**Supplementary Materials**

**Temperature-induced effects on development, reproduction and predation of *Harmonia axyridis* fed on first instar larvae *Spodoptera litura***

**Running title:** Life table study, predation and population projection

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**Life table and predation rate analysis**

The age-stage survival rate *sxj* was calculated as;

 (1)

where *n*01 is the number of insects used at the beginning of the life table study and *nxj* is the number of insects surviving to age *x* and stage *j* ([Chi and Liu 1985](#_ENREF_1)).

The age-specific survival rate (*lx)* and age-specific fecundity (*mx)* were calculated as:

 (2)

 (3)

Where *β* is the stage number, *sxj* is the age-stage specific survival rate, i.e. the possibility that an individual (newly hatched) lives to age *x* and stage *j*.

The net reproductive rate (*R*0) is the total number of offspring that an individual is expected to produce during its life and was calculated as:

 (4)

The intrinsic rate of increase (*r*) was then predicted iteratively following the Euler–Lotka equation with age indexed from 0 ([Goodman 1982](#_ENREF_3)) as:

 (5)

The finite rate of increase (*λ*) was calculated as

 (6)

The mean generation time (*T*) is the time that a population needs to increase to $R\_{0}$-fold of its size at the stable age-stage distribution, and was calculated as:

 (7)

Age-stage life expectancy (*exj*) is the time that an individual or insect of *x* and *j* is predicted to live ([Chi and Su 2006](#_ENREF_2)) as:

 (8)

where  is the probability that an individual of age *x* and stage *j* will survive to age *i* and stage *y*, and it is calculated by assuming *sxj* = 1.

The age-stage reproductive value (*vxj*) was defined as the contribution of individuals of age *x* and stage *j* to the future population and is calculated according to ([Tuan et al. (2014a)](#_ENREF_5), [Tuan et al. 2014b](#_ENREF_6)).

 (9)

The age-stage specific predation rate *cxj* was calculated as:

 (10)

where *dxj*,*i* is the recorded predation rate for the *i*th individual at age *x* and stage *j*.

The age specific predation rate (*kx*) was calculated as:

 (11)

The age-specific net predation rate (*qx*) by taking survival rate into consideration was calculated as:

 (12)

The net predation rate (*C*0) is defined as the number of prey consumed by an average individual predator during its lifetime. It includes all individuals that died in the pre-adult stages and those that survived to the adult stage. It was calculated as:

 (13)

The transformation rate (*Qp*) is defined as the number of prey needed for a predator to produce a single offspring. It was calculated as:

 (14)

The finite predation rate (*ω*) was calculated according to [Yu et al. (2013)](#_ENREF_7) as:

 (15)

where *axj* is the proportion of individuals belonging to age *x* and stage *j* in a stable age-stage distribution, and *ψ* is the stable predation rate.

The total population size at time t was calculated as:

 (16)

where *nxj,t* is the number of individuals of age *x* and stage *j* at time *t* ([Huang et al. 2018](#_ENREF_4)).

The predation potential at time *t* was calculated as in [Huang et al. (2018)](#_ENREF_4):

 (17)

**References**

**Chi, H., and H. Liu** (1985) Two new methods for the study of insect population ecology. *Bull. Inst. Zool. Acad. Sin* 24, 225-240.

**Chi, H., and H.-Y. Su** (2006) Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead)(Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer)(Homoptera: Aphididae) with mathematical proof of the relationship between female fecundity and the net reproductive rate. *Environmental entomology* 35, 10-21.

**Goodman, D.** (1982) Optimal life histories, optimal notation, and the value of reproductive value. *The American Naturalist* 119, 803-823.

**Huang, H.-W., H. Chi, and C.L. Smith** (2018) Linking demography and consumption of *Henosepilachna vigintioctopunctata* (Coleoptera: Coccinellidae) fed on *Solanum photeinocarpum* (Solanales: Solanaceae): with a new method to project the uncertainty of population growth and consumption. *Journal of economic entomology* 111, 1-9.

**Tuan, S.-J., N.-J. Li, C.-C. Yeh, L.-C. Tang, and H. Chi** (2014a) Effects of green manure cover crops on *Spodoptera litura* (Lepidoptera: Noctuidae) populations. *Journal of economic entomology* 107, 897-905.

**Tuan, S.J., C.C. Lee, and H. Chi** (2014b) Population and damage projection of *Spodoptera litura* (F.) on peanuts (Arachis hypogaea L.) under different conditions using the age‐stage, two‐sex life table. *Pest Management Science* 70, 805-813.

**Yu, J.-Z., H. Chi, and B.-H. Chen** (2013) Comparison of the life tables and predation rates of *Harmonia dimidiata* (F.)(Coleoptera: Coccinellidae) fed on *Aphis gossypii* Glover (Hemiptera: Aphididae) at different temperatures. *Biological Control* 64, 1-9.

**Supplementary Figure 1**Survival rate of (*sxj*) of the *Harmonia axyridis* preying on 1st instar *Spodoptera litura* at different temperatures

**Supplementary Figure 2** Life expectancy of (*exj*) of the *Harmonia axyridis* preying on 1st instar *Spodoptera litura* at different temperatures

**Supplementary Figure 3** Reproductive value of (*vxj*) of the *Harmonia axyridis* preying on 1st instar *Spodoptera litura* at different temperatures

**Supplementary Figure 4** Age-stage specific predation rate (*cxj*) of the *Harmonia axyridis* preying on 1st instar *Spodoptera litura* at different temperatures