

Modeling Environmental Influences in the *Psyllaephagus bliteus* (Hymenoptera: Encyrtidae)–*Glycaspis brimblecombei* (Hemiptera: Aphalaridae) Parasitoid–Host System

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Abstract

Glycaspis brimblecombei Moore (Hemiptera: Aphalaridae) is an invasive psyllid introduced into the Mediterranean area, where it affects several species of *Eucalyptus*. *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae) is a specialized parasitoid of this psyllid that was accidentally introduced into Italy in 2011. We developed a model of this host–parasitoid system that accounts for the influence of environmental conditions on the *G. brimblecombei* population dynamics and *P. bliteus* parasitism rates in the natural ecosystem. The Lotka–Volterra-based model predicts non-constant host growth and parasitoid mortality rates in association with variation in environmental conditions. The model was tested by analyzing sampling data collected in Naples in 2011 (before the parasitoid was present) and defining several environmental patterns, termed Temperature–Rain or T–R patterns, which correspond to the host growth rate. A mean value of the host growth rate was assigned to each T–R pattern, as well as a variation of the parasitoid mortality rate based on temperature thresholds. The proposed model was applied in simulation tests related to T–R patterns carried out with a data series sampled between June 2014 and July 2015 in five Italian sites located in Campania, Lazio, Sicily, and Sardinia regions. The simulation results showed that the proposed model provides an accurate approximation of population trends, although oscillation details may not be apparent. Results predict a 64% reduction in *G. brimblecombei* population density owing to *P. bliteus* parasitoid activity. Our results are discussed with respect to features of the host–parasitoid interaction that could be exploited in future biological control programs.

Key words: lerp psyllid, associated parasitoid, red gum plantation, dynamic, temperature-rain pattern

Glycaspis brimblecombei Moore (Hemiptera: Aphalaridae) is an invasive species that affects *Eucalyptus* in the Mediterranean region (Borrajó et al. 2009, Cocquempot et al. 2012, Bella 2013, Bella and Rapisarda 2013, Malumphy et al. 2013, Reguia and Peris-Felipo 2013, Ben Attia and Rapisarda 2014, Eppo 2014). In Italy, the red gum lerp psyllid was first collected in Lazio, Campania, and Basilicata in June 2010 (Laudonia and Garonna 2010), and then in

Sardinia and Sicily in 2011 (Pibiri 2011, Lo Verde et al. 2011). The specific parasitoid, *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae), was accidentally introduced into Italy (Sicily) in 2011 (Caleca et al. 2011) and recorded in Lazio, Campania, and Sardinia in 2012 (Pantaleoni et al. 2012, Laudonia et al. 2013, Margiotta et al. 2014). Ecological models have been used to predict the potential spread of *G. brimblecombei* worldwide and particularly in Brazil

(Queiroz et al. 2013), as well as to study its spatial distribution on *Eucalyptus camaldulensis* plantations (Ferreira Filho et al. 2008).

The use of mathematical models to describe ecological processes and to predict tendencies has increased in the past decades to provide a better understanding of complex natural systems (Murdoch et al. 2003, Turchin 2003, Briggs and Hoopes, 2004). In particular, model results have implications for natural enemy release strategies in classical biological control programs (Ferreira and Godoy 2014). The pioneering prey-dependent model of Lotka (1925) and Volterra (1926) and many variations of this basic approach (Yamamura and Yano 1988, Murdoch and Stewart-Oaten 1989, Murdoch et al. 1992, Krivan 1997, Tonnang et al. 2009) have often been used to describe the host–parasitoid interactions. Discrete time models exploiting differential equations to represent the growth of host–parasitoid populations have also been used that are based on the Lotka (1925) and on the Nicholson and Bailey (1935) approach.

Research increasingly attempts to include biological realism into models by incorporating behavioral and biological aspects of individual species and interactions such as in host–parasitoid relationships. More limited attention has been given to incorporating environmental influences into model definitions.

In this paper, we describe a model of the *G. brimblecombei*–*P. bliteus* host–parasitoid interaction in natural environment that is based on the Lotka–Volterra model and takes into account the influence of temperature and rainfall on the psyllid population growth rate (Margiotta and Laudonia 2015). The introduction of environment influences into models is justified by several statistical studies on observed data that highlighted the influence of temperature and rainfall on the growth rates of the populations. Daane et al. (2005) provided extensive results on the parasitoid (*P. bliteus*)–host (*G. brimblecombei*) biological interactions based on laboratory experiments in closed and controlled environments. The optimum temperature for the development of *G. brimblecombei* nymphs was detected in laboratory environments (Wilcken et al. 2010). The influence of temperature and rain on the growth of *G. brimblecombei* has been stressed by Laudonia et al. (2013) through a statistical analysis of data collected in Naples during the year 2011 in absence of the parasitoid, *P. bliteus*.

Temperature and rain are likely important factors that influence the parasitoid–host interactions and should be incorporated into models. In this study, we define criteria to include values of the host growth rate in absence of the parasitoid and the parasitoid mortality rate in the absence of host, based on variations of the environmental conditions in the 7 d prior to the sampling date. Criteria to state the parameter values are based on the definition of several environmental patterns, termed Temperature-Rain patterns (T-R patterns), corresponding to different behaviors of the host growth rate. Different approximate values of this parameter were associated to these T-R patterns. Moreover, a temperature-threshold-dependent variation of the parasitoid mortality rate is also considered (Daane et al. 2012).

Here we propose a model that has been exploited in simulation tests related to data series sampled at several Italian sites characterized by different environmental conditions. According to the observed data, the simulated host population has been defined. An approximation of the host *G. brimblecombei* population reduction, given by the parasitoid *P. bliteus* activity, has been computed.

Materials and Methods

Sampling

Date were collected weekly from June 2014 to July 2015 in *Eucalyptus* plantations across four Italian regions: Campania

(Naples), Lazio (Casaccia), Sardinia (S. Maria la Palma), and Sicily (Catania and Balestrate).

