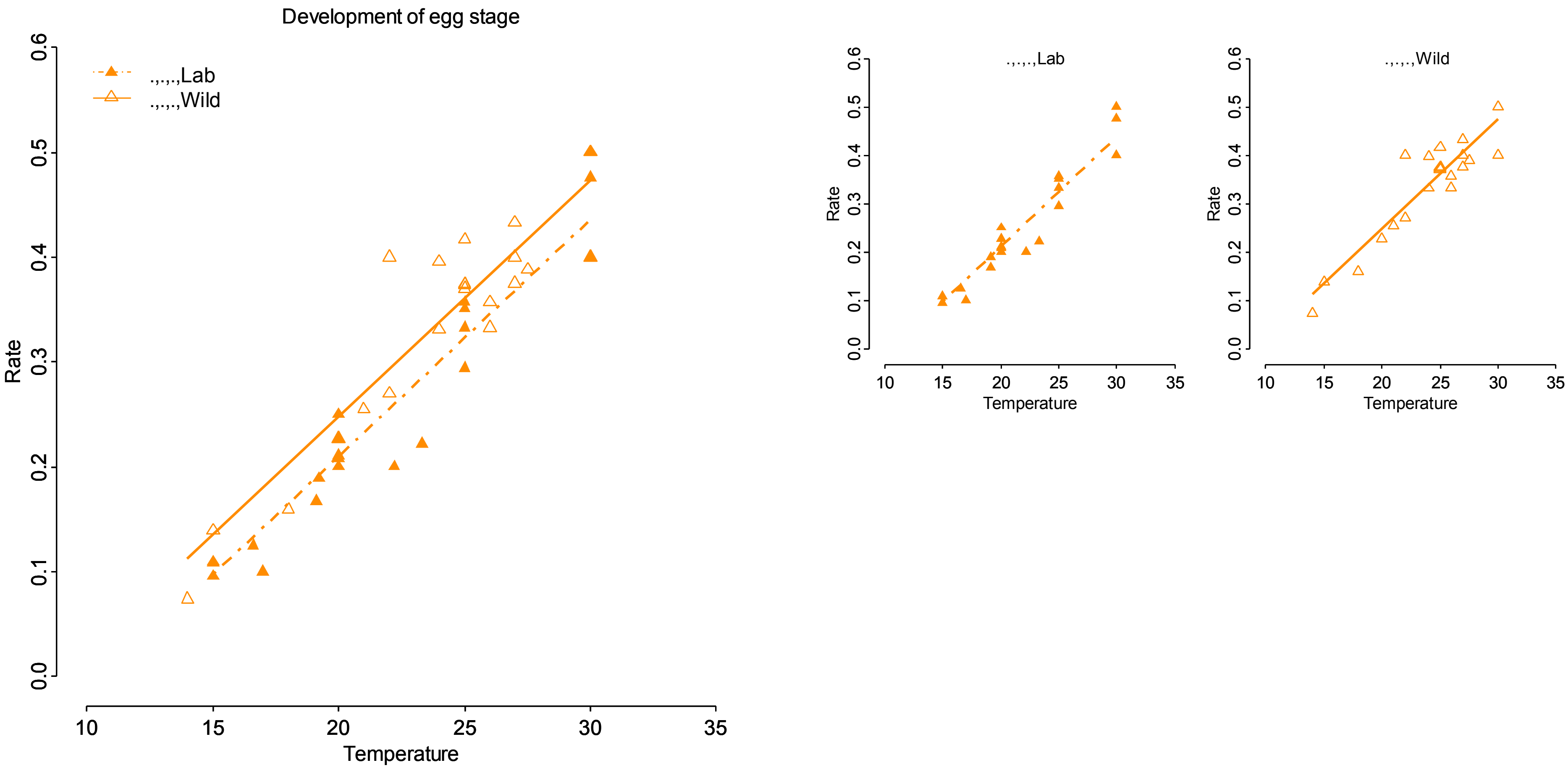
ESMB
Graphs of best, most parsimonious model for each response variable.

For each response variable a mixed model has been fitted comprising fixed intercepts and slopes for temperature for each subgroup (that is based upon one factor or a combination of factors), and random effects for the source studies. Hence, within a subgroup the data of each study are assumed to be scattered around a separate line (curve), each line (curve) having a unique random intercept, and all lines (curves) sharing the same slope. The model comprises two components of variance representing variation (in intercept) between lines within each subgroup, and variation between data points within separate lines. The lines indicated in the figure correspond to the mean intercept and common slope for subgroup. Because components of variance are estimated from information pooled over subgroups, and because the model generates positive correlation between data from the same study, it is possible, as can be observed for some subgroups, that predicted individual intercepts of different studies within subgroups are all above or all below the estimated mean intercept.

In the figures the average predicted models are shown. Our statements in the description of the models, results, and in the further interpretation are about the overall predicted model with the average intercept for the whole population. In all figures lines (curves) of predicted models are only shown within the range of observations of the respective sub-groups.

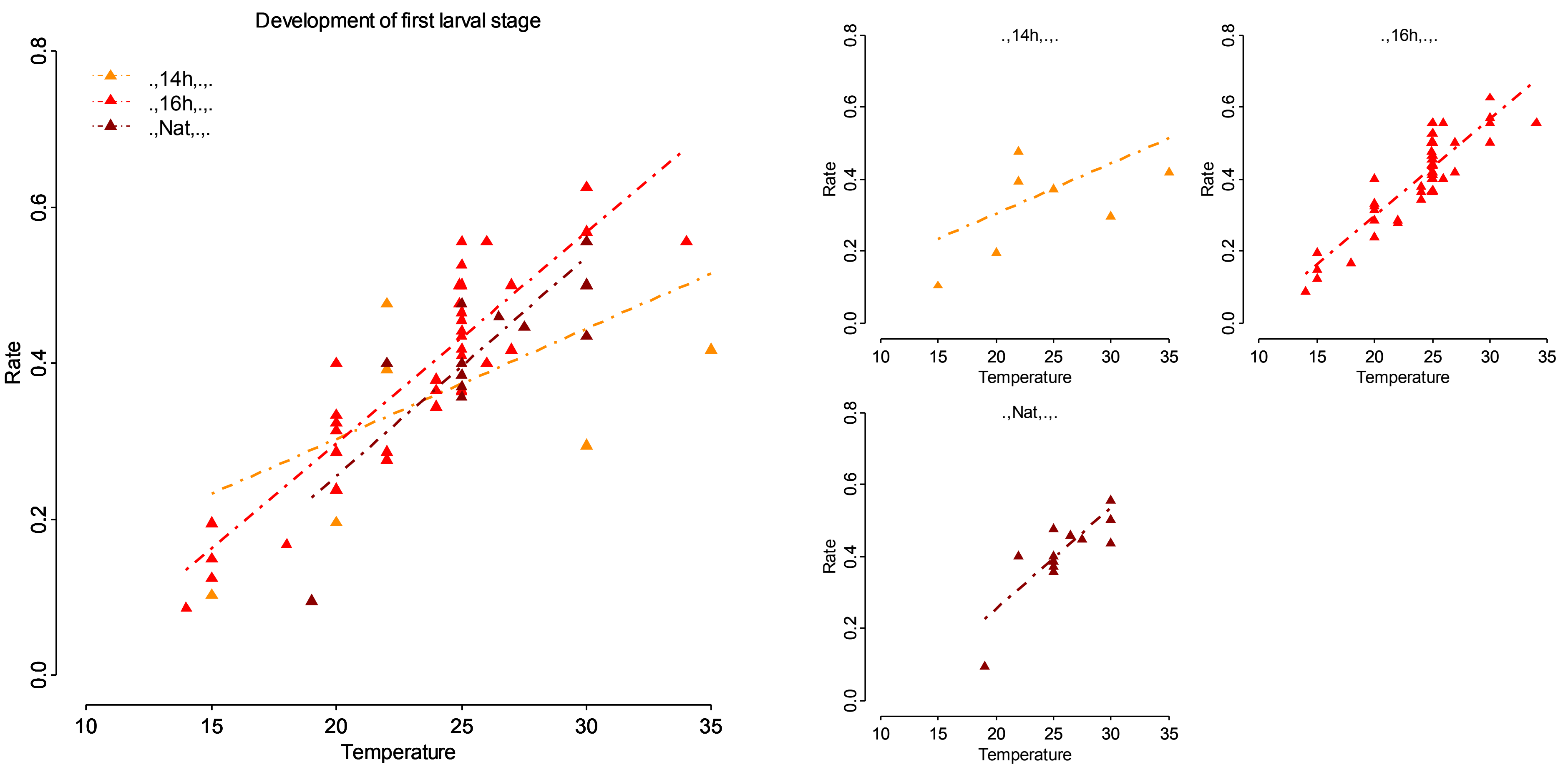


Development of the egg stage (D0) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. Reared strains have a smaller intercept than wild strains; at a certain temperature development rate is higher for wild populations than for reared pouplations.

*Development rate egg = —0.2027074 + 0.0225313*Temperature —0.0375638*reared*

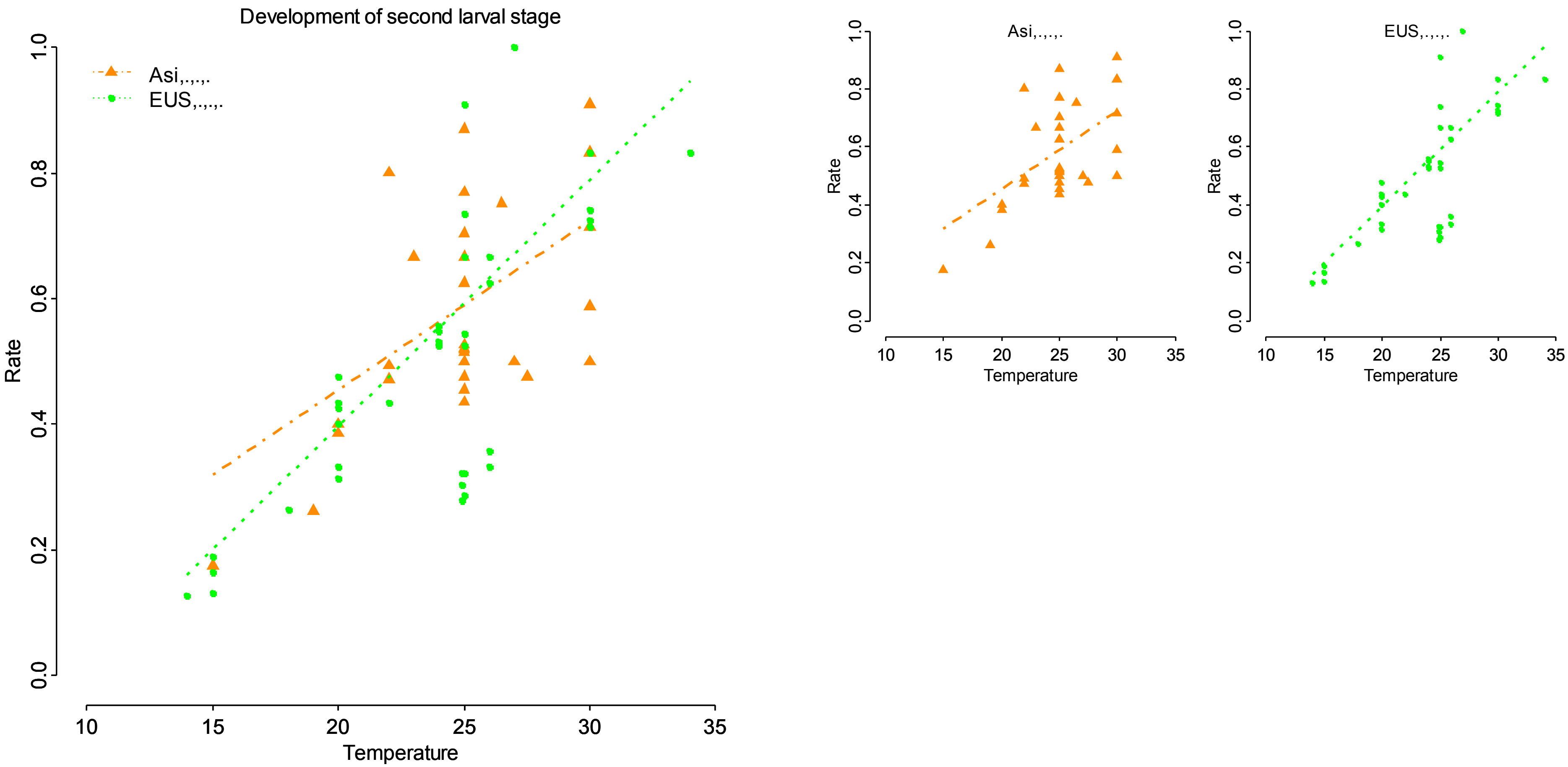


Development of first larval stage (D1) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature under short day is weaker than the response under long and natural day. At higher temperatures development is fastest under long and natural day. At low and intermediate temperatures differences are small. At temperatures below 20°C, however, the model predicts fastest development under short day.

