Life History of *Chaetorellia succinea*: Laboratory and Field Studies in North America

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Figure 1 A & B. Yellow starthistle (YST) *Centaurea solstitialis* is an invasive weed of Eurasian origin. YST is an annual plant and was first reported in 1869 in California. It is now widespread, occupying around 12 million acres. The California Department of Food & Agriculture estimates that 42% of California townships now have YST infestations and this weed is continuing to spread. YST infests rangelands, orchards, vineyards, pastures, parks and natural areas where it causes significant economic and environmental losses.

Introduction: Yellow starthistle (YST), *Centaurea solstitialis*, is one of the most important invasive weeds in the Western U.S. (fig. 1). Several natural enemies were imported for biological control of YST in California. Many of these insects have been studied in Europe and in U. S. quarantines, however, the accidentally introduced fly *Chaetorella succinea* (fig. 2 A & B) has not been adequately studied and little life history information is available despite its increasing impact on this weed. Understanding its developmental biology is important as it is currently not in synchrony with the target host plant (fig. 3). In this poster, we provide a summary of biological studies conducted both in the laboratory and in the field that were aimed at providing information on its phenology and development under California and Oregon field conditions.

Figure 2 A. The Tephritid fly, *Chaetorellia succinea*, was accidentally introduced in North America in 1994, and is now well established across parts of California, Oregon and Idaho. **B.** This insect overwinters as diapausing 3rd instar larvae in the seed heads of YST. It forms a hybernacula made of plant tissue that helps protect it from harsh environmental conditions until the flies emerge in the spring.

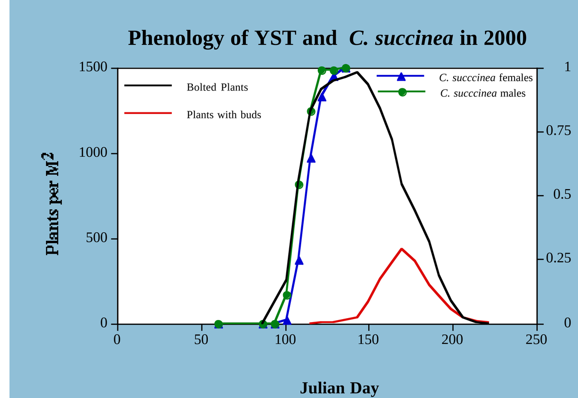


Figure 3. Adults of *Chaetorellia succinea* emerge well before the flower buds that they attack are developed by YST. Preliminary data suggests that high fly mortality occurs prior to oviposition and thus potential exists for improving this synchrony through selective introduction of additional germ plasm from Europe.

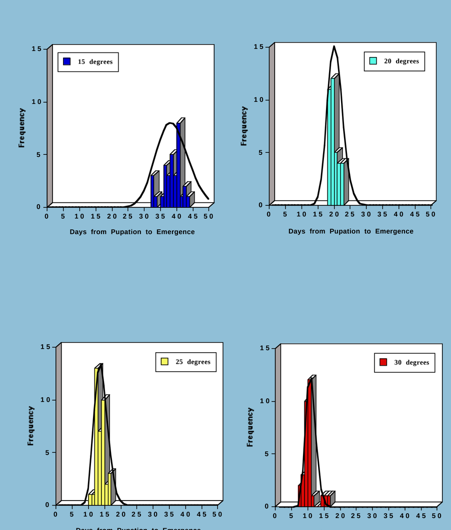
Figure 4 A & B. The insects were maintained using three different methods. In the first method, the insects were incubated directly in the damaged seed heads from which they were collected. Test insects were further held by dissecting individual hybernacula from infested seed heads and also naked larvae, both of which were held individually in screwcap vials where they could be easily monitored without disturbing the insects.

Figure 5. Within-season developmental studies of these natural enemies were conducted on live YST plants to determine developmental rates, survival rates, and fecundity patterns under a series of constant and fluctuating environmental conditions (data not presented here).

Figure 6. Emergence traps were placed into 7 different field sites in California and Oregon and were monitored as frequently as every day in some locations. Samples were returned to the laboratory where all specimens were examined microscopically for proper taxonomic identification to species. Counts were recorded for each species by sex and date of collection. Similar assessments were done for flies collected in sweepnet samples from each location (data not presented here).

Methods: Laboratory studies- Natural diapausing larvae were collected from multiple field sites in mid-winter and returned to the laboratory where they were placed in temperature and light controlled incubators (fig. 4 A & B). Five temperatures (10, 15, 20, 25 & 30 ° C) were used in combination with two light conditions, long (15hr/d) and short (12 hr/d) light cycles. Since the larvae and pupae can not be seen inside of the seed heads or hybernacula (only emerging flies can be detected), additional larvae were dissected from the seed heads and hybernacula, and held naked within glass screwcap vials where they were monitored daily for pupation (naked larvae only) and adult emergence (all samples). Similar developmental studies were conducted on eggs, larvae and adults on living plants (fig. 5) to measure within-season population parameters, however, these results are not presented here.

Figure 7. Histograms showing the distribution of times for the duration of the pupal stage when reared at different temperatures. Similar information is also available for post-diapause larval development (not shown here). The lines represent fitted curves that were obtained using time-varying-distributed delays (k=35) of a simulation model that is used to estimate field emergence patterns from field measured environmental conditions.