The population sizes of both the host and the parasitoid were approximated by sampling parasitized and non-parasitized nymphs of Stages 3–5 (Olivares et al. 2004) observed in a fixed-dimension psyllid sample. This evaluation methodology is justified because *P. bliteus* preferentially lays eggs in third- and fourth-instar psyllids (Daane et al. 2005). Adults were not monitored because this study focused on psyllid development and parasitism levels. In total, 30 lerps, the tapered-shaped white shelter secreted by the nymphs, of *G. brimblecombei* per sampling date were examined under a stereo-microscope (40/50×) to calculate the relative percentage of populations of host and parasitoid. The samples were separated into specimens without and with signs and symptoms of parasitoid activity. Specimens with a melanized wound resulting from oviposition by a parasitoid, normally visible near the articulation point of the first pair of legs to the thorax; specimens with low mobility and abnormal coloration; mummies; and psyllids with parasitoid exit holes were classified as parasitized. Healthy and parasitized specimens were dissected using 00 insect pins and their number was recorded for each sample. Parasitized nymphs with preimaginal stage, eggs and first larvae, of *P. bliteus* inside and with a parasitoid exit hole were counted separately.

It has been reported that with high population density of *P. bliteus* and with host populations in decline, the parasitoids may lay their eggs inside first or second nymphal instars (Boavida et al. 2016). However, parasitism in these instars was not considered here because these instars do not develop.

The number of nymphs of *G. brimblecombei* on 60 randomly collected leaves was recorded every 2 wk following the method reported in the paper by Laudonia et al. (2013). The number of nymphs and the parasitism percentage were used to estimate the population size of the psyllid and its parasitoid, expressed as average number of host/parasitoid per leaf. Maximum and minimum daily temperature data, as well as the number of rainy days, were used, taking into account the mean value of both parameters on the 7 d prior to sampling date. Climatic data have been provided by CEMEC Regione Campania (for Naples sampling site <http://bollettinimeteo.regione.campania.it/>, accessed 28 October 2016), ARSIAL Regione Lazio (for Casaccia sampling site weather station “Bracciano Vigna di Valle” 42.045273 N, 12.124209 E), SAR Regione Sardegna (for S. Maria la Palma sampling site weather station “Olmedo,” 40.39415548 N, 8.21422424 E), and SIAS Regione Sicilia (for Balestrate sampling site, weather station 301 “Castellammare del Golfo, TP,” 38.012930 N, 12.888770 E; for Catania sampling site: weather station 228 “Catania,” 37.263006 N, 15.4322 E).

To estimate the population size distributions of the host and the parasitoid in the sampling period in the five sites, Shapiro–Wilk normality test was performed. Differences among localities were analyzed using Kruskal–Wallis nonparametric test, and the post hoc tests were performed using the Dunn–Bonferroni approach.

Lotka–Volterra Model

The system of differential equations introduced by Lotka–Volterra can be expressed as follows:

$$\begin{aligned}x' &= ax - bxy \\ y' &= -cy + dxy\end{aligned}\quad (1)$$

In the modeling application, the unknown functions $x(t)$ and $y(t)$ represent the following:

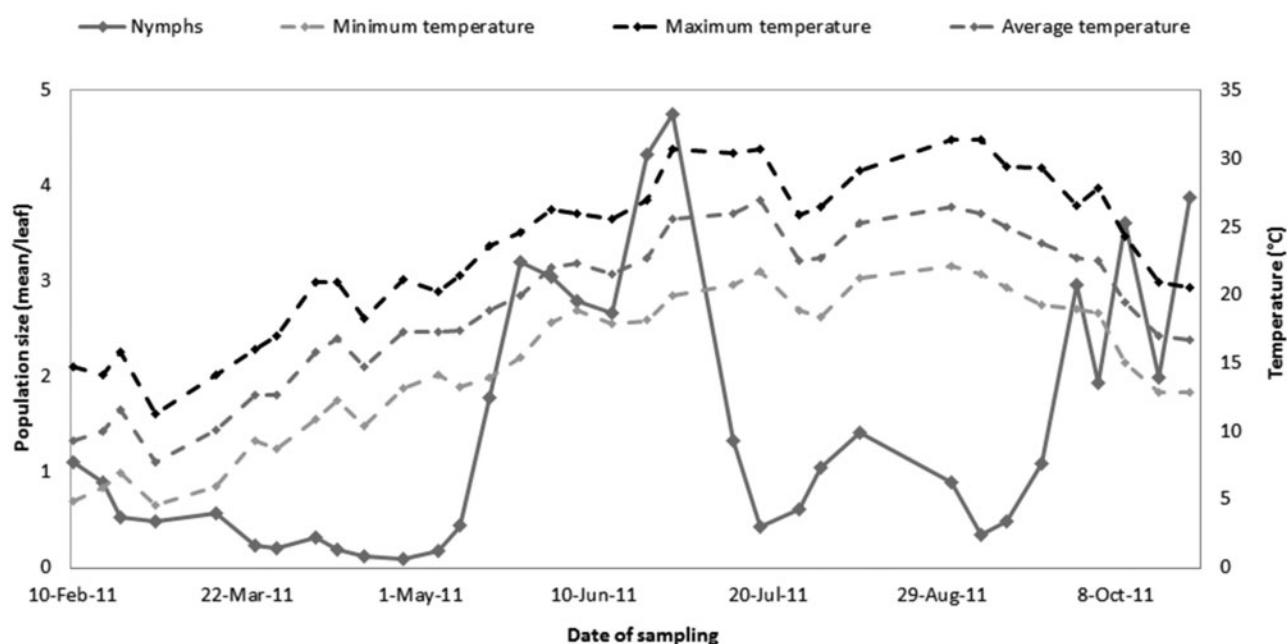


Fig. 1. Naples 2011: Observed mean/leaf values of *Glycaspis brimblecombei* nymphs in the absence of the parasitoid and mean temperature values in the week before the sampling date (in Laudonia et al. 2013).