*Development rate first larval stage= 0.0202418 + 0.014147*Temperature —0.2639167*long-day —0.3263597*natural-day + 0.0129154*Temperature*long-day + 0.0139451*Temperature*natural-day*

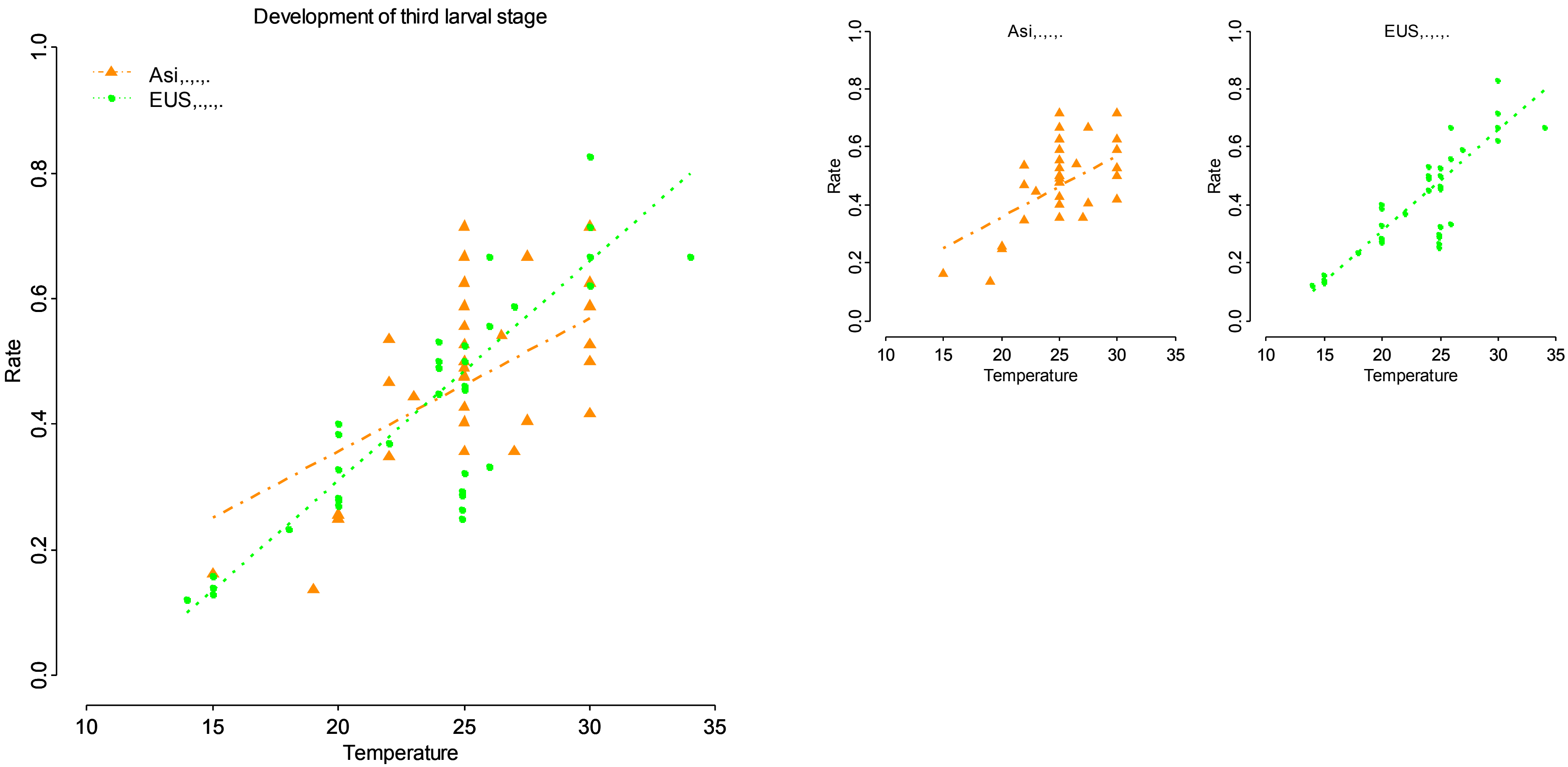


Development of second larval stage (D2) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature of Asian populations is weaker than the response of invasive populations. At higher temperatures invasive populations develop fastest. At low and intermediate temperatures differences are small. At temperatures below 25°C, however, the model predicts fastest development under short day.

*Development rate second larval stage = —0.3899278 + 0.0393027*Temperature + 0.3032745*Asia —0.0122397*Temperature*Asia*

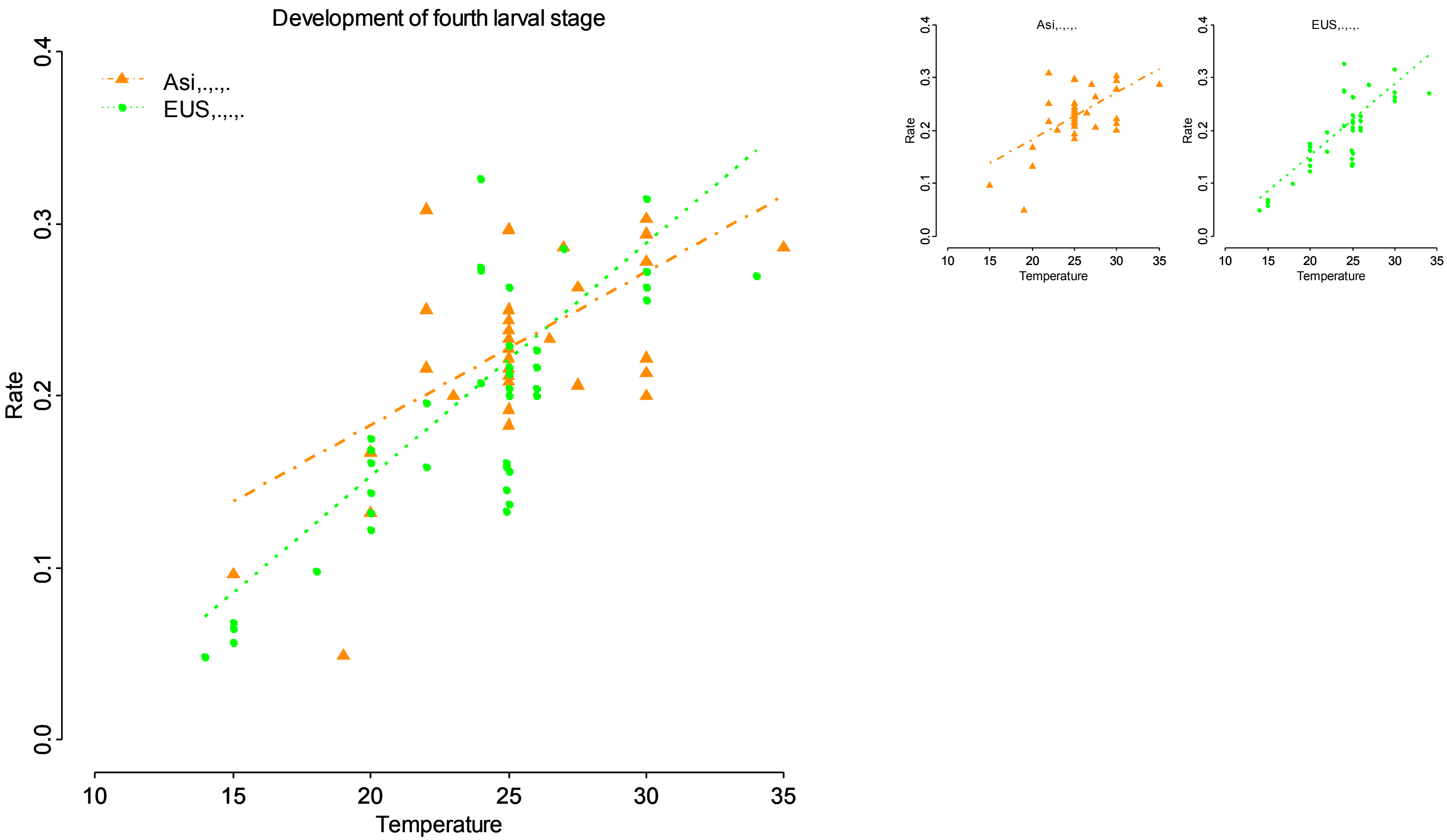


Development rate of third larval stage (D3) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature.The response to temperature of Asian populations is weaker than the response of invasive populations. At higher temperatures invasive populations develop fastest. At low and intermediate temperatures differences are small. At temperatures below 23°C, however, the model predicts fastest development under short day.

