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Changes in abundance of larvae and adults of *Popillia japonica* (Coleoptera: Scarabaeidae: Rutelinae) and other white grub species in Northwest Arkansas and their relation to regional temperatures

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The Japanese beetle (*Popillia japonica* Newman) (Coleoptera: Scarabaeidae: Rutelinae) is an invasive species that currently covers most of the eastern United States (NAPIS 2015). In 1997, *P. japonica* was found in northwest Arkansas (Johnson 2004), where it is established and spreading. This region and northeastern Oklahoma represent the southwestern border of the *P. japonica* infestation (NAPIS 2015). Though larval densities have been relatively low in northwest Arkansas, adult populations are destructive (Wood et al. 2009). The objective of our study was to document recent year-to-year changes in *P. japonica* abundance.

Larvae were collected during Apr and May from 2010 to 2012. Field sites used in this study included 2 fruit orchards, 1 horticultural nursery, 3 public golf courses, 3 city parks, and the University of Arkansas Research and Extension Farm (UAREF), although in 2012 the peach orchard, located in Springdale, Arkansas, was removed from the survey at the request of the owner. In 2010, 10 field sites were selected to collect larvae of *P. japonica* and other white grub species, with 10 samples from each site. Sampling locations were non-irrigated areas with no recent pesticide exposure. Samples were collected by sifting 0.1 m² of soil approximately 8 cm deep, and locations were determined from random selection on a grid map prior to outings. All scarab larvae discovered were identified via raster pattern (Vittum et al. 1999).

From 2005 to 2012, adult *P. japonica* traps were set as a ~1 km line transect on the UAREF (Fayetteville, Arkansas, USA). The number of traps varied among years, ranging from 3 traps in 2005 to 20 traps in 2012. Jumbo Jug (Trécé Inc., Adair, Oklahoma, USA) funnel mouth traps (1.9 L) and modified 3.8 L traps were used and baited with dual floral and sex lures (eugenol, geraniol, phenyl ethyl propionate, and Japonilure) and spaced 19 m apart. Traps were placed when the first adults of *P. japonica* of the season were found and removed when counts fell < 10 per trap per week. Traps were emptied weekly and beetle numbers were determined volumetrically (250 beetles/100 mL).

Popillia japonica yearly density was compared across all sites using a 1-way analysis of variance (ANOVA) in JMP® 10.0 (SAS Institute Inc.). The mean weekly trap captures of *P. japonica* adults were compared using ANOVA with repeated measures to determine changes in abundance. The mean weekly adult trap captures were averaged over the number of weeks and the number of traps.

To examine the association of temperature with changes in *P. japonica* abundance, we examined National Oceanic and Atmospheric

Administration (NOAA 2012) archival data from the Drake Field Airport meteorological station in Fayetteville, Arkansas, which is 12 km from UAREF. The mean monthly temperatures from Jul and Aug of 2004 to 2011 were compared with the mean weekly adult trap captures from the UAREF traps during the same month of the succeeding year. Data were tested using Spearman's ρ non-parametric correlation in JMP® 10.0.

In spring 2010, 200 soil samples were examined from the 10 sites. Mean total white grub density (all species) was 0.69 larvae/0.1 m², with *P. japonica* larval density at 0.57/0.1 m². During fall 2010 and spring 2011, 300 soil samples were collected. Mean white grub density was 0.57/0.1 m², with *P. japonica* larval density at 0.41/0.1 m². In spring 2012, 200 soil samples were examined. Mean white grub density was 0.1 larvae/0.1 m², with *P. japonica* larval density at 0.05/0.1 m². Japanese beetle larval population densities differed significantly, being higher in 2010 and 2011 than in 2012 ($\alpha = 0.05$, $df = 2$, $P = 0.038$).

For the UAREF, mean weekly counts of *P. japonica* adults captured by year can be found in Table 1. Data from 2009 were not included in this analysis because of loss of replication data; however, the mean 2009 trap capture of 4,661.6 was used in the temperature data analysis. The number of beetles caught between years differed significantly, with captures in 2006 significantly higher than all other years ($\alpha = 0.05$, $df = 6$, $P < 0.001$). Trapping in 2012 represented the lowest capture and was significantly lower than the numbers collected in 2007, 2009, 2010, and 2011.