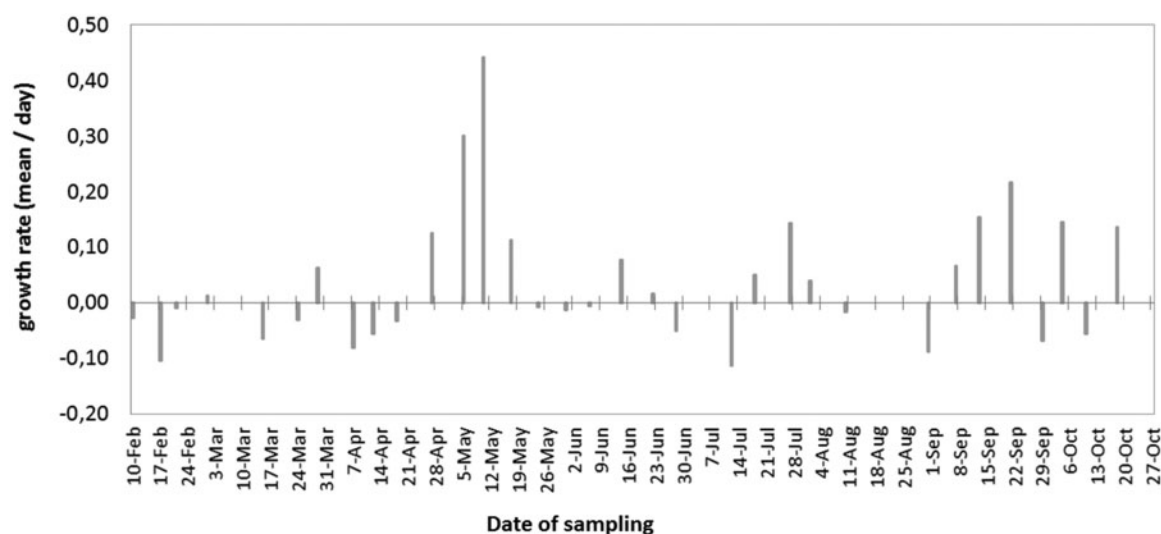


Fig. 2. Naples 2011: Mean/day values of the nymphal population growth rate of *Glycaspis brimblecombei* collected in the absence of the parasitoid and related to the observation interval after the sampling date (in Laudonia et al. 2013).

$x(t)$ = number of hosts at a time t ; and
 $y(t)$ = number of parasitoids at a time t .

The parameters a , b , c , and d , all positive constants in the basic model, represent the following values:

a = host population growth rate in absence of parasitoids;

b = host population reduction rate by the interaction between hosts and parasitoids;

c = parasitoid population mortality rate in absence of hosts; and

d = parasitoid population increase rate by the interaction between hosts and parasitoids.

In our approach, we consider temperature and rain as important factors influencing the growth of both the host (Laudonia et al. 2013) and parasitoid (Daane et al. 2005) populations.

Subsequently, different values of the parameters a and c are exploited, depending on the average temperatures and the percentage of rainy days in the week preceding the sampling date. In the following section, the proposed criteria to choose values of parameters a and c are described. The values of parameters b and d are constant. As a preliminary step, separate equations by switching from a continuous to a discrete time domain have been obtained using a numerical algorithm that computes the x and y function values at the time $t + \Delta t$ using their values at the previous time t . Simulation starts at time $t = 0$ with increment of $\Delta t = 1/7$ corresponding to a single day. Then, any integer time value is suitable for approximating a 7-d period. The initial levels of the two populations are fixed according to the collected values. Statistical analysis and computations were performed using the software R 3.1.3 (The R Foundation) for

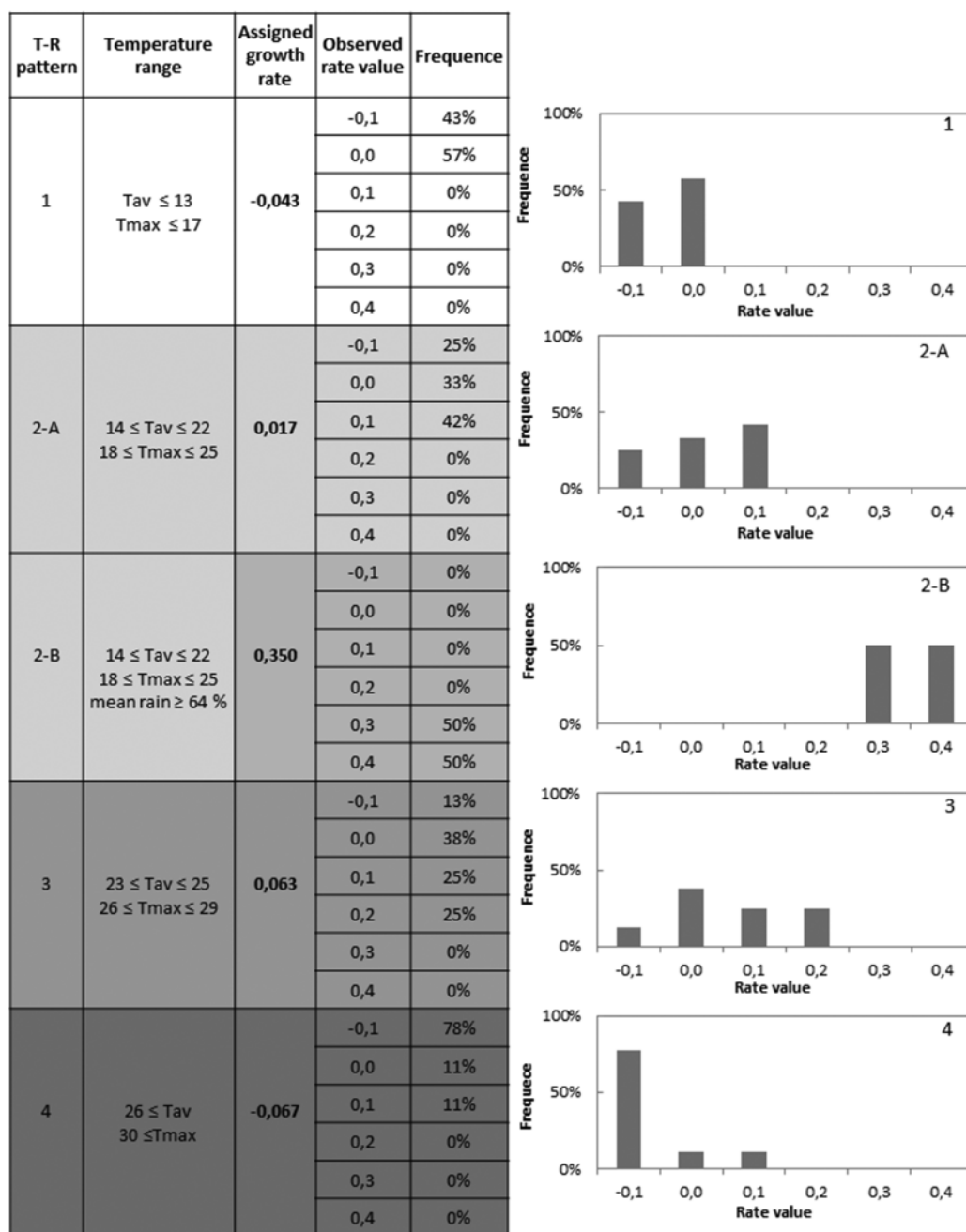


Fig. 3. T-R patterns and corresponding values of the growth rate a .

growth rate, SPSS 22 (Armonk, NY: IBM Corp.) for growth rate and frequency, and Excel 2013 (Microsoft) for Kruskal–Wallis test, means tests and normality tests.