*Development rate third larval stage = —0.388284 + 0.034911*Temperature + 0.323332*Asia —0.013755*Temperature*Asia*

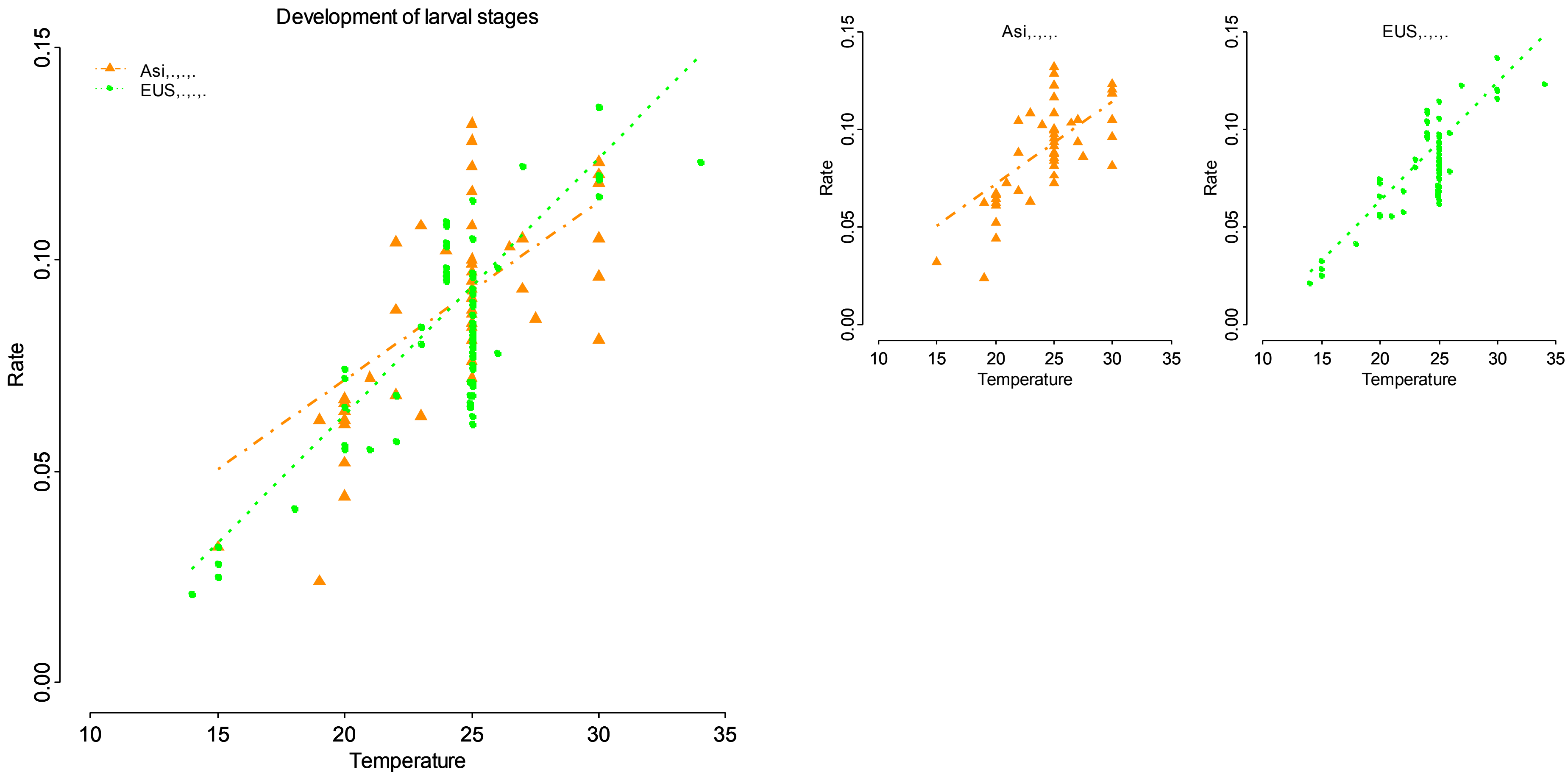


Development of fourth larval stage (D4) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted.. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature of Asian populations is weaker than the response of invasive populations. At higher temperatures invasive populations develop fastest. At low and intermediate temperatures differences are small. At temperatures below 27°C, however, the model predicts fastest development under short day.

*Development rate fourth larval stage = —0.1175589 + 0.0135345*Temperature + 0.1228659*Asia —0.0046532*Temperature*Asia*

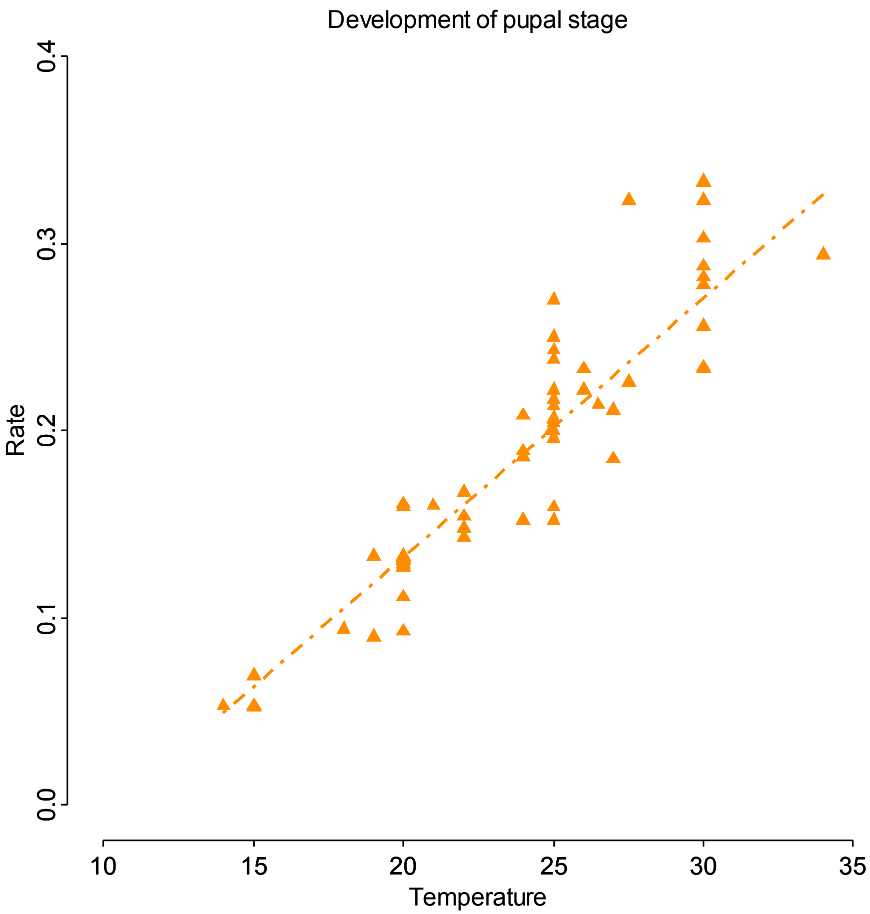


Development rate of all larval stages (D5) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature of Asian populations is weaker than the response of invasive populations. At higher temperatures invasive populations develop fastest. At low and intermediate temperatures differences are small. At temperatures below 24°C, however, the model predicts fastest development under short day.

*Development rate larval stages = —0.05825680 + 0.00606840*Temperature + 0.04579460*Asia —0.00186560*Temperature*Asia*

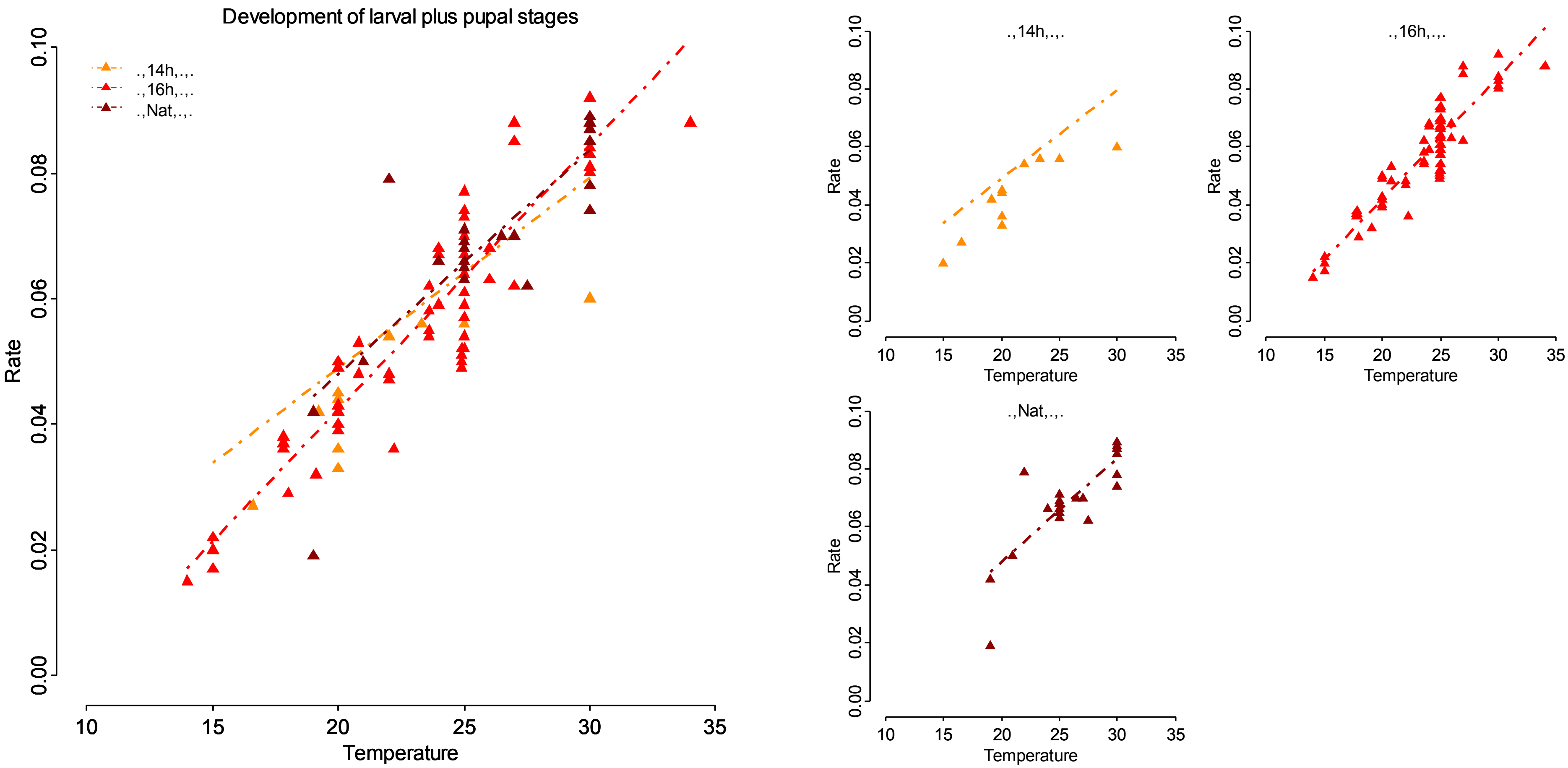


Development rate of pupal stage (D6) of *Harmonia axyridis*, shown as rate against temperature. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. No effects of origin, day length, food or strain are observed.

