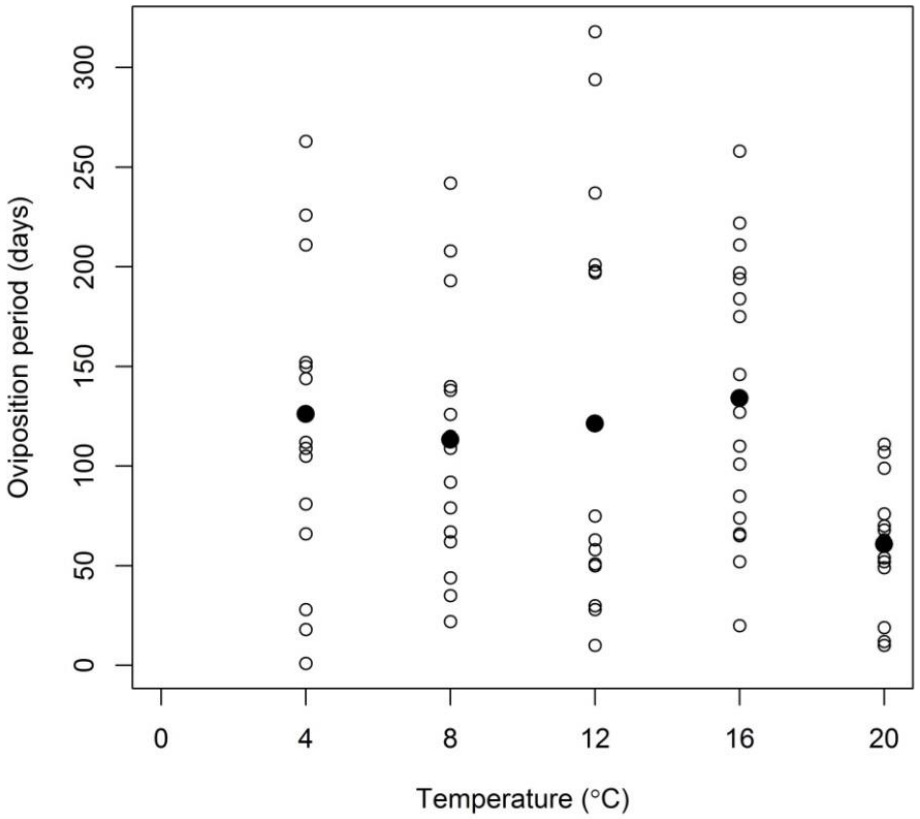
## Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*




| Temperature ˚C | Preoviposition period (days) (mean±sd) |
|---|---|
| **4** | 93.07 (± 81.47) [a] |
| **8** | 41.56 (± 35.51) [ab] |
| **12** | 25.93 (± 13.03) [bc] |
| **16** | 18.83 (± 20.09) [cd] |
| **20** | 14.62 (± 9.63) [d] |

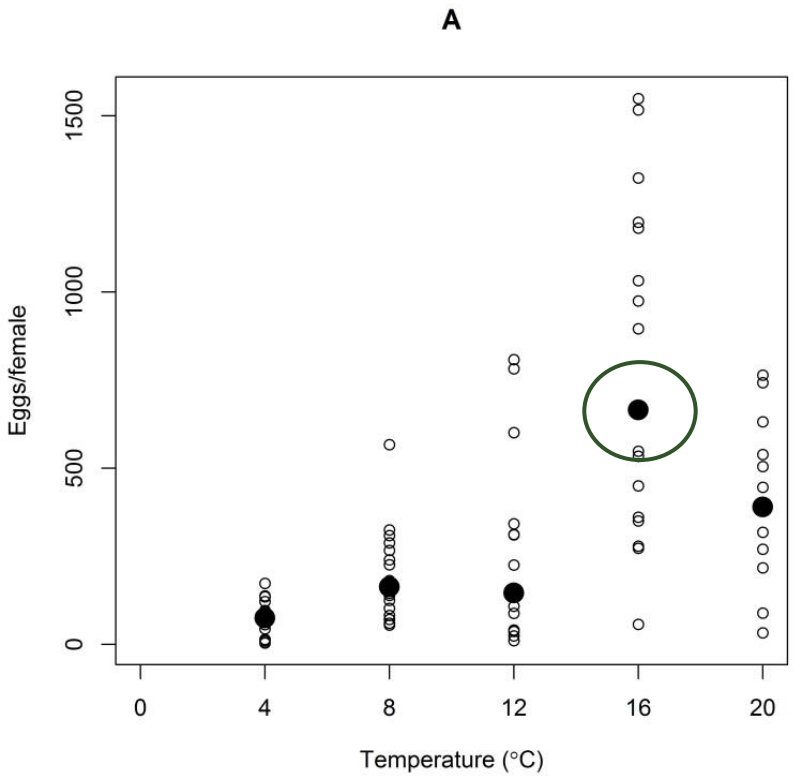
## Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