Selection Criteria for Choice of Parameter Values

Host characterization required the definition of criteria to state values of the growth rate in the absence of the parasitoid, according to variations of environmental conditions. With this aim, we analyzed observations carried out in the Naples area before parasitoid arrival in 2011 (Laudonia et al. 2013). Sample data of *G. brimblecombei* population size are represented in Fig. 1, expressed as mean/leaf of the number of nymphs of the psyllid. The mean values of the

minimum, average, and maximum temperatures for the 7 d prior to the sampling are also shown.

To approximate the variability-range of parameter a , we exploited these observed mean/leaf values to compute the mean/day values of the nymph growth rate related to the observation interval after the sampling date. The obtained values are shown in Fig. 2 and exhibit a spring peak with high values of growth rate. Nearly half of the values are negative, indicating a population decrease. Figure 3 shows the relationship between the observed growth rate and the environmental conditions. We identified T-R patterns as characterizing different behaviors of host growth rate. A T-R pattern provides a couple of intervals related to the average and the maximum temperature, respectively, and highlights if the rainfall exceeds the

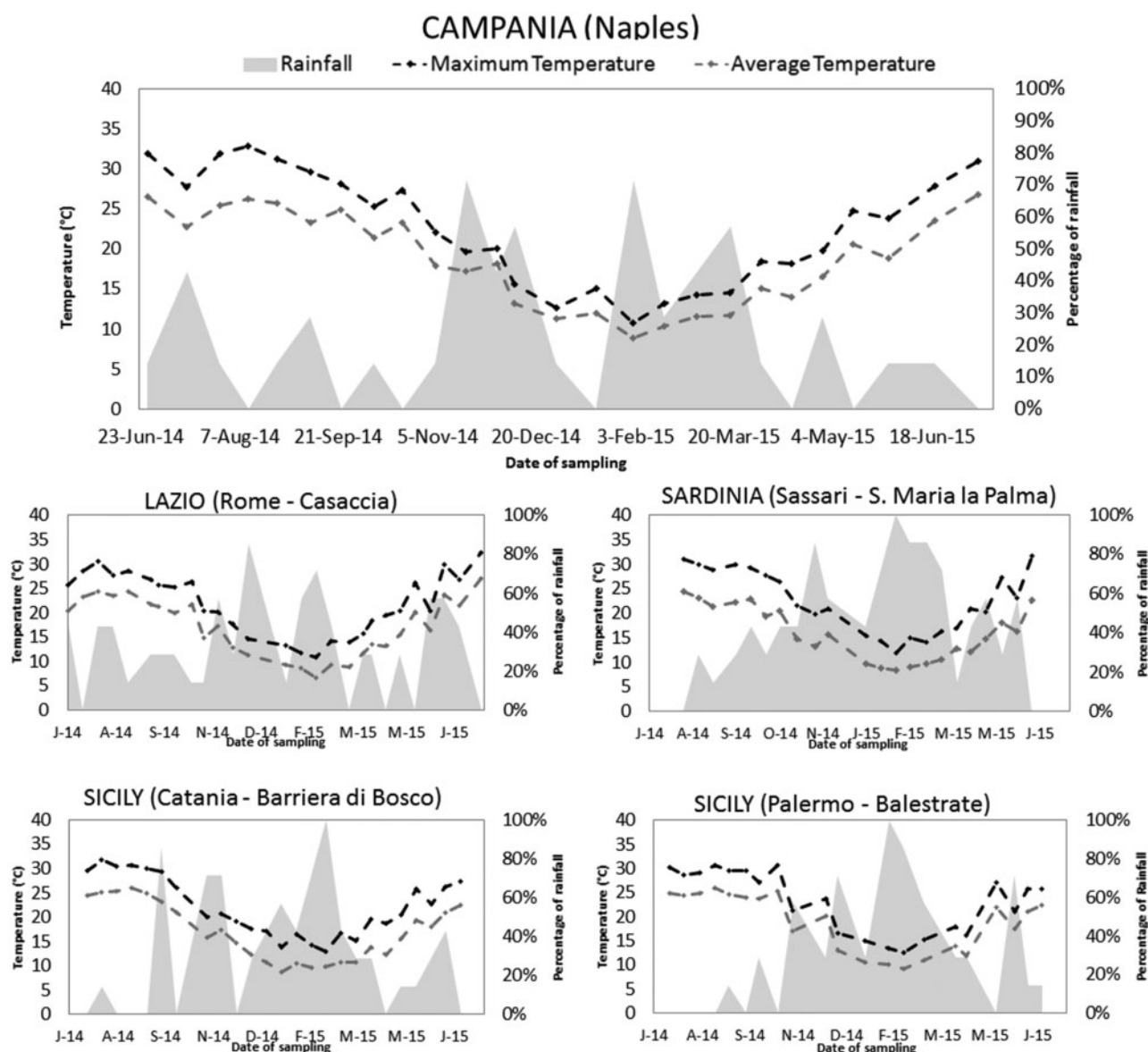


Fig. 4. Average and maximum Celsius temperatures (y-axis) and rainfall percentage (secondary y-axis) in the 7 d before the day of simulation (x-axis).

threshold value of 64% rainy days during the 7 d prior to each sampling (T-R pattern: 2B). The behavior of the host growth rate characterizing a fixed T-R pattern is represented by the frequency distribution of the growth rate values observed in the related environment conditions. Following which, an approximate value of the host growth rate was associated to each T-R pattern. This value is the mean value of the host growth rate computed by using the frequency distribution characterizing the T-R patterns. The corresponding values of the host growth rate are shown in Fig. 3, and that provide selection criteria for choosing the rate values used in the simulation tests. On the right side of Fig. 3, the frequency distribution graphs associated with the T-R patterns are shown to highlight the related behavior of the host growth rate.