*Development rate pupal stage = —0.1446802 + 0.013856*Temperature*

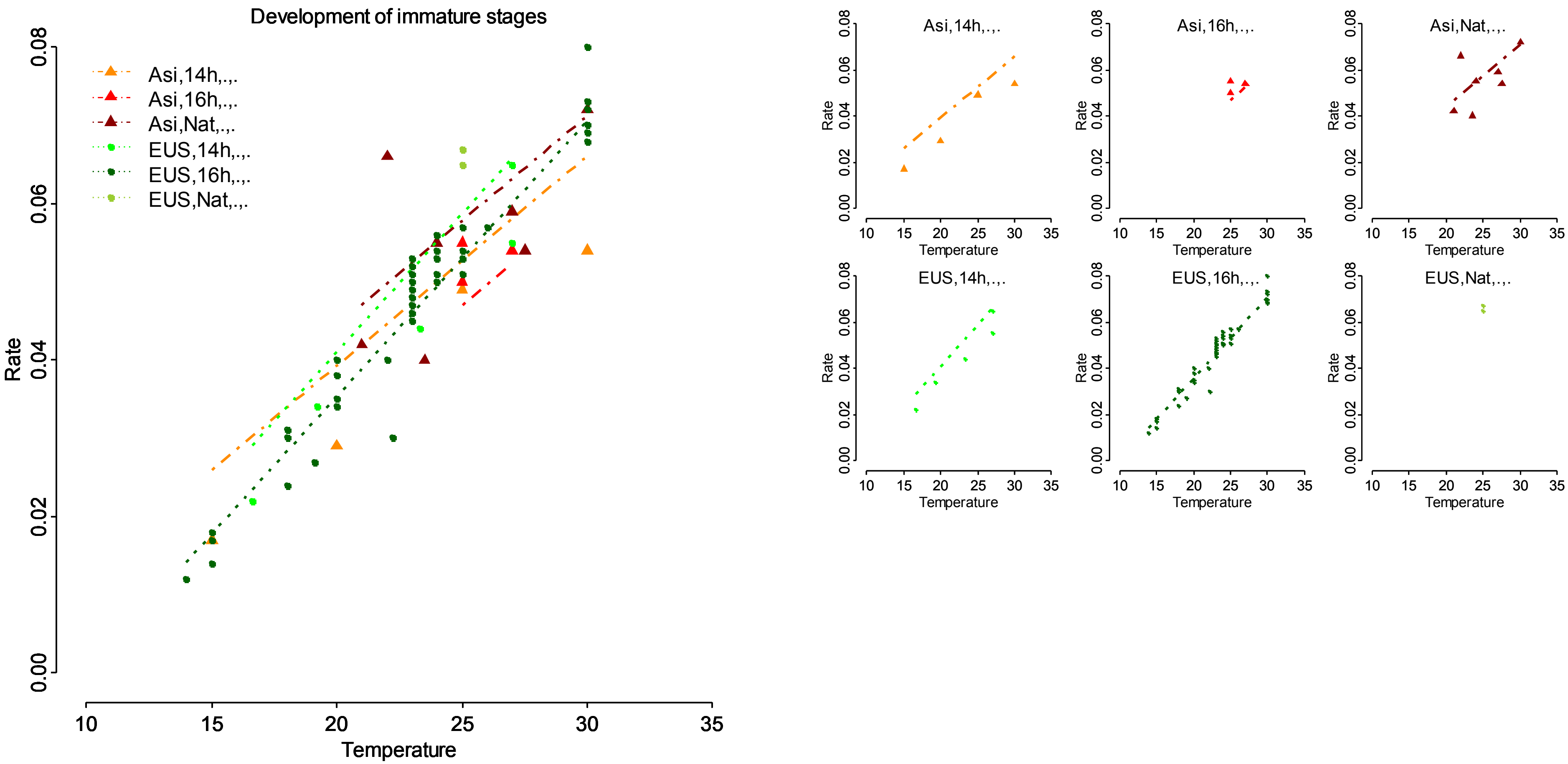


Development of larval + pupal stages (D7) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted.. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature is slightly different between photoperiods: weakest under short day and strongest under long day. At temperatures below 22°C, the model predicts fastest development under short day, while above 28°C fastest development is predicted under long day. No clear differences exist between 22°C and 28°C. The models have been fitted using a mixed model where the source study is added as random effect. The resulting model predicts a different intercept for each study. For the overal model however, an average intercept is taken for the whole population. As a result the mean predicted model for a subgroup (in this case short day) can deviate from the original datapoints. All studies in the short day subgroup had smaller intercepts than the intercept for the mean predicted model.

*Development rate larval + pupal stages = —0.0118257 + 0.0030406*Temperature —0.0300592*long-day —0.0113082*natural-day + 0.0011676*Temperature*long-day + 0.0005187*Temperature*natural-day*

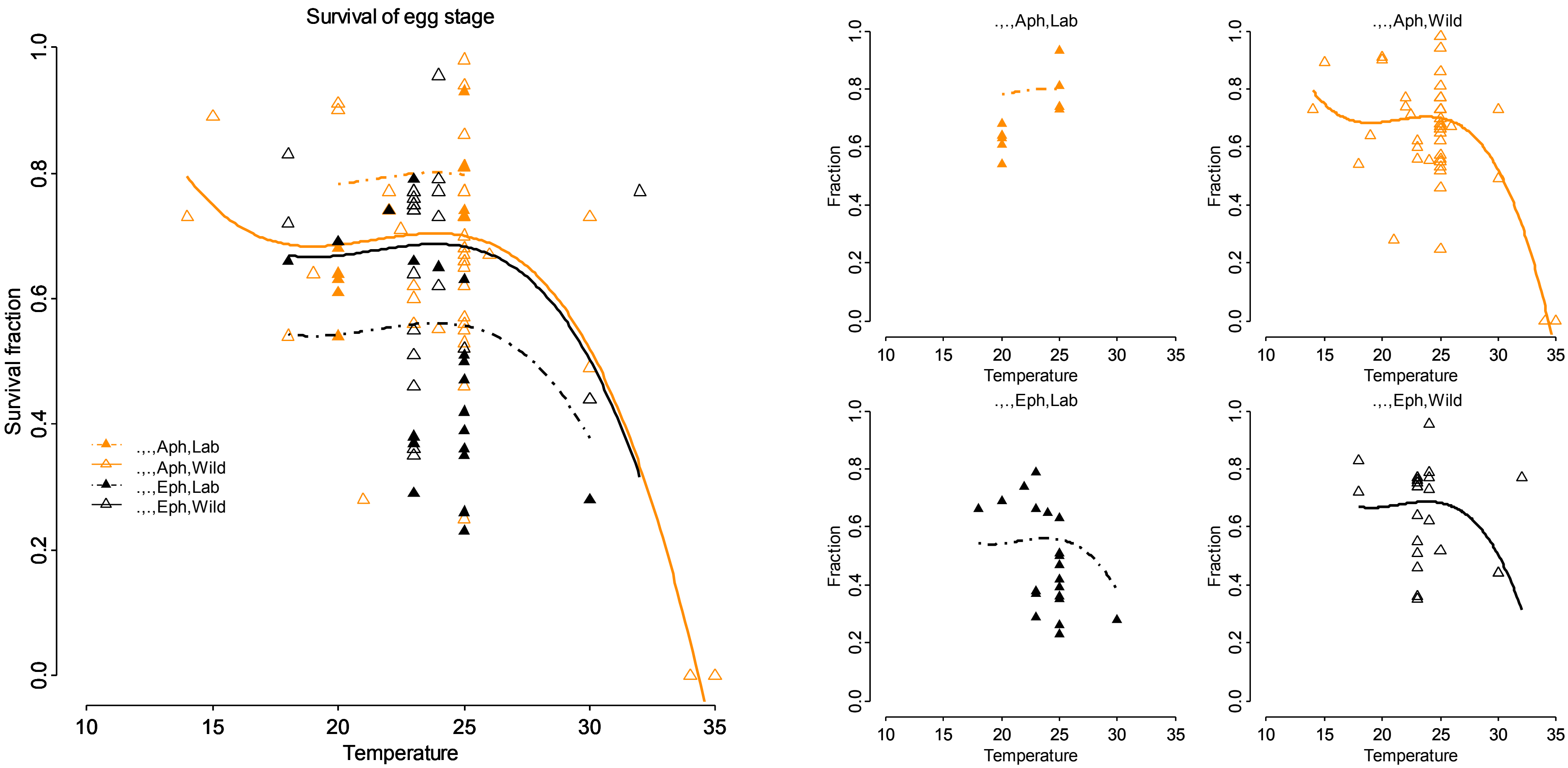


Development of all immature stages (D8) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Development rate increases with increasing temperature. The response to temperature of Asian populations is weaker than that of invasive populations. For both Asian and invasive populations, development is faster under short day than under long day. In case of Asian populations development is fastest under natural day. The models have been fitted using a mixed model where the source study is added as random effect. The resulting model predicts a different intercept for each study. For the overal model however, an average intercept is taken for the whole population. As a result the mean predicted model for a subgroup (in this case short day for both Asian and invasive populations, and to a lesser extent long day for Asian populations) can deviate from the original datapoints. All studies in the short day subgroups and the Asian natural day subgroup had smaller intercepts than the intercept for the mean predicted model, while those for the Asian long day subgroup had larger intercepts.

*Development rate immature stages = —0.0294284 + 0.0035231*Temperature + 0.0149913*Asia —0.0057551*long-day + 0.0051021*natural-day —0.0008373*Temperature*Asia*



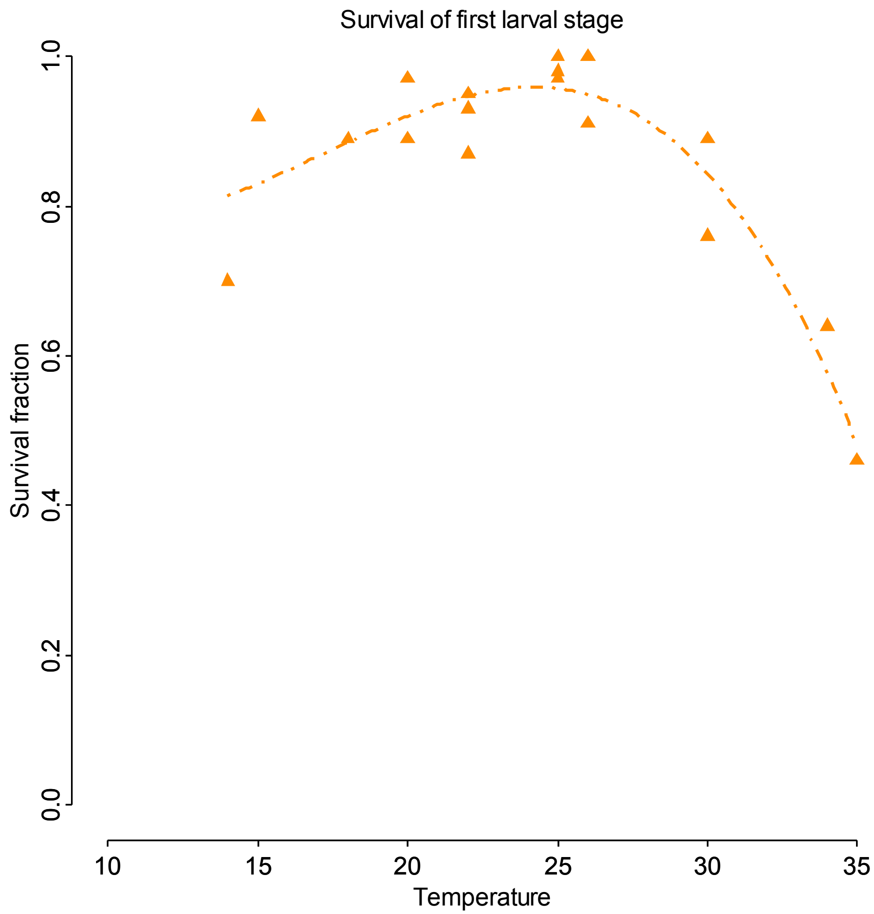
Survival of Egg (S0) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Survival of the egg stage, has a cubic relation with temperature. Egg survival depends on the food of the adults and whether the adults were laboratory reared or collected from the wild. Eggs from aphid-fed populations survive better than those from Ephestia-fed populations. Survival of wild populations is intermediate, while reared aphid-fed populations survive best and reared Ephestia-fed populations worst. In the range of 20°C to 30°C the optimum temperature for survival is 23.9°C.