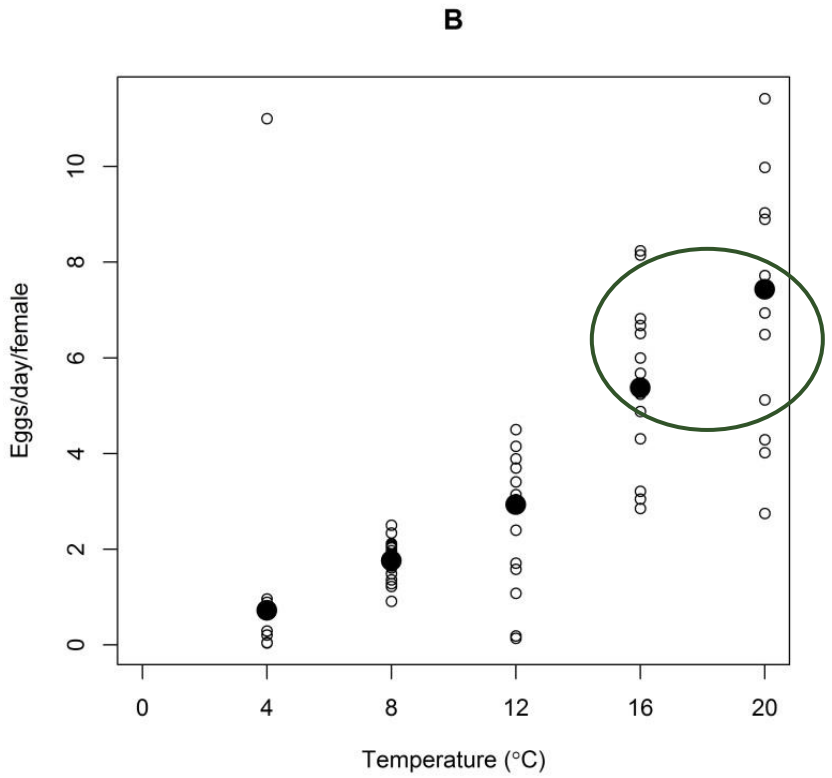


Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

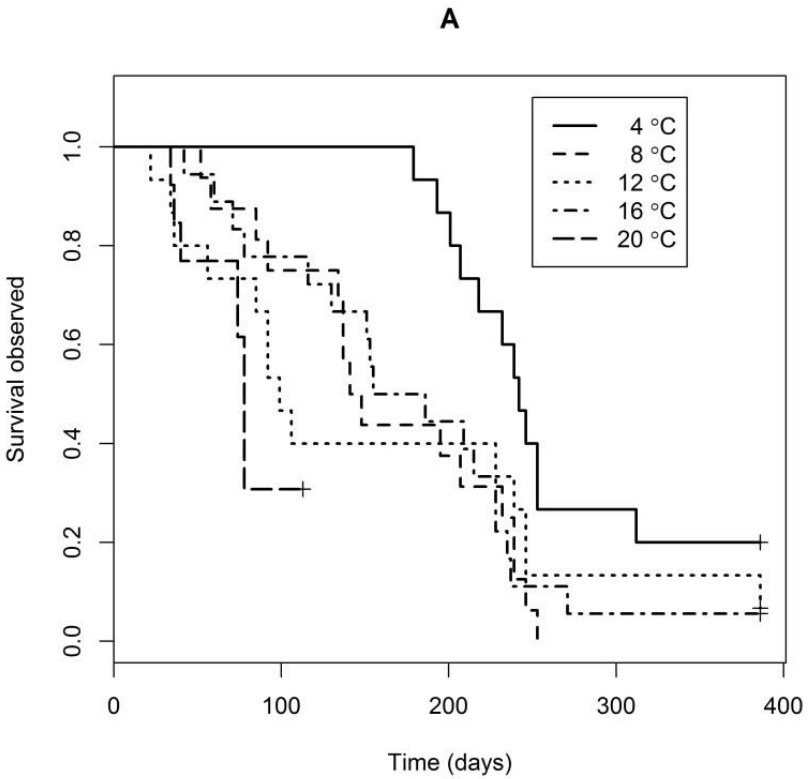
# Egg-laying

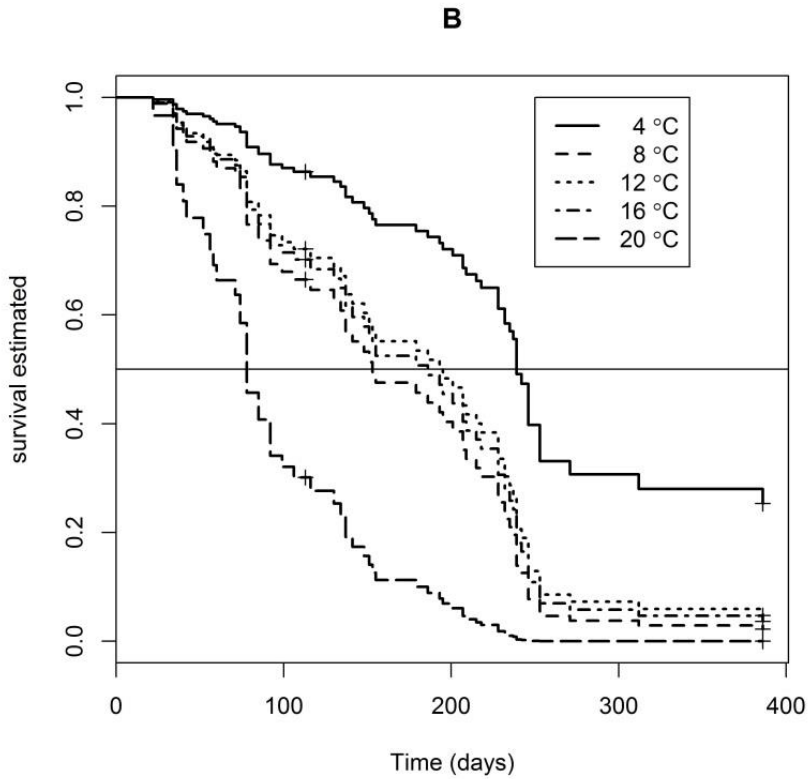


Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

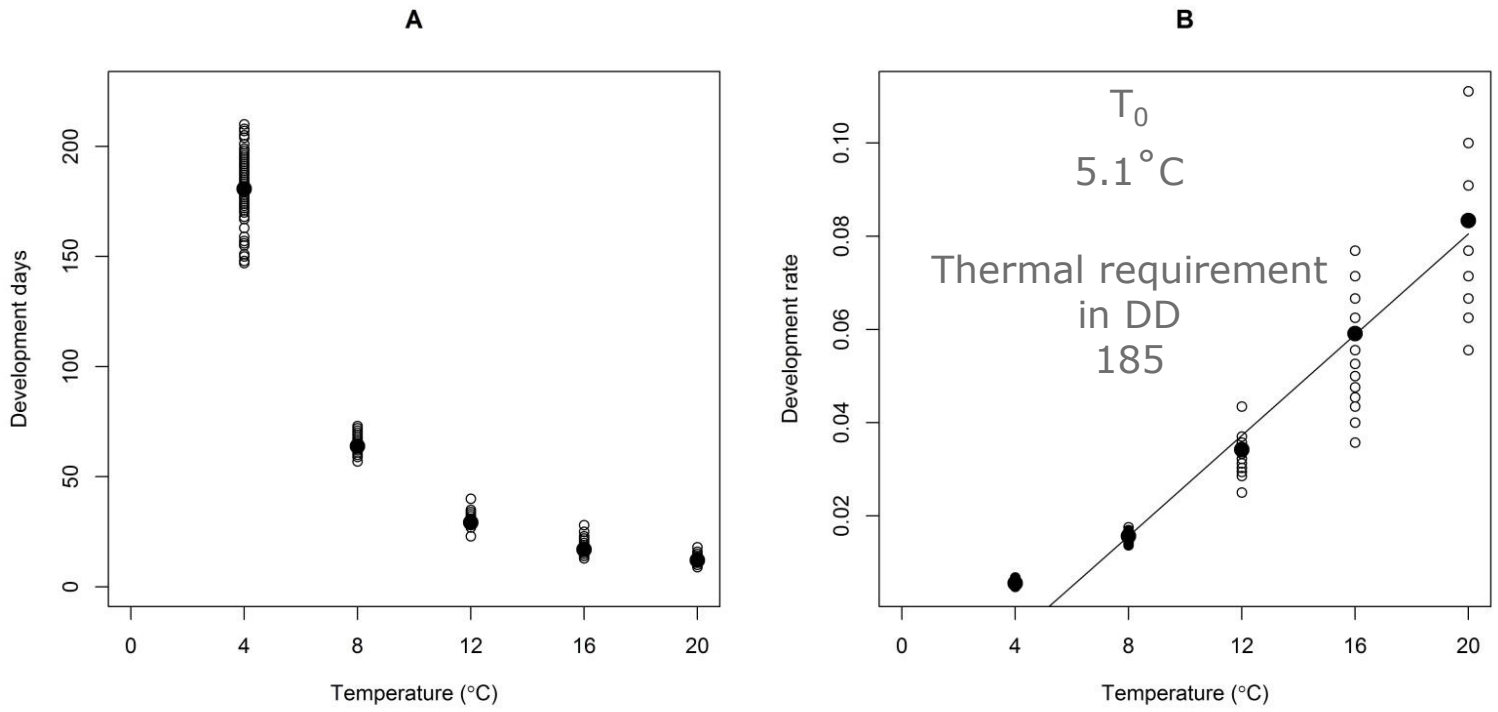
# Female survival time




50%

## Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

# Egg hatching rate

| Temperature ˚C | Hatching % |
|---|---|
| 4 | 47.27 [a] |
| 8 | 69.96 [b] |
| 12 | 72.37 [b] |
| 16 | 66.22 [b] |
| 20 | 67.89 [b] |

Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

## The maximum egg-laying at 16°C

~19 days until egg-laying starts

Estimated total egg-laying/female ~ 696 eggs

Estimated daily egg-laying rate ~ 5 eggs

Estimated female lifespan ~ 186 days

## Study 2: Effect of temperature on reproduction and embryonic development of the cabbage stem flea beetle, *Psylliodes chrysocephala*

The shortest egg development time and still high hatching rate at 20°C

### In the field

Earliest start of egg-laying, highest egg-laying intensity and earliest larval appearance in the field at temperatures around 16°C in the autumn