It is worth emphasizing that maximum values of the population growth rate are observed when the rainfall exceeds the threshold value of 64% and with a temperature range lower than the optimal temperature for development of nymphs in the laboratory environment (22–26 °C; Wilcken et al. 2010).

Patterns from the performed analysis, on data collected in the Naples area in the year 2011, have also been adopted in four other Italian observation sites located in Lazio, Sicily, and Sardinia regions. The approximation of climatic influence, in the considered sites, was needed because data on the nymphal population growth rate of the *G. brimblecombe* in the absence of the parasitoid are not available in these areas. Combinations of average and maximum temperature values not belonging to one of the four defined patterns are approximated to the closer pattern.

To define the value of the parameter c , which provides the parasitoid mortality rate in the absence of the host, we take into account results given in the paper by Daane et al. (2012) that point to an increase of the host *P. bliteus* mortality rate in high temperatures. Based on the simulated results, 28 °C is assumed as the temperature threshold to select the value of 0.40 for the parameter c . In the other cases, the value chosen was 0.20. In absence of the hosts, *P. bliteus* is exponentially brought to extinction owing to lack of development.

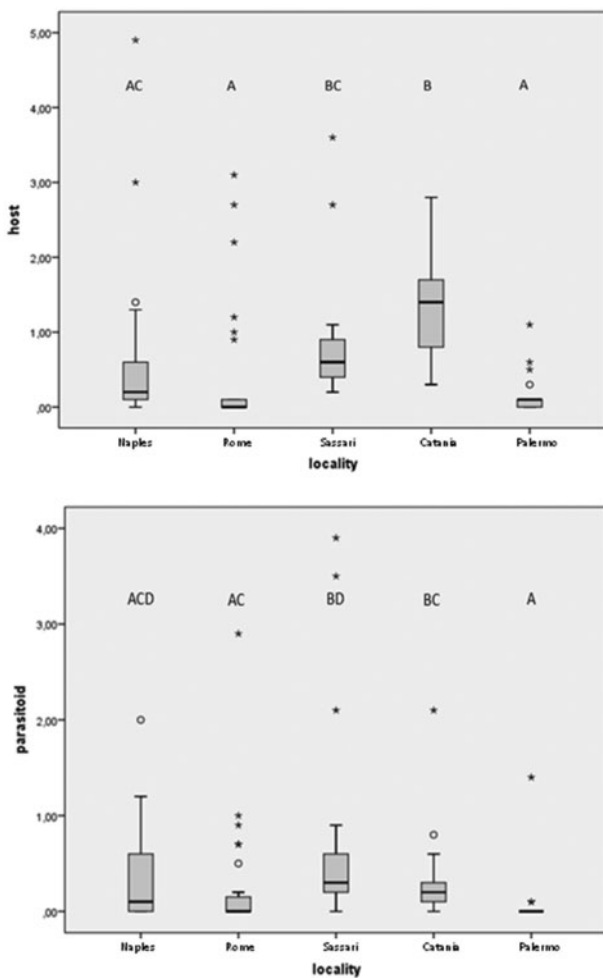


Fig. 5. The box-and-whisker graphs of the population size (expressed as mean/leaf) distributions for host and parasitoid.

Evaluation of parameters b and d , related to the interaction between the two populations, is very difficult to estimate under field conditions. Simulated results suggest that the parameter b , the host population reduction rate under the activity of the parasitoid, can be lower than the parameter d , the parasitoid population increase rate, owing to host consumption. These parameters are a coefficient of the combinatorial term xy in the equation, and low b and d values of 0.001 and 0.004, respectively, are exploited in the simulation tests.

Figure 4 shows the means of maximum and average temperature and rainfall percentage in the 7 d before the sampling date. Based on the three values associated with any sampling date, we state the corresponding T-R pattern, and then, we choose the value of the parameter a applied in the simulation test to generate the value of the host population size in the next sampling date.

Results

Collected Data and Simulation Results

The box-and-whisker graphs of the population size distributions, expressed as mean/leaf for the host and the parasitoid in the sampling period in the five sites, are shown in Fig. 5. As the data do not have a normal distribution (Shapiro–Wilk normality test $P < .001$, except for Host: Catania, $P = .134$), a Kruskal–Wallis nonparametric test

was conducted to evaluate differences among the five groups on median change in population density for both the host and the parasitoid. The test was significant (Host: $\chi^2(4) = 53.528$, $P < .000$; Parasitoid: $\chi^2(4) = 25.203$, $P < .001$). Follow-up tests were performed to evaluate pairwise differences among the five groups using the Dunn–Bonferroni approach. The different population trends recorded in the five sites can be summarized as in the following text.

For the initial phase (from June 2014 to August 2014, except for Catania from June 2014 to September 2014), we found that for Naples and Rome, the size of host populations was higher than for the parasitoid's size with a subsequent strong decreasing trend for host numbers and an increasing trend for the parasitoid. For Catania and Palermo, the initial size of the host population was not much higher than that of the parasitoid and there was a trend for both to increase and then decrease. For Sassari, the size of the host population was slightly lower than that of the parasitoid and there was a decreasing trend for both followed by an increase in both and a second decline.

The intermediate phase extended from August 2014 to April 2015, except for Rome and Sassari, where it extended from September 2014 to April 2015. For Naples, Sassari, and Palermo, there was a stationary trend with low values for the host and close to zero values for the parasitoid. For Catania, there was a stationary trend for the parasitoid to remain at very low levels, whereas the host population exhibited increases and decreases, including some very high peaks on number.

For Rome, we observed extinction of both host and parasitoid in the period from September 2014 to March 2015. Starting from November 2014, the absence of eggs and nymphs of Stages 1–2 of *G. brimblecombei* has also been observed, owing to a severe defoliation of host plants caused by the exotic insect *Thaumastocoris peregrinus* Carpintero et Dellapé (Heteroptera: Thaumastocoridae).