Survival egg = 0.7039827 —0.0026369(Temperature—Mean Temperature)^2 —0.0003625*(Temperature—Mean Temperature)^3 —0.0170202*Ephestia + 0.0969806*reared — 0.222801*reared*Ephestia*

Mean temperature = 23.85204



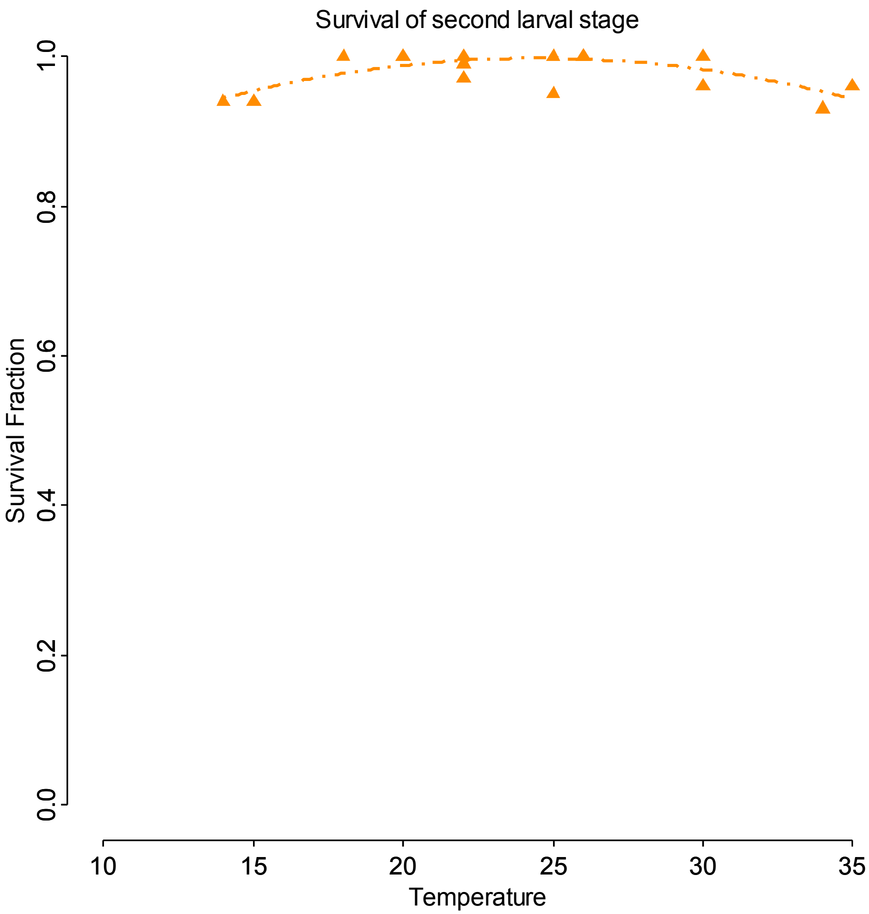
Survival of first larval stage (S1) of *Harmonia axyridis*, shown against temperature. The x-axis shows temperature starting at 10°C.

Description

Survival of the first stage, has a cubic relation with temperature. No effect of origin, day length, food or strain are observed. Maximum survival of the first larval stage is at approximately 25°C.

Survival first larval stage = 0.9589344 —0.0027141(Temperature—Mean Temperature)*^{2} *—0.0001294*(Temperature—Mean Temperature)*^{3}

Mean temperature = 24.21053



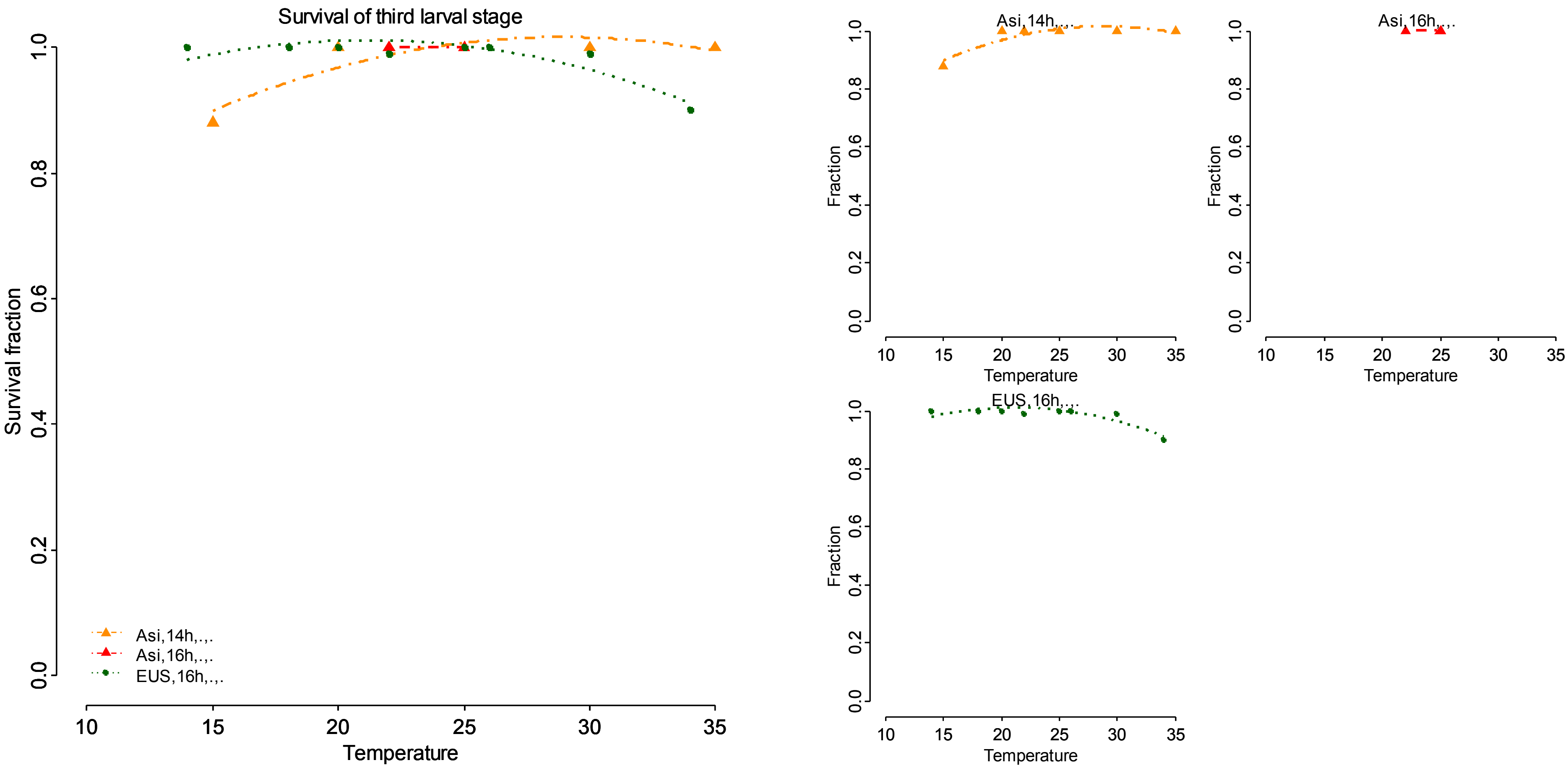
Survival of second larval stage (S2) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Survival of the second stage, has a cubic relation with temperature. No effect of origin, day length, food or strain are observed. Maximum survival of the second larval stage is at approximately 25°C.

Survival second larval stage = 0.9977448 —0.0004895(Temperature—Mean Temperature)*^{2}

Mean temperature = 24.42857



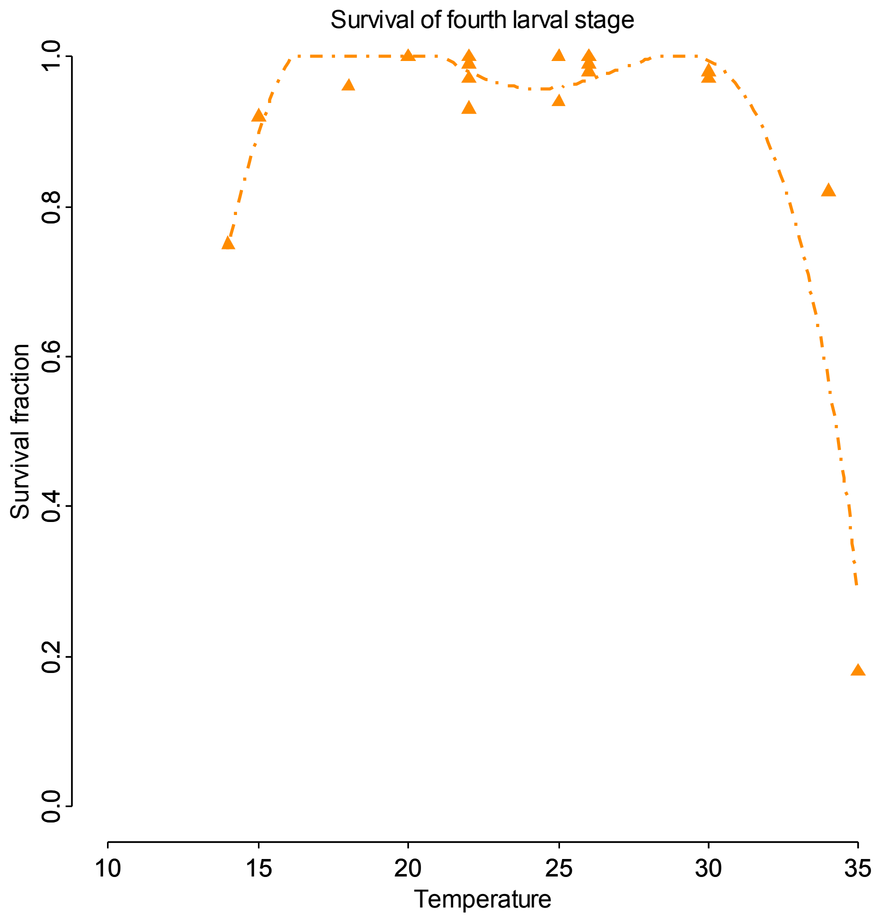
Survival of third larval stage (S3) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Survival of the third larval stage, has a quadratic relation with temperature. For Asian populations under short day, optimum survival is observed at slightly higher temperatures than for invasive populations under long day.

*Survival third larval stage = 1.0278772 —0.0011066*Temperature —0.0006086*(Temperature—Mean Temperature)^2 —0.1572371*Asia*short-day + 0.0736305*invasive*long-day + 0.0065784*Temperature*Asia*short-day —0.0028320*Temperature*invasive*long-day*

Mean temperature = 24.40909



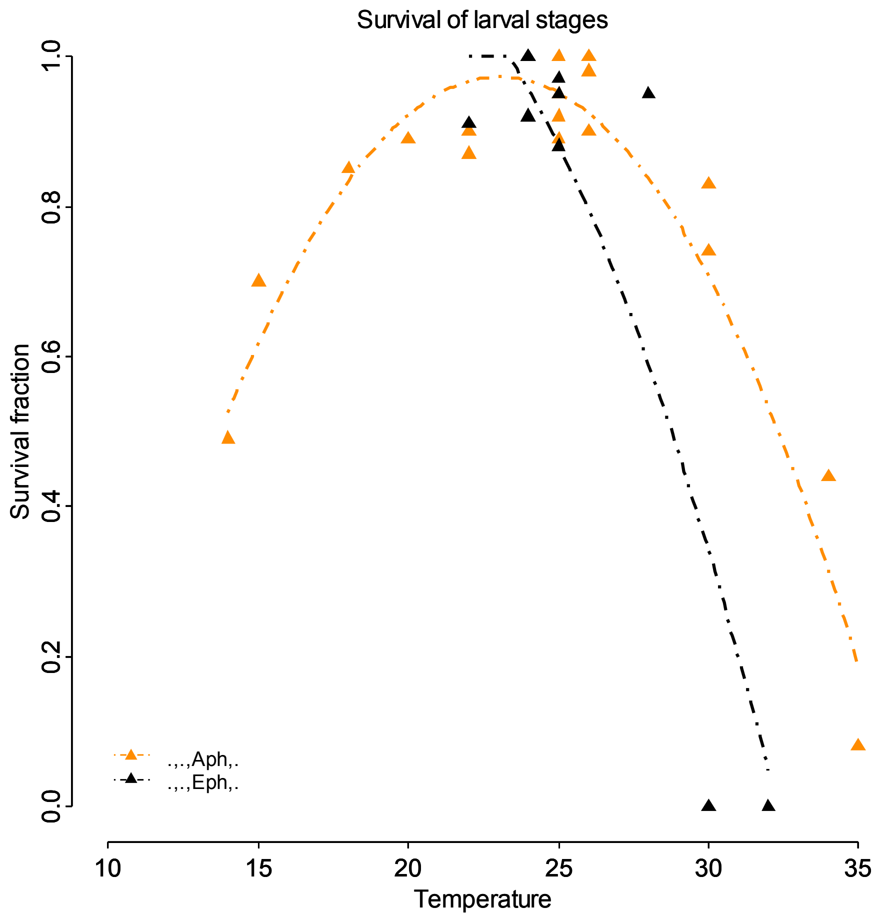
Survival of fourth larval stage (S4) of *Harmonia axyridis*, shown against temperature. The x-axis shows temperature starting at 10°C.