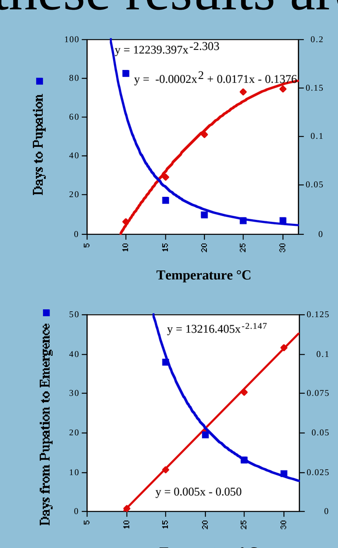
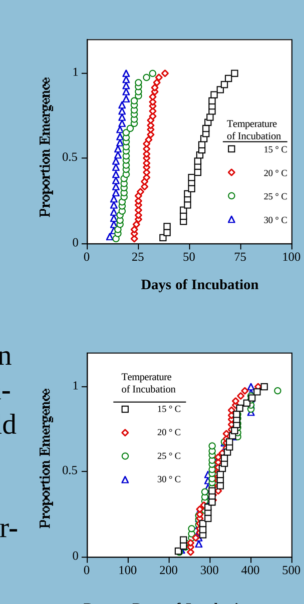


Figure 8. Temperature-dependent development (both days and 1/days) for post-diapause development of larvae (**A**) and pupae (**B**) of *Chaetorella succinea*. At 10 ° C, the larvae pupated but adults did not emerge presumably due to high mortality.

Figure 9. Cumulative adult emergence (males and females combined) over a Julian day scale (**A**) and a degree day scale (**B**). These data were used to construct both a degree-day model and a dynamic simulation model that has been compared to independent field data. These models are being used to predict emergence times in different locations and years.



Results: Laboratory studies- Post-diapause development of larvae and pupae took different amounts of time at the different incubation temperatures (fig. 7). These data were used to calculate both the mean and variance of the temperature-dependent developmental rate functions and to estimate a developmental base temperature (9 ° C), that allowed a predictive model to be developed (fig. 8 A & B). Cumulative emergence curves for each temperature (fig. 9 A) show the overall effect of temperature on the combined overwintering larval and pupal development. Placement of these same data on a degree-day scale (base 9.0 ° C), suggests that the model accurately describes the laboratory data. Similar results were obtained when compared to independently collected field trapping data (fig. 11).

Methods: Field studies- Emergence traps (fig. 6) were placed into the field just prior to the initiation of fly emergence at multiple field sites in California and Oregon. Traps were monitored frequently for insect emergence and counts were recorded for both male and female flies. In parallel with the collection of trap data, weekly sweepnet samples of fly abundance were collected along with detailed host plant samples and background environmental conditions (not presented here). Data was collected not only on *C. succinea* but also on *Urophora sirunaseva*, another important natural enemy of YST.

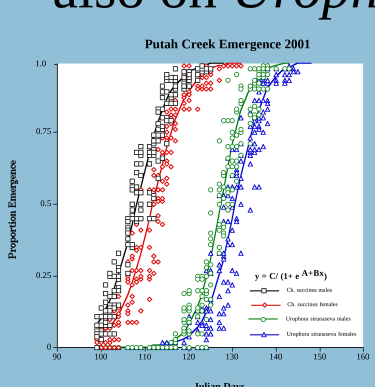


Figure 10. Emergence patterns of both *Chaetorella succinea and Urophora sirunaseva* at a single field site (Putah Creek, California). These data have been plotted on both a Julian day scale (**A**) and a degree day scale (**B**). Note the clear separation of the emergence times of the two species and the tendency for males to emerge earlier than females.

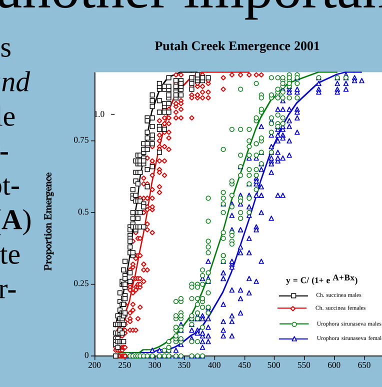
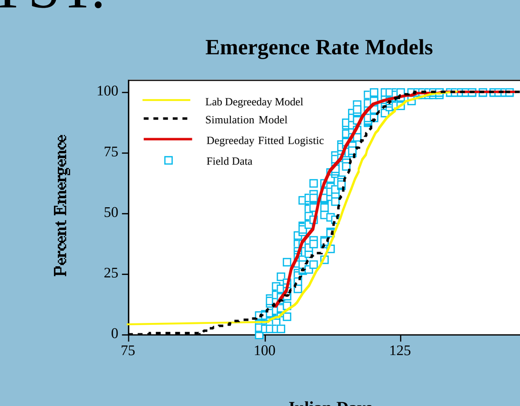


Figure 11. A comparison of actual field data (points), a degree day model(solid line) and simulation model results (dashed line) in predicting the combined emergence of both male and female *C. succinea* based on local weather data collected near Putah Creek.



Results: Field studies- Extensive collections of both *C. succinea* and *U. sirunaseva* were achieved at all sites, however, both species were not always present at all locations. *Chaetorella succinea* was found to be most prevalent and emerged significantly earlier than *U. sirunaseva*. In both species, the males were the first to emerge, however, there was substantial overlap in timing of emergence across sex (fig. 10 A). Non-linear regression was used to estimate logistical patterns of cumulative emergence for both Julian days and degree days. When the analysis was controlled for both geographic location and trap placement within a site, differences in emergence times between males and females were statistically significant. Future models will need to separate the sexes and estimate local variability in emergence caused by microclimatic conditions. Likewise, adult longevity needs to be studied and incorporated into this evaluation.

Summary: A combination of laboratory and field studies on the developmental biology of Tephritid natural enemies of YST, have provided useful predictive models of fly emergence in the spring. This information is being linked with other data on the within-season biology to help develop management strategies for these natural enemies and to assist biological control scientists in making decisions about our ability to predict and potentially alter the synchrony of these agents using additional European germ plasm.