For the final phase that extended from May 2015 to June 2015, except for Naples and Rome, where it extended from May 2015 to July 2015, at all sites, except for Rome, we observed an increasing trend of the host population, with higher value in Catania, and analogous for the parasitoid population, although with values proportionally lower; in Rome, the extinctions were not definitive and the presence of both host and parasitoid is observed again in this phase, probably owing to the migration of individuals from nearby areas and general improvement in the tree conditions in spring (Fig. 6 and Table 1).

The proposed model allows an approximation consistent with demographic trends, even if details of oscillations are lost. Simulation test will need an initial adaptation phase where the simulated steps may provide a poor approximation of the collected data. During this phase, the simulated values may differ from the collected values, but the overall trend generally holds, as highlighted by the graphs of relative percentage of the host–parasitoid populations (Fig. 7).

Evaluation of the Host Reduction Owing to the Parasitoid Activity

To perform the evaluation of the reduction in the host *G. brimblecombei* population by *P. bliteus* activity, observed data series related to the host population in the absence of the parasitoid are necessary. As the parasitoid presence/absence in the same area, during a period, are mutually exclusive events, this exact evaluation cannot be made.

A rough evaluation of this reduction has been computed by considering the observed data in the year 2011 as an approximation of the 2014–2015 data in the absence of the parasitoid. The comparison between the mean value of the sampled host population size

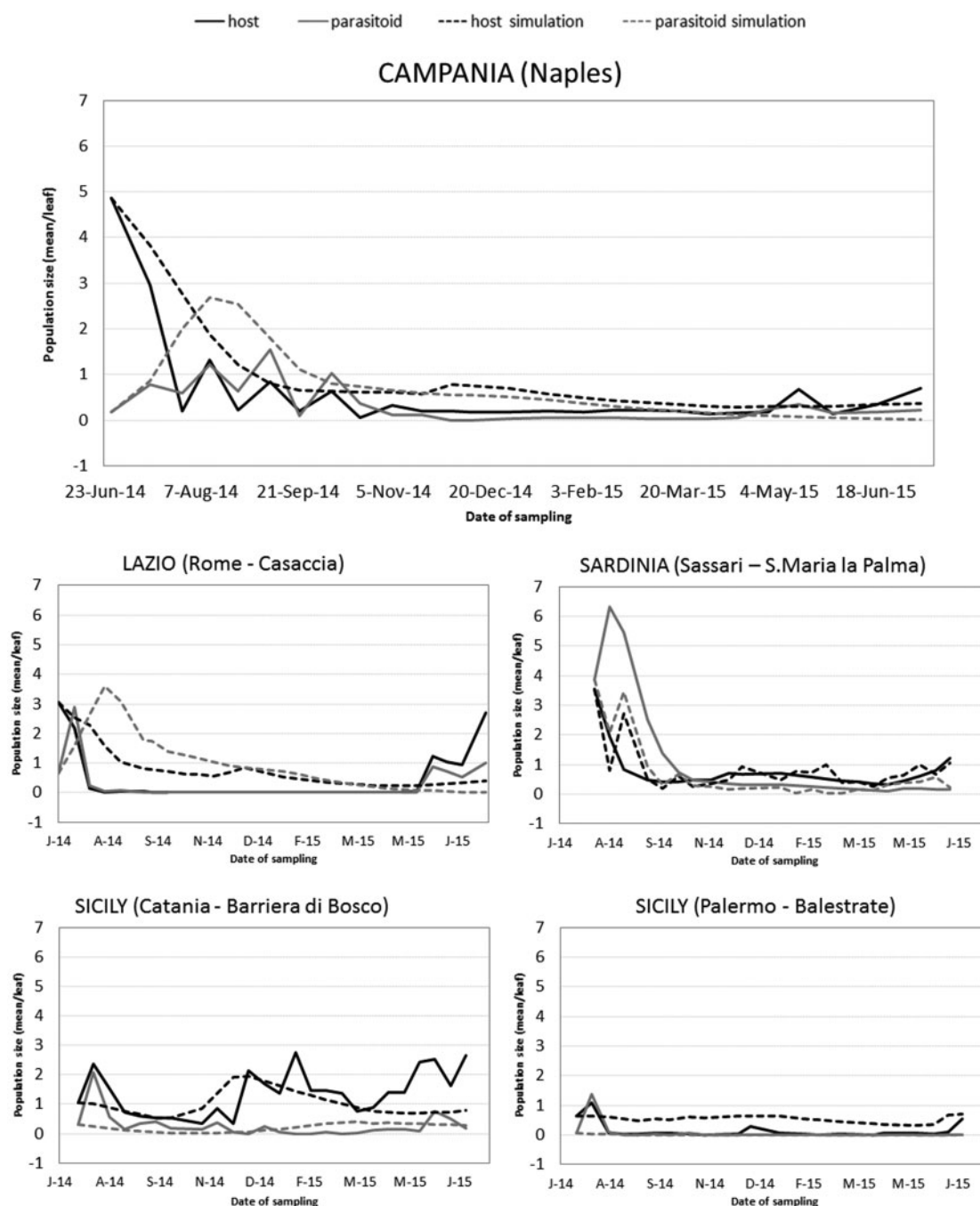


Fig. 6. Mean/leaf values of host and parasitoid population size (y-axis) in collected data (x-axis). Simulation results are also provided.

during 2014–2015, with the presence of the parasitoid, and the mean value of the sampled host population size during the year 2011 in the absence of it, allows us to estimate that parasitization causes a 64% reduction in the host population. The reduction values are obtained by exploiting the formula:

$(1 - \text{mean sampled host in presence of parasitoid} / \text{mean sampled host in absence of parasitoid}) \%$.

To justify the use of the observed data in the year 2011 as an approximation of the 2014–2015 data in the absence of the parasitoid, a simulation test providing the host population 2014–2015 in the absence of the parasitoid has been performed. The absence of the parasitoid corresponds to choosing values $c = 1$ and $b = d = 0$ in the proposed model. These parameter values have been exploited in a

simulation test with the values of the host growth rate selected on the basis of the T-R patterns corresponding to the environmental conditions observed in the Naples area from June 2014 to July 2015. They provide a rough approximation of the trend of the host *G. brimblecombei* population in the absence of the parasitoid in this period.