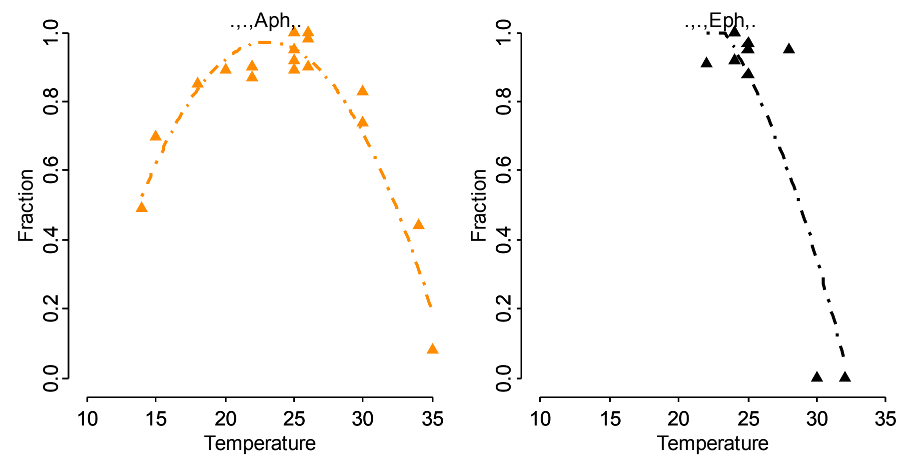
Description

The temperature response of the fourth larval stage is a fourth order polynomial. No effect of origin, day length, food, or strain is observed.

Survival fourth larval stage $= 0.9570912 + 0.0044967 \cdot (\text{Temperature}-\text{Mean Temperature})^2 - 0.0001533 \cdot (\text{Temperature}-\text{Mean Temperature})^3 - 0.0000762 \cdot (\text{Temperature}-\text{Mean Temperature})^4$

Mean temperature = 24.30435





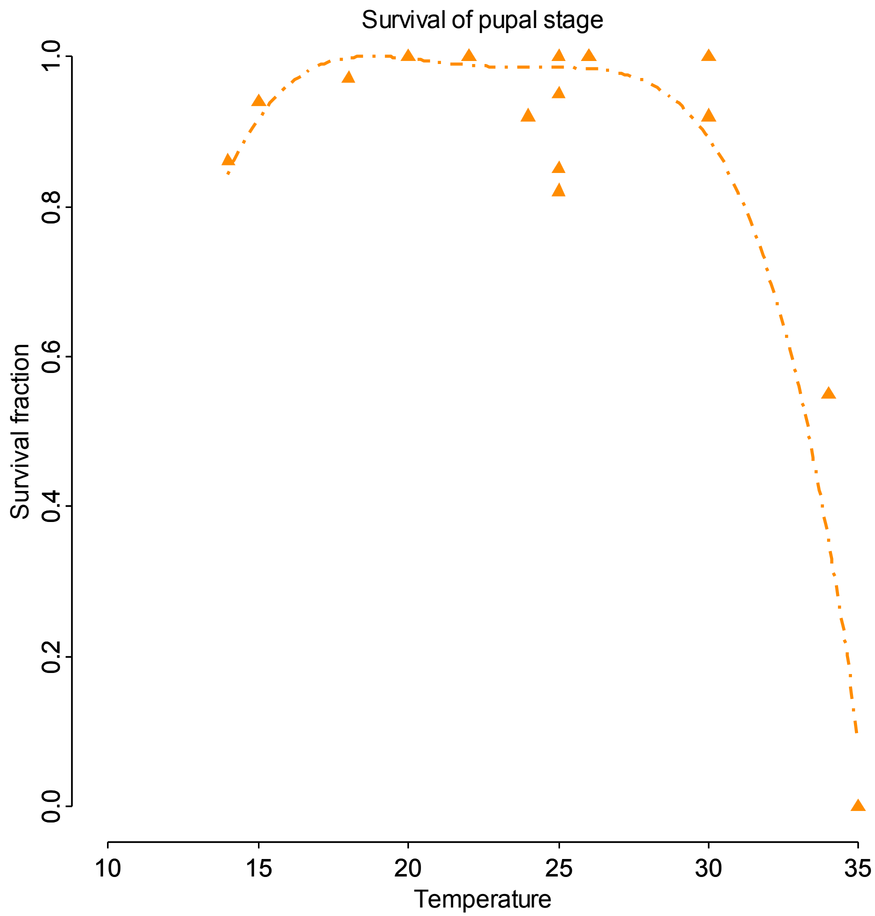
Survival of larval stages (S5) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Survival of the larval stages has a cubic relation with temperature. For *Ephestia*-fed populations the relationship could only be fitted for higher temperatures. Optimum survival of aphid-fed populations is 96.2% at 24.7°C.

$$Survival\ larval\ stages = 0.9021193 + 0.0024186*Temperature - 0.0054176*(Temperature - Mean\ Temperature)^2 - 0.0002202*(Temperature - Mean\ Temperature)^3 + 1.1764963*Ephestia - 0.0522495*Ephestia*Temperature$$

Mean Temperature=24.46341



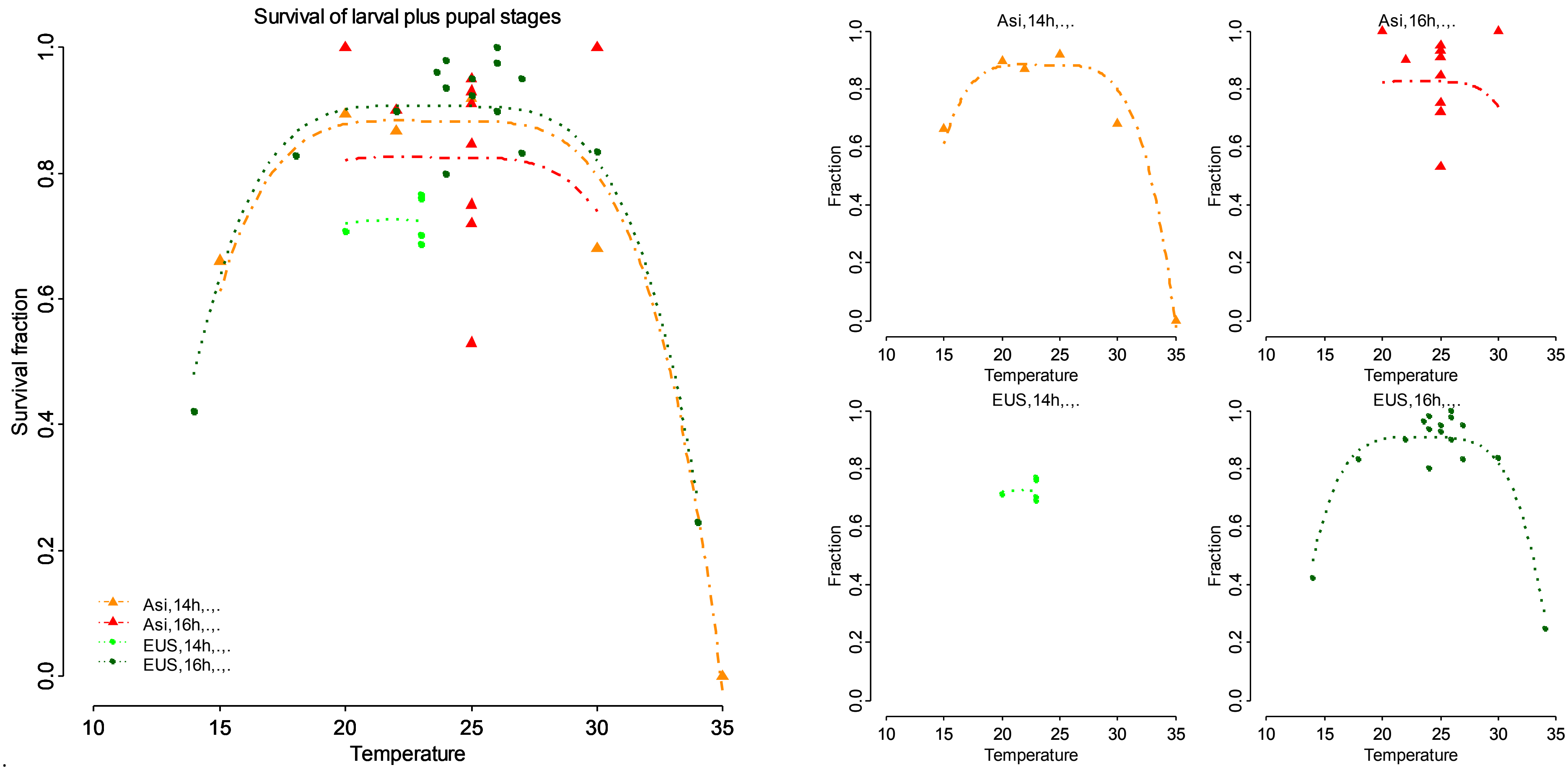
Survival of the pupal stage (S6) of *Harmonia axyridis*, shown against temperature. The x-axis shows temperature starting at 10°C.

Description

The temperature response of the pupal stage is a fourth order polynomial. No effect of origin, day length, food, or strain is observed.

$$Surivival\ pupal\ stage = 0.09854 - 0.0003241*(Temperature - Mean\ Temperature)^{3} - 0.00004268*(Temperature - Mean\ Temperature)^{4}$$