Study 3: Survival of cabbage stem flea beetle larvae, *Psylliodes chrysocephala L.*, exposed to low temperatures
Submitted to Entomologia Experimentalis et Applicata

**Winter temperature and larval mortality**

**Cold tolerance of the cabbage stem flea beetle?**

**Cold acclimation ⟶ increased survival**
**Declining temperatures**
**Declining daylength**

**Lethal time**
**The time of 50% mortality at low temperature**

## Study 3: Survival of cabbage stem flea beetle larvae, *Psylliodes chrysocephala L.*, exposed to low temperatures

Acclimated and non-acclimated larvae

Temperatures: -5 and -10°C

Exposure times

1, 2, 4, 8, 12, 16 and 20 **days** at -5°C

6, 12, 24, 36, 48, 72, 96, 120 and 144 **hours** (6 days) at -10°C

First and second instar larvae

Temperature: -5 and -10°C

Exposure times

8 days at -5°C

2 days at -10°C

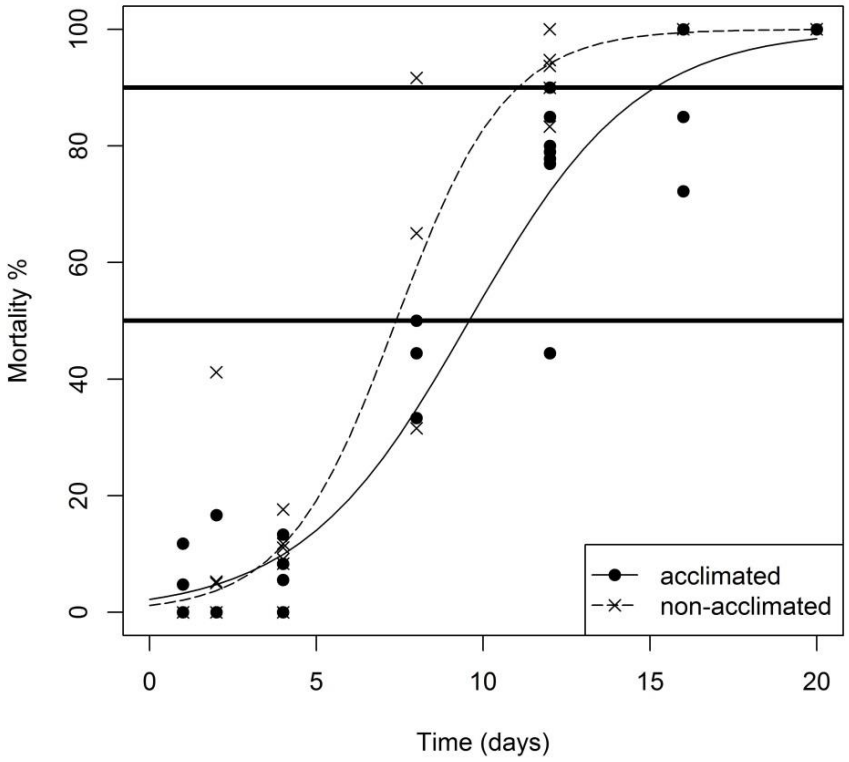
Study 3: Survival of cabbage stem flea beetle larvae, *Psylliodes chrysocephala L.*, exposed to low temperatures

# Sensitivity of larval stage

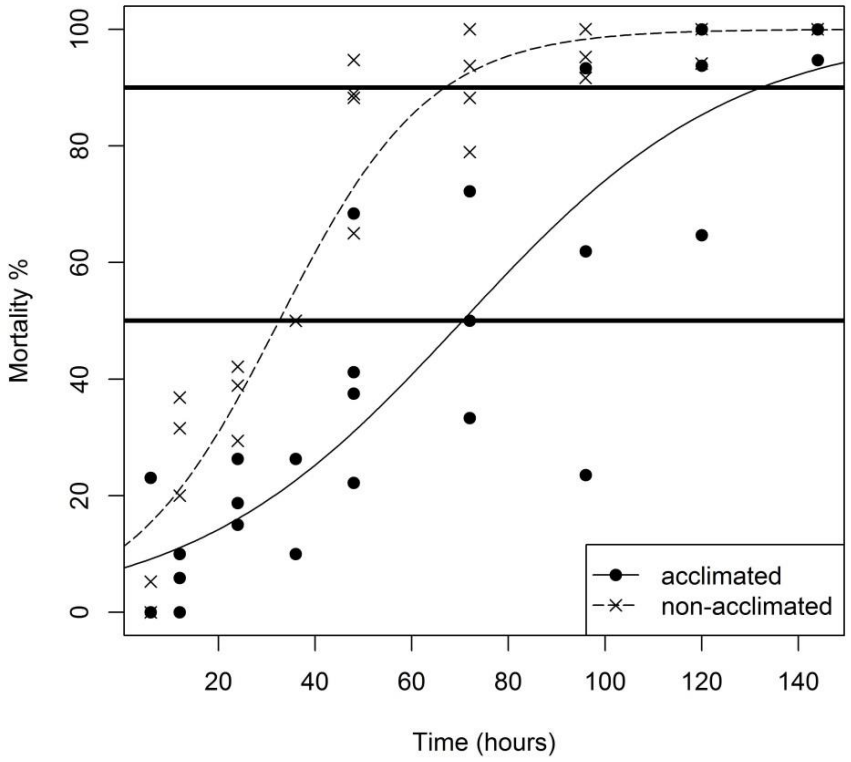
| Temperature | Larval stage | Mortality % (mean ± SD) |
|---|---|---|
| **-5°C** | $L_1$ | **81.22** ± 12.97 **a** |
| | $L_2$ | **51.26** ± 17.90 **b** |
| **-10°C** | $L_1$ | 70.53 ± 19.49 a |
| | $L_2$ | 76.12 ± 11.36 a |