As previously mentioned, Laudonia et al. (2013) have reported observations on the sampled data series related to the population dynamics of *G. brimblecombei* in the Naples area in the period from February to October 2011 in the absence of the parasitoid. The simulation results in the absence of the parasitoid from June 2014 to July 2015, shown in Fig. 7, have been compared with the values observed in the year 2011. This comparison is shown in Fig. 8,

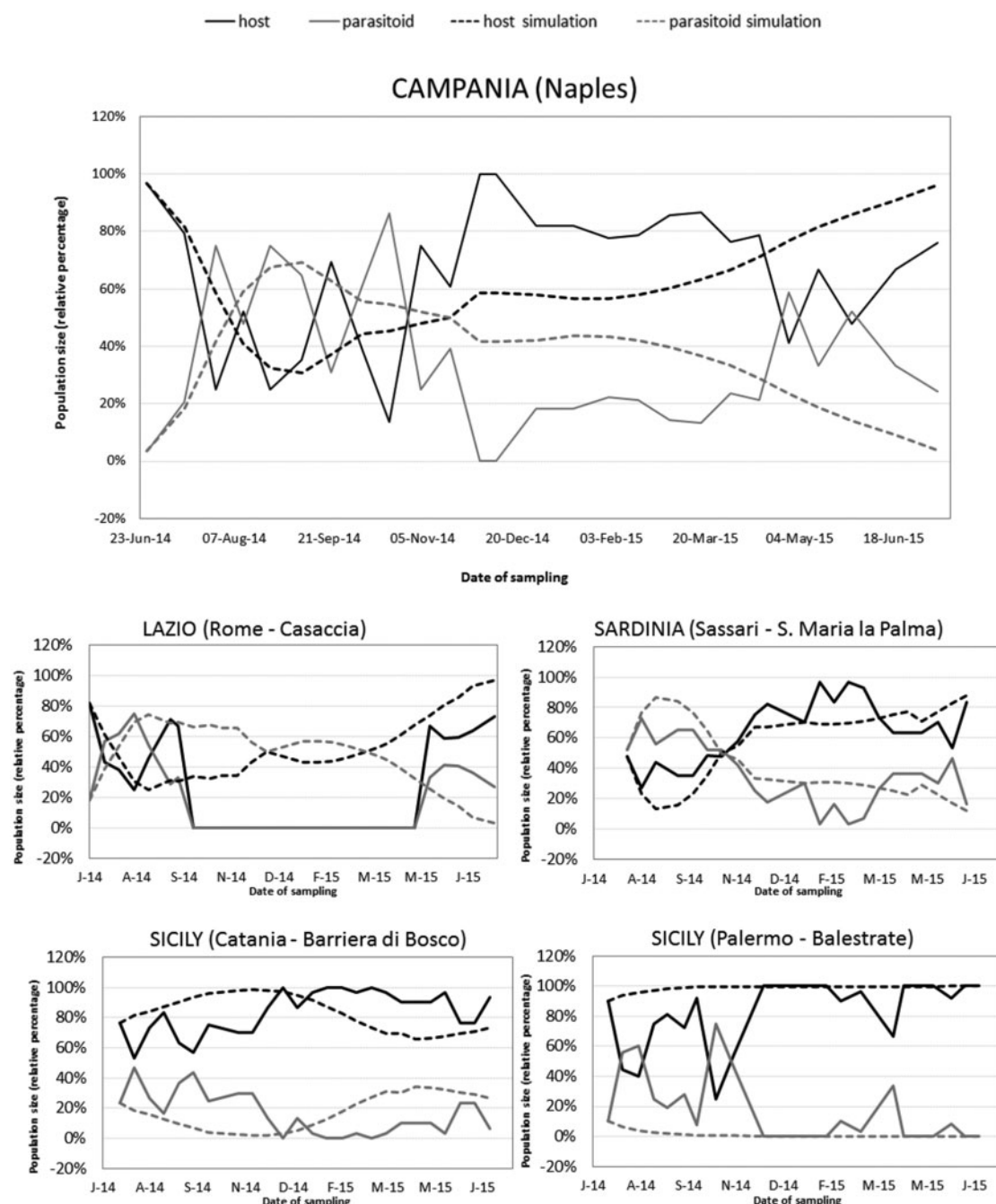


Fig. 7. Relative percentage (y-axis) of host (black line) and parasitoid (gray line) population sizes in the date of sampling (x-axis).

where for consistency, only the months from February to October were considered.

The obtained simulation results during 2014–2015 are in accordance with the trend of the host population observed in the year 2011, the parasitoid being absent in both cases. It is justified by the similarity in the environmental conditions during the two periods. Indeed, the mean values of the maximum temperatures and of the average temperatures show differences of 3 and 2%, respectively.

The evaluation of the host reduction owing to the parasitoid activity is a rough approximation of the real value that cannot be computed. However, it confirms the usefulness of the application of biological control tools to reduce the host population.

Discussion

In this paper, the host–parasitoid *G. brimblecombei*–*P. bliteus* interactions were considered by estimating the active parasitization of 3–5 nymphal instars (Daane et al. 2005).

The insect host is extremely invasive, particularly in new colonized areas (Santana and Burckhardt 2007, Garonna et al. 2011, Lo Verde et al. 2011, Bella and Rapisarda 2013), and the encyrtid is known as a very active species, similar to other members of the family (Daane et al. 2005, Caleca et al. 2011, Huerta et al. 2011).