Mean temperature = 24.47826



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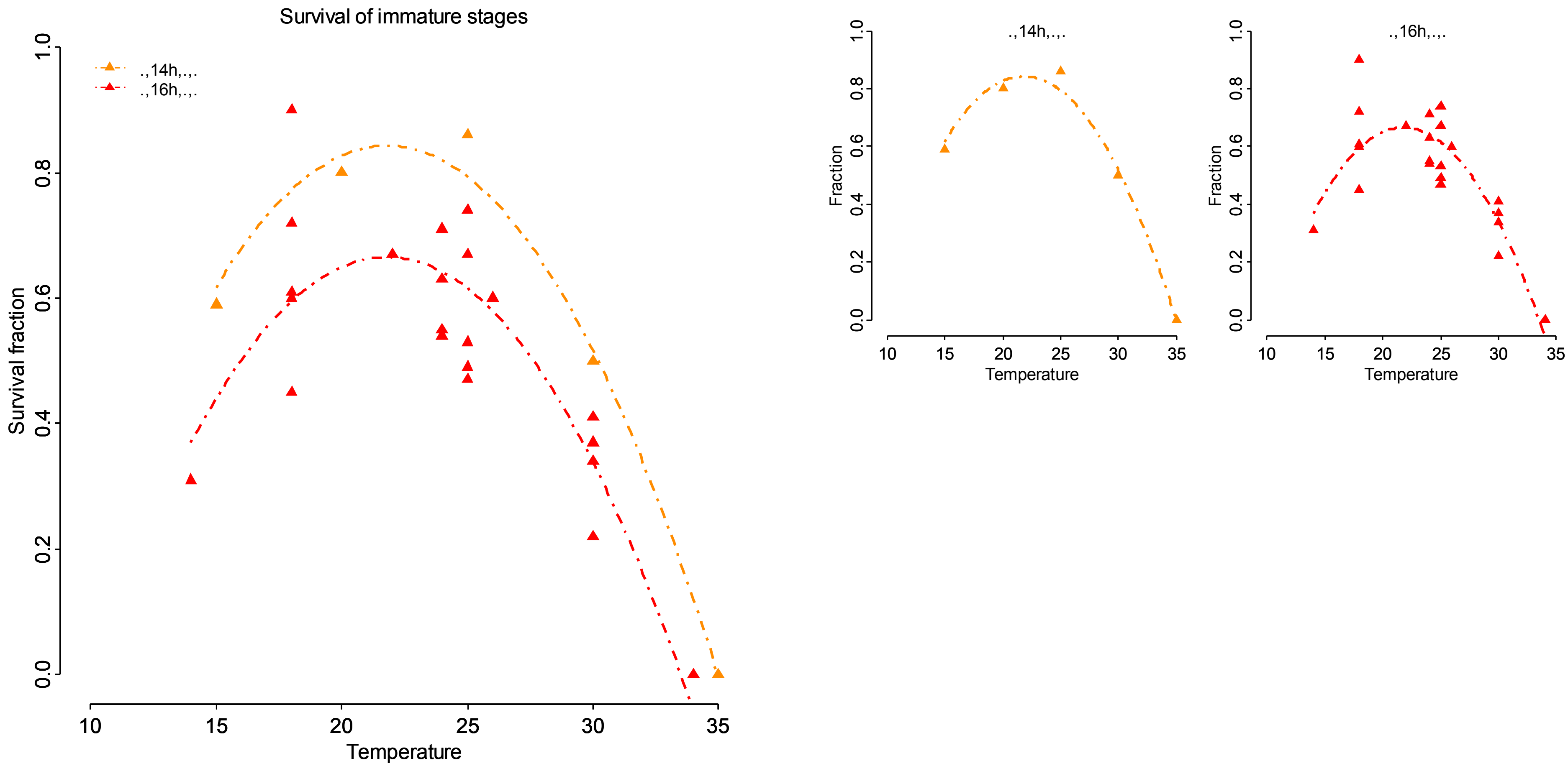
Survival of larval+pupal stages (S7) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

The temperature response of the larval+pupal stages is a fourth order polynomial. Invasive populations have highest optimum survival (90.7%) under long day and lowest survival under short day (72.6%). Asian populations are intermediate (88.4% short day, 82.6% longday). Optimum temperature is in the range of 21.6°C to 22.2°C.

$$\textit{Survival larva+pupa} = 0.7250 - 0.0001816 \cdot (\textit{Temperature} - \textit{Mean Temperature})^3 - 0.00005417 \cdot (\textit{Temperature} - \textit{Mean Temperature})^4 + 0.1579 \cdot \textit{Asia} + 0.1812 \cdot \textit{long-day} - 0.2391 \cdot \textit{Asia} \cdot \textit{long-day}$$

Mean Temperature=24.38421

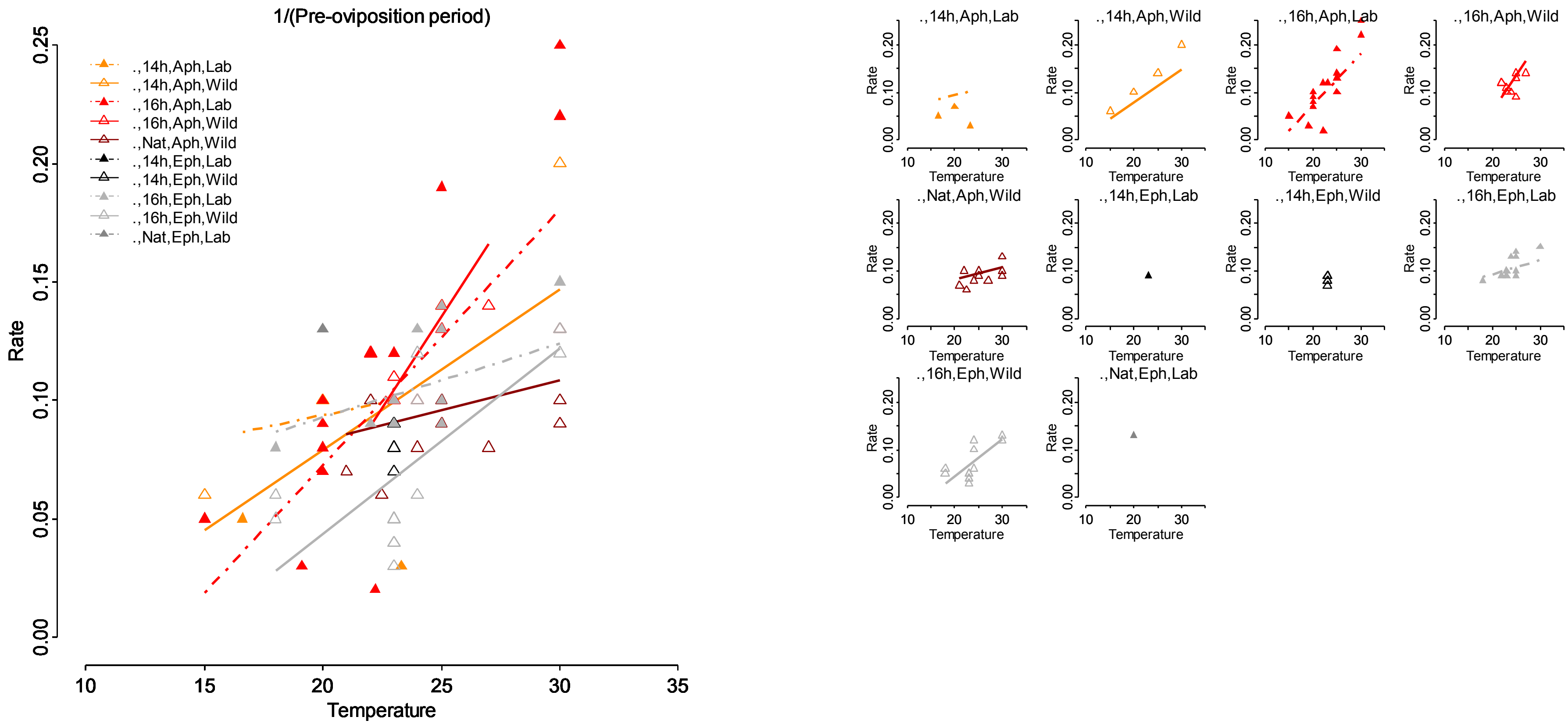


Survival of immature stages (S8) of *Harmonia axyridis*, shown against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Survival of all immature stages, has a quadratic relation with temperature. Highest survival is observed for populations under short day with an optimum of 84.3%, while lowest survival is observed for populations under long day with an optimum of 66.5%. The optimum temperature is 21.8°C.

*Survival immature stages = 1.374265 —0.023101*Temperature —0.004869 (Temperature—Mean Temperature)2 —0.177619*long-day*
Mean Temperature = 24.17857



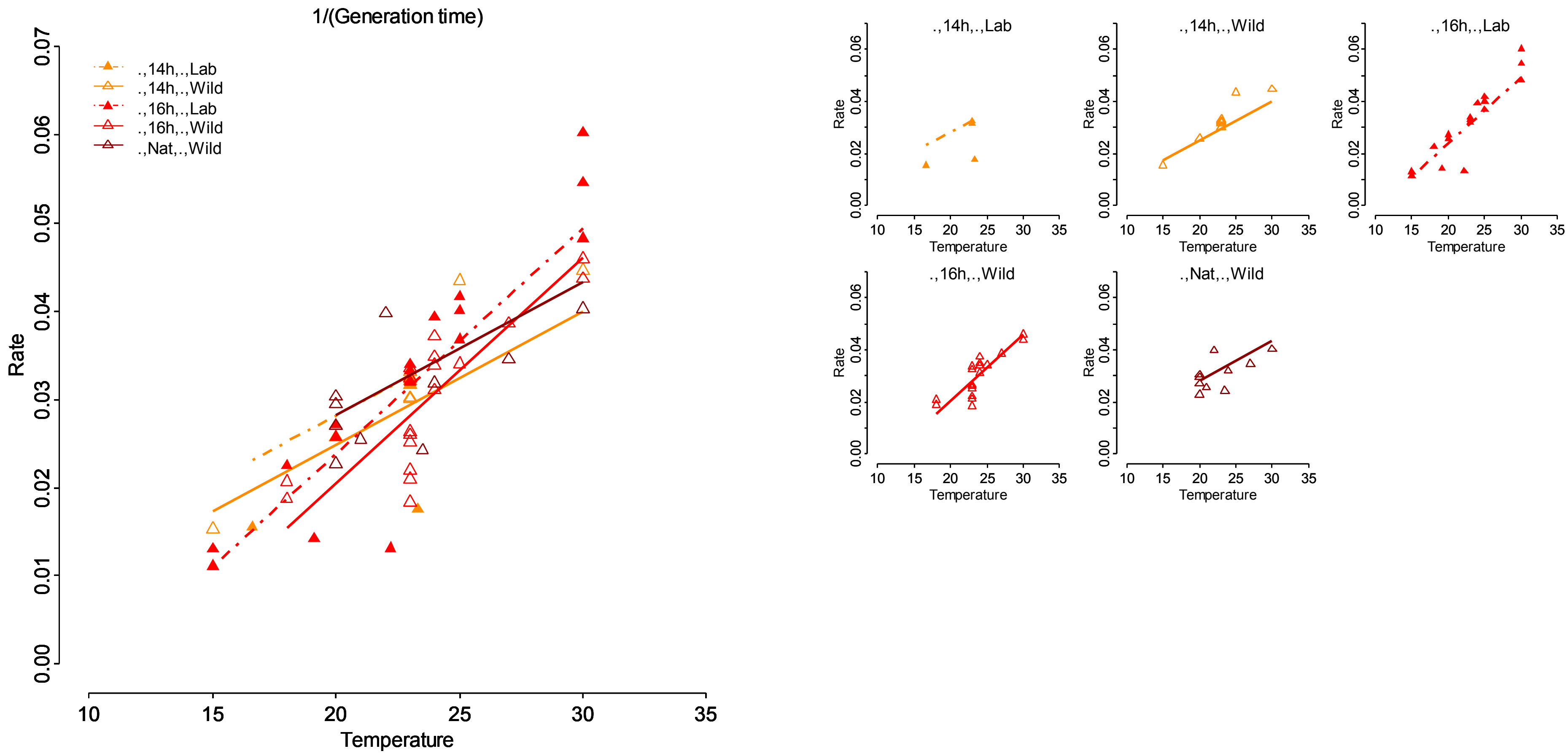
Pre-oviposition period (A1) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

The inverse of the pre-oviposition period increases with increasing temperature. Photoperiod, food, and strain influence the response to temperature. Aphid-fed populations under long day conditions show the strongest response to temperature. Above 22°C development is fastest for wild, aphid-fed populations under long day. At lower temperatures the model predicts that wild, aphid-fed populations under short day and reared, *Ephestia*-fed populations under long day develop fastest. Response to temperature is strongest under long day, weaker under short day, and weakest under natural day. Wild populations show a stronger response to temperature than reared populations.