Table 1. Mean weekly trap counts for adults of *P. japonica* from 2005 to 2012 at the University of Arkansas Research and Extension Farm (UAREF).

Year	Weekly trap capture (mean \pm SE)
2005	3,528.5 (\pm 488.5) b
2006	5,228.2 (\pm 226.1) a
2007	908.9 (\pm 199.4) d
2008	2,992.2 (\pm 218.5) b
2010	2,244.9 (\pm 218.5) c
2011	464.8 (\pm 267.5) de
2012	116.3 (\pm 189.2) e

Means followed by different letters indicate significant differences between weekly trap captures ($\alpha = 0.05$, $P < 0.0001$; ANOVA with repeated measures).

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Jul temperatures fluctuated from 2.6 °C below average in 2004 to 3.1 °C above average in 2011. Aug temperatures fluctuated between 3.3 °C below average in 2004 to 3.0 °C above average in 2011. Changes in beetle counts at the UAREF appeared related to the mean temperature during the corresponding month of the previous year (Fig. 1) with mean captures having a -0.595 correlation with Jul temperature changes and a -0.714 correlation with Aug temperatures.

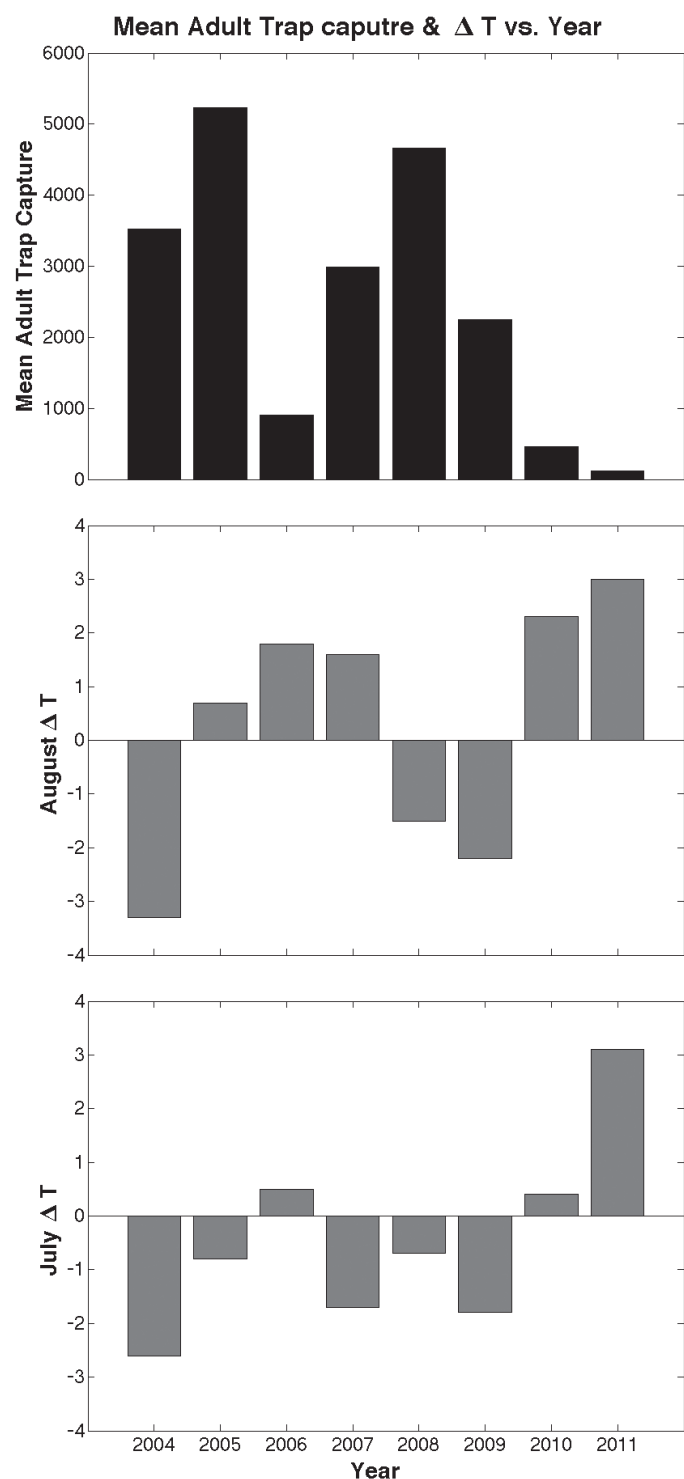


Fig. 1. Weekly mean trap captures of *Popillia japonica* adults from 2005 to 2012 and corresponding change in mean temperature (ΔT) of Jul and Aug relative to the historical mean (2004–2011) for northwest Arkansas.

Numbers of *P. japonica* 3rd instars in Arkansas were relatively low, and we found densities lower than previous estimates (Wood et al. 2009). The relatively low larval densities in Arkansas make it difficult to explain the damaging numbers of adults. The immense area of the cultivated and uncultivated grasslands in northwest Arkansas may result in the emergence of very large numbers of adults, which then aggregate causing significant damage.

Fluctuations in the UAREF beetle abundance were evident between 2005 and 2010, with a rapid and steady decline following 2009. Temperatures during Jul and Aug may be responsible for the sharp decline in beetles after 2009. First instars are present during Jul and Aug and suffer significant thermal death above 35 °C (Ludwig 1928), thus likely experiencing declines from heat exposure. Additionally, multiple hot summers in succession, which occurred from 2010 to 2012, would cause cumulative reduction in the *P. japonica* population, as was observed.