## Study 3: Survival of cabbage stem flea beetle larvae, *Psylliodes chrysocephala L.*, exposed to low temperatures

-5°C




-10°C



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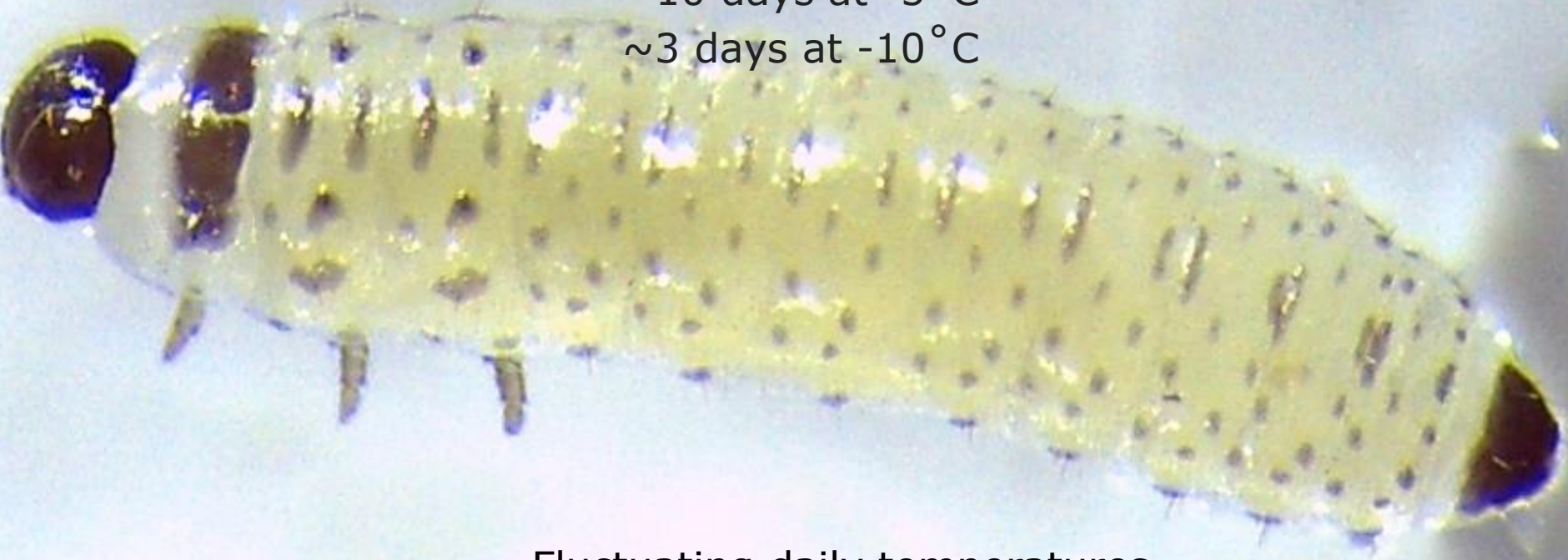