The models have been fitted using a mixed model where the source study is added as random effect. The resulting model predicts a different intercept for each study. For the overal model however, an average intercept is taken for the whole population. As a result the mean predicted model for a subgroup (in this case Asian populations under short day) can deviate from the original datapoints. All studies in the reared, aphid-fed, short day subgroup had smaller intercepts than the intercept for the mean predicted model, while all studies in the wild, aphid-fed, short day subgroup had larger intercepts.

*Pre-oviposition rate = —0.0561396 + 0.006763*Temperature —0.1946567*long-day + 0.0895888*natural-day + 0.1389385*Ephestia + 0.1084527*reared + 0.0086858*Temperature*long-day —0.0042683*Temperature*natural-day —0.0076624*Temperature*Ephestia —0.0046911*Temperature*reared+0.0345513*Ephestia*reared*

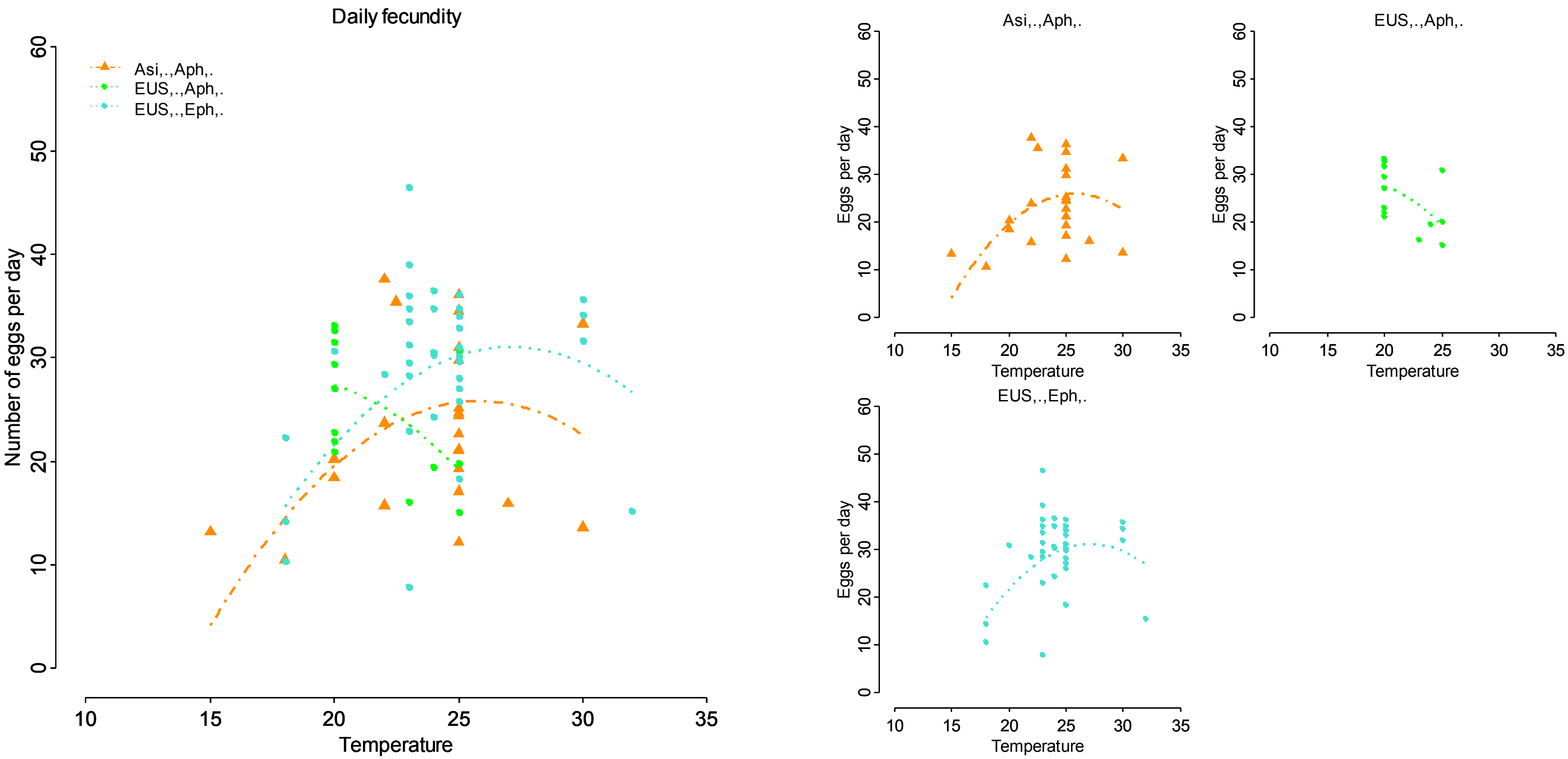


Generation time (A2) of *Harmonia axyridis*, shown as rate against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x—axis shows temperature starting at 10°C.

Description

The inverse of the generation time increases with increasing temperature. The factors day length and strain influence the response to temperature. The response to temperature under long day is stronger than under short or natural day (within both wild and reared populations). Reared strains develop faster than wild strains. For temperatures below 25°C the model predicts fastest development for both reared populations under short day and wild populations under natural day, while at higher temperatures reared populations under long day develop fastest. The models have been fitted using a mixed model where the source study is added as random effect. The resulting model predicts a different intercept for each study. For the overal model however, an average intercept is taken for the whole population. As a result the mean predicted model for a subgroup (in this case short day) can deviate from the original datapoints. All studies in the reared, short day subgroup had smaller intercepts than the intercept for the mean predicted model.

*Rate of generation time= —0.00516 2 + 0.001503*Temperature —0.02525*long-day + 0.003169*natural-day + 0.003334*reared + 0.001044*Temperature*long-day + 0.000008813*Temperature*natural-day*



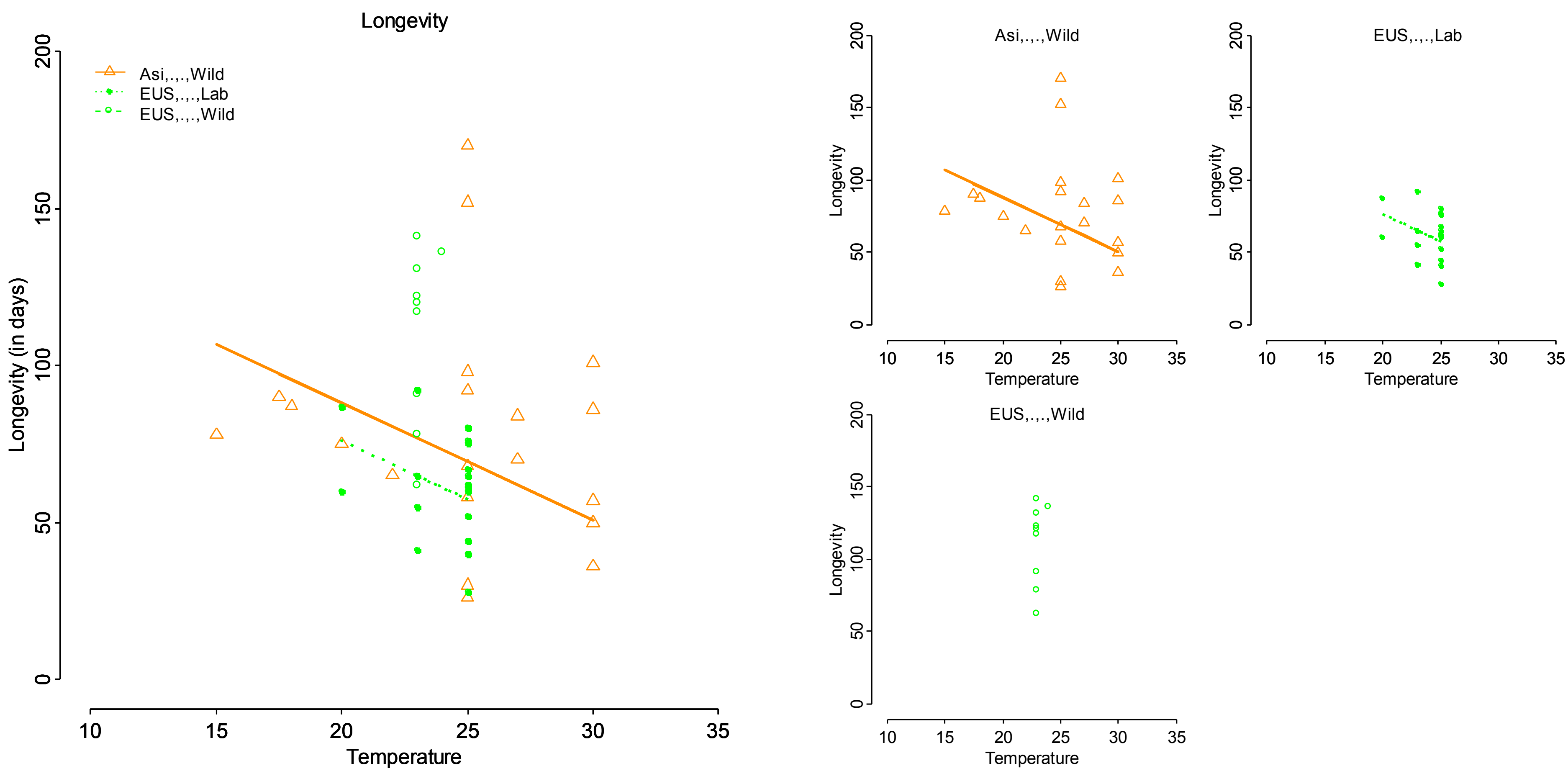
Daily fecundity (A3) of *Harmonia axyridis* shown against temperature. Left panel: all fitted relationships in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. X-axis shows temperature starting at 10°C.

Description

Daily fecundity has a quadratic relationship with temperature. Origin and food influence the relationship with temperature. Highest fecundity *Ephestia*-fed invasive populations is 31.0 eggs/day at 27.1°C and for aphid-fed Asian populations 25.8 eggs/day at 25.8°C. Aphid-fed invasive populations have a much lower optimum temperature for maximum fecundity (at least 27.3 eggs/day, observed around 20°C), than *Ephestia*-fed invasive populations and aphid-fed Asian populations. All data points at 20°C, except one, originate from two studies performed in the Azores, where earlier generations were given a mixture of two aphid species and *Ephestia*, while the tested beetles were given only aphids (Soares et al. 2001; 2004). In addition, no data points at more extreme temperatures are available and the low values at 25°C caused high leverage. We therefore suggest that the fitted relationship might be an artefact.

$$\text{Daily fecundity}=70.728 - 2.0488\cdot\text{Temperature} - 0.186\cdot(\text{Temperature}-\text{Mean Temperature})^2 - 65.1251\cdot\text{Asia} - 72.8992\cdot\text{Ephestia} + 2.8672\cdot\text{Temperature}\cdot\text{Asia} + 3.3577\cdot\text{Temperature}\cdot\text{Ephestia}$$

with Mean Temperature=23.60959



Longevity (A4) of *Harmonia axyridis*, shown as against temperature. Left panel: all fitted relationships together in one graph. For definition of individual groups see legend. Right panel: each group plus fitted line in separated graphs. The title of each graph shows for which group the data points are shown and the line is plotted. The x-axis shows temperature starting at 10°C.

Description

Longevity shows a linear relationship with temperature. Longevity is shorter at higher temperatures. Both origin and food influence the response to temperature. Wild Asian populations have a higher longevity than reared invasive populations. For wild invasive populations data at 23°C and 24°C are available. This subgroup significantly differs from the other subgroups and at that temperature the model predicts a longevity of 113 days, so longest of all populations, however, the small temperature range impairs a solid comparison. The best model does not contain an effect of sex, photoperiod, food, or strain..

*Longevity=198.6459 —3.7358*Temperature —35.9428*Asia —47.9969*reared*