The low density of *P. japonica* in Arkansas had remained unexplained. Northwest Arkansas lacks substantial populations of pathogens or parasitoids that would significantly lower *P. japonica* populations (Petty et al. 2012); however, Arkansas is on the extreme southwestern border of *P. japonica* infestations in the United States, and a mixture of non-preferred turfgrasses (bermudagrass) for oviposition (Wood et al. 2009) and suboptimal weather conditions may create an unsuitable environment. The impact of high temperatures in Arkansas on *P. japonica* does not come as a complete surprise. Allsopp (1996) predicted the spread of *P. japonica* to its outermost borders, which extend west through Nebraska and Texas and south to mid-Georgia and Mississippi. This prediction was made using rainfall and temperature data and the modeling program CLI-MEX 4.3. The Allsopp (1996) prediction has been accurate, although small isolated populations have been found as far west as Colorado and Arizona (NAPIS 2015). Should *P. japonica* continue to expand southwest into the United States, the increasingly warm and dry climate may cause this beetle to become a minor pest.

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Summary

The Japanese beetle is a relatively new pest in Arkansas that damages turfgrass, horticultural plants, and fruit crops. From 2005 to 2012, *P. japonica* mean weekly trap capture declined 98%. Previous studies showed there were few microbial and parasitoid natural enemies of *P. japonica* in the region, so fluctuations in *P. japonica* populations are likely due to abiotic factors, such as extremes of summer drought and heat along this invasive species' southwestern border.

Key Words: Japanese beetle; abiotic factor; drought; heat

Sumario

El escarabajo japonés es una plaga relativamente nueva en Arkansas que causa daño al césped, las plantas hortícolas y cultivos frutales. Del 2005 a 2012, el promedio de los *P. japonica* capturados en trampas semanales se redujo 98%. Estudios previos mostraron que hay unos pocos enemigos naturales microbiano y parasitoides de *P. japonica* en la región, por lo que las fluctuaciones en las poblaciones de *P. japonica* son probablemente debido a factores abióticos, tales como los extremos de sequía del verano y del calor a lo largo de la frontera suroeste de esta especie invasora.

Palabras Clave: escarabajo japonés; factores abióticos; la sequía; el calor

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