Time of 50% mortality of acclimated larvae

~10 days at -5°C

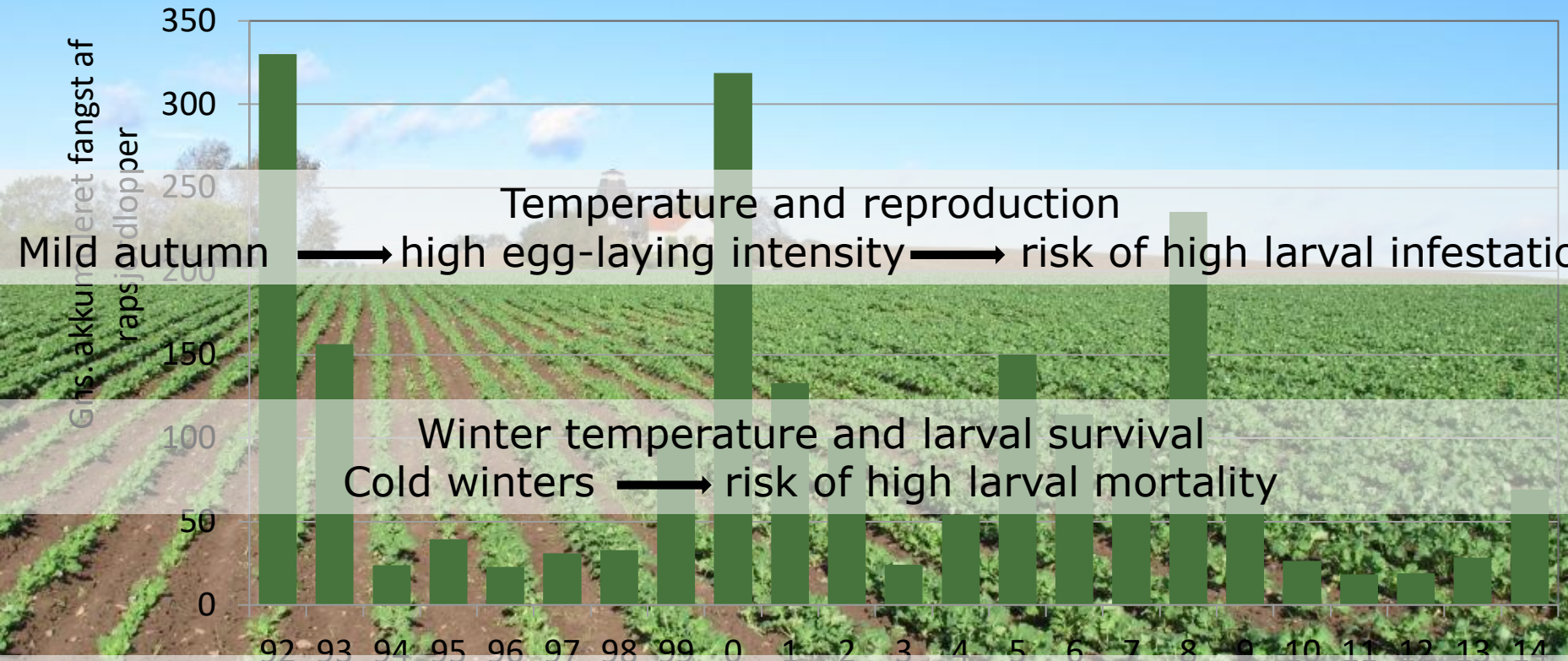
~3 days at -10°C

Fluctuating daily temperatures

A wider temperature range and more exposure times

Determintation of the lower lethal temperature (minimum exposure time)

1992-2014




Temperature and reproduction

Mild autumn → high egg-laying intensity → risk of high larval infestation

Winter temperature and larval survival

Cold winters → risk of high larval mortality

Natural enemies

Threshold and thermal requirement in DD

Cumulated relative fecundity in day-degrees

184 DD > 5.1°C

First trap catches

Start of DD summation for the preovipostion period

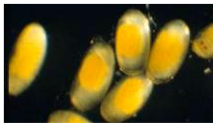
Start of DD summation for 50% egg-laying

Start of DD summation for egg hatching

Field invasion

Threshold of trap catches

Start of egg-laying



50% eggs laid

50% eggs hatched

Action

# THANK YOU

Peter Esbjerg
Jens Bligaard
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Anders Tolver
Anders C. Jensen
Anders Nørgaard
Celine Robert
Finn Olsen
Tine Lund
Benny Petersen
Jørgen Eilenberg
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Ministry of Higher Education and Science

LANDBRUG FØDEVARER SEGES

Release of beetles: 11/9

Temperature at time of release 12°C

Mean preoviposition at 12°C ~ 26 days

Mean number of eggs per day at 12°C ~ 2,58

Mean development time at 8°C ~ 64 days

Eggs from ~ 11/10

First instar larvae from ~ 11/12

# Determination of larval density/plant

# Total egg-laying and daily rate

| Temperature °C | Eggs/female (estimated) | P | Eggs/day/female (estimated) | P |
|---|---|---|---|---|
| 4 | 57.34 | - | 0.81 | - |
| 8 | 179.66 | 0.019 | 1.73 | 0.02 |
| 12 | 199.06 | 0.772 | 2.31 | 0.244 |
| 16 | 695.62 | <0.001 | 5.43 | <0.001 |
| 20 | 371.28 | 0.005 | 6.82 | 0.113 |

# Female survival time (estimated)

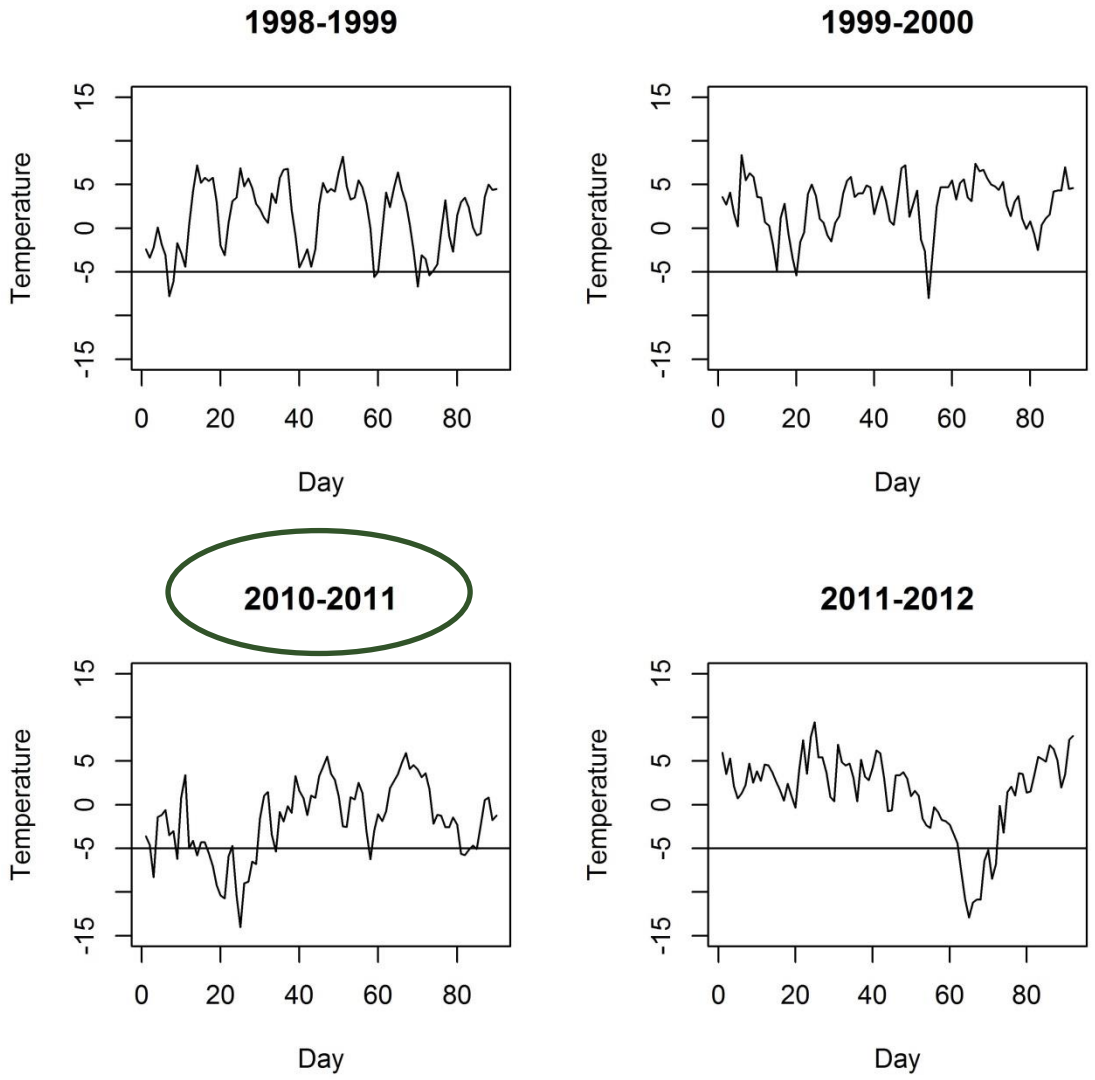
| Temperature ˚C | 50% survival time (days) | 95% CI |
|---|---|---|
| 4 | 239 [a] | 218 - NA |
| 8 | 153 [b] | 116 - 232 |
| 12 | 195 [b] | 137 - 239 |
| 16 | 186 [b] | 137 - 237 |
| 20 | 78 [c] | 60 - 215 |

# Estimation of egg development time from estimates of $T_0$ and the thermal constant

| Temperature °C | 4 | 8 | 12 | 16 | 20 | Reference |
|---|---|---|---|---|---|---|
| Development time (days) | - | 64 | 26.9 | 17 | 12.4 | Mathiasen et al., 2015 |
| | 300 | 50 | 27.3 | 18.8 | 14.3 | Alford, 1979 |
| | - | 50 | 25 | 16.7 | 12.5 | Johnen & Meier, 2000 |
| | - | 160 | 32 | 17.8 | 12.3 | Bonnemaison & Jourdheuil, 1954 |

Study 3: Survival of cabbage stem flea beetle larvae, *Psylliodes chrysocephala L.*, exposed to low temperatures

## Daily mean winter temperatures in DK from 1990-2013



# Statistical analysis

- Poisson regression with intensity (beetle density) log transformed to an unrestricted scale and subjected to analysis of variance by the GLMER procedure in R.

- Tests for significant effects and differences were assessed by model reduction and based on Likelihood ratio tests.

- Poisson regression of plant injury was based on:

$$y = a + b\,(\text{beetles}) + c\,(\text{Time})$$

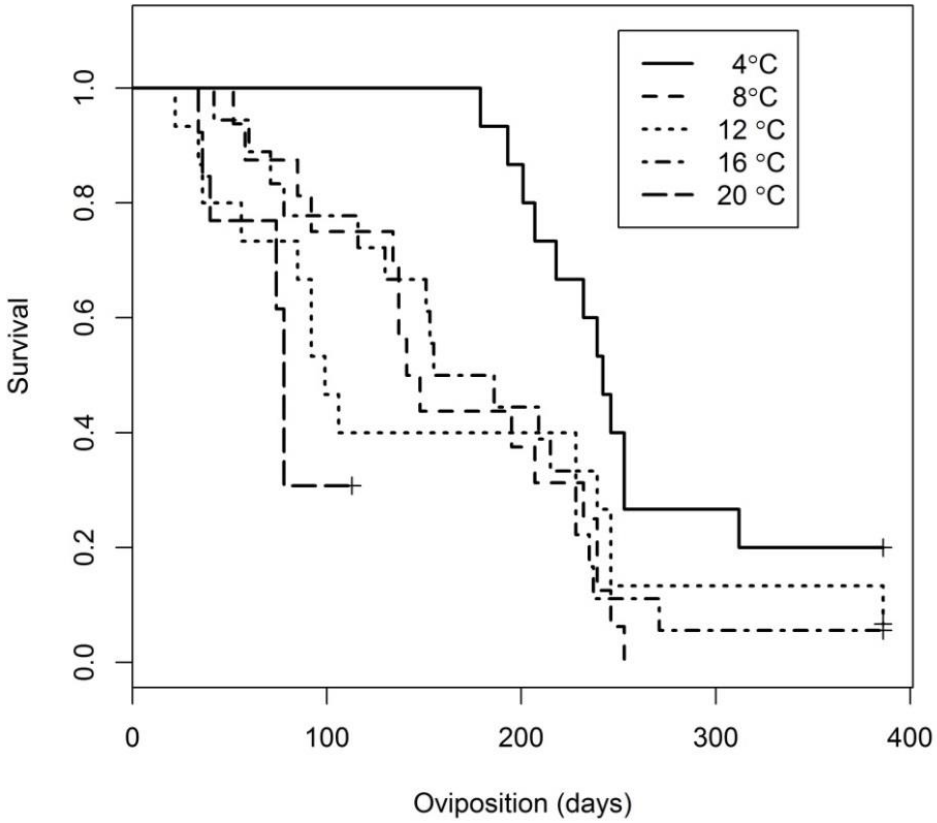
- Estimates of leaf damage from regression were back transformed to quantify the estimated differences at increasing number of beetles.

- Poisson regression of larval density/plant was based on:

$$y = a + b\,(\text{beetles}) + c\,(\text{beetles}^{\wedge 2})$$

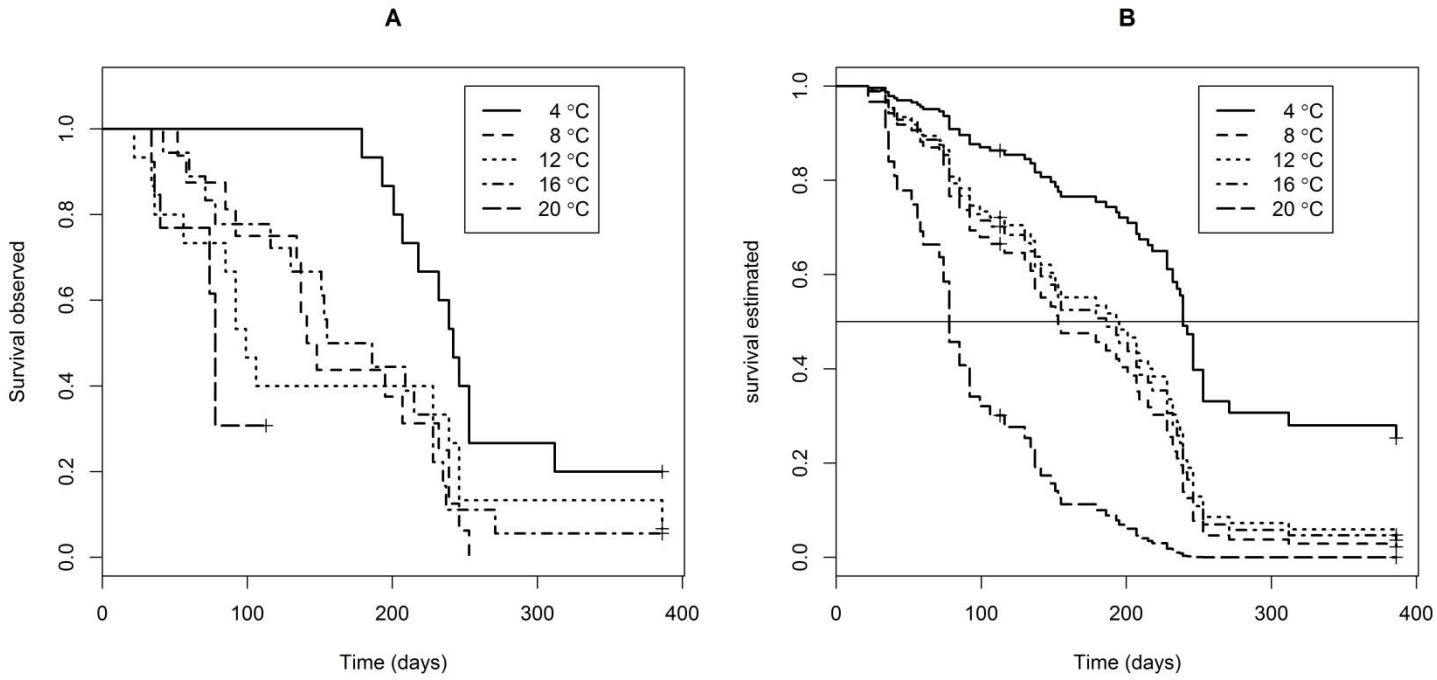
- 95% confidence intervals of larval density were estimated from model by parametric bootstrapping

# Statistiacal analysis of oviposition period




Kaplan-Meier survival analysis to test the effect of temperature on the length of the oviposition period

# Statistical analysis of female survival time




Cox proportional hazard model for comparison among temperature and to estimate time of 50% survival