Sampling data were collected from June 2014 to July 2015 throughout five Italian sites. The population growth of the

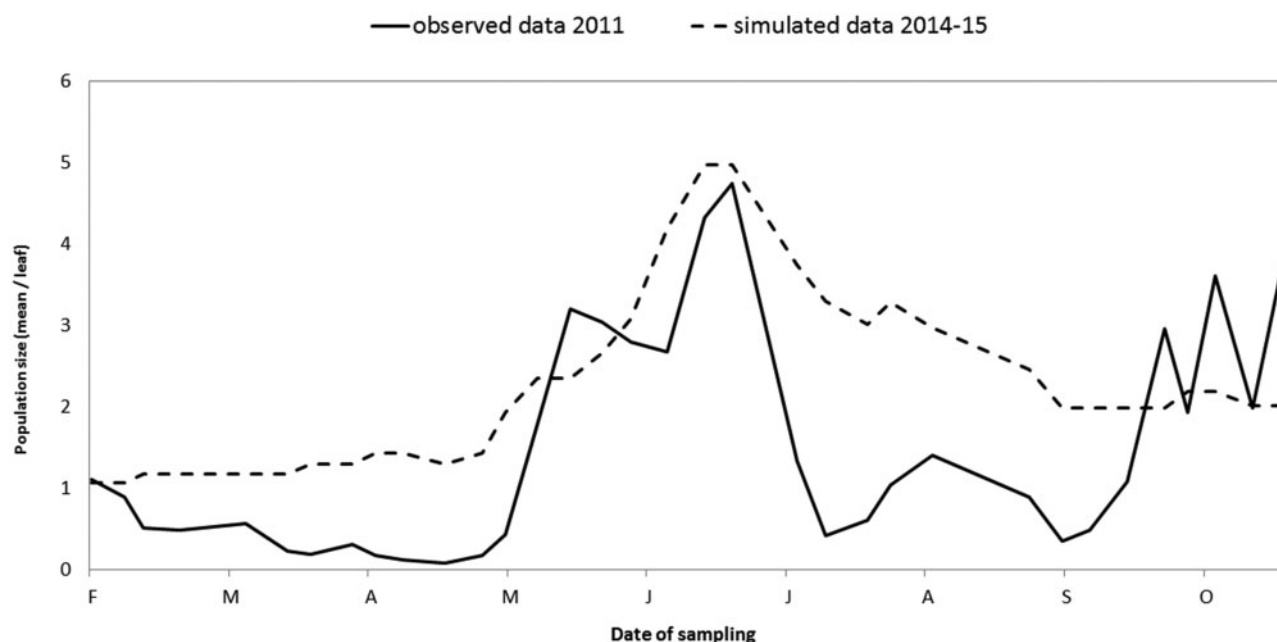


Fig. 8. Trend of the observed host population 2011 in the absence of the parasitoid compared with the simulated host population 2014–2015 in the absence of the parasitoid in the same months.

Table. 1 Case summaries table

		Initial phase			Intermediate phase			Final phase			Total		
		N	Mean	Var	N	Mean	Var	N	Mean	Var	N	Mean	Var
Naples	Host	4	2,35	4,217	18	0,21	0,023	4	0,98	0,223	26	0,65	1,170
	Parasitoid	4	0,70	0,173	18	0,25	0,263	4	0,30	0,087	26	0,33	0,236
Rome	Host	5	1,10	2,105	17	0,00	0,000	5	1,18	0,897	27	0,42	0,777
	Parasitoid	5	0,78	1,477	17	0,00	0,000	5	0,62	0,157	27	0,26	0,373
Sassari	Host	4	1,90	2,233	15	0,53	0,057	3	0,93	0,043	22	0,84	0,643
	Parasitoid	4	2,60	1,880	15	0,22	0,033	3	0,40	0,040	22	0,68	1,159
Catania	Host	3	1,67	0,443	18	1,14	0,443	4	2,30	0,233	25	1,39	0,572
	Parasitoid	3	1,00	0,930	18	0,14	0,019	4	0,40	0,100	25	0,28	0,186
Palermo	Host	3	0,60	0,250	14	0,05	0,007	4	0,18	0,049	21	0,15	0,075
	Parasitoid	3	0,53	0,563	14	0,01	0,001	4	0,00	0,000	21	0,08	0,093
Total	Host	19	1,54	1,998	82	0,40	0,298	20	1,13	0,765	121	0,70	0,825
	Parasitoid	19	1,14	1,454	82	0,13	0,076	20	0,36	0,113	121	0,32	0,420

N = number of sampling dates considered, Mean = mean of the population size distribution, Var = variance of the population size distribution.

parasitoid depends not only on its egg production but also on the chance of finding host nymphs to lay the eggs. The observed data show that when the parasitoid population exceeds the size of the host population, there is a subsequent significant reduction in the population of the parasitoid, which can reach a level close to zero. On the other hand, the host population, although heavily reduced, is able to maintain a higher level of survival. In fact, adults, young nymphs, and eggs, which are not under attack of the parasitoid, ensure the presence of subsequent generations. This significant ecological feature is called persistence (Nicholson 1933), i.e., collected values equal to zero, corresponding to population extinction (can be followed by non-zero values in a further sampling period). This behavior can be owing to several reasons:

- sampled data are zero, but the population is not really extinct: rare individuals remain present at the site and escape sampling;

- the population was actually extinct at the site, and the following repopulation is owing to migration of individuals from neighboring areas.

Based on these reasons, it is worth noticing that the psyllid has a non-uniform spatial distribution on the leaves of a single tree and on the trees of a defined area (Ferreira Filho et al. 2008). Moreover, the developmental phases of the two populations, *G. brimblecombei* and *P. bliteus*, are not synchronized. In the literature, the influence of environmental factors has received less attention compared with the inclusion of biological realism in the model by considering behavioral and biological aspects of the species, and of the host–parasitoid relation. To highlight the influence of environmental conditions on the population dynamics, the modeling technique based on the Lotka–Volterra model has been proposed. The previous observations carried out in Italy (Laudonia et al. 2013) and

Portugal (Boavida et al. 2016) suggest that climate conditions (e.g., high temperature, without rainfall) lead to a reduction in population size of *G. brimblecombei*.

In this paper, using the data series collected in the absence of the parasitoid (Laudonia et al. 2013), a more detailed analysis is performed to define criteria for choosing suitable values of the host growth rate depending on climatic conditions. It leads to the definition of several environment patterns, T-R patterns, that correspond to different behaviors of the host growth rate. An approximated value of the mean host growth rate is assigned to each T-R pattern. On the one hand, field experiments showed that *P. bliteus* is adversely affected by extreme summer heat and suggest that regional climatic differences can contribute to the lower parasitism rates observed in California's warmer interior valleys (Daane et al. 2012). Taking into account these results, in the proposed model, two different values relating to high and low temperature are used for the parameter c that provides the mortality rate of the parasitoid in the absence of the host. These criteria have been exploited to set the parameter values in simulation tests related to the data series sampled at five Italian sites during June 2014 and July 2015. The simulation results obtained are consistent with the main features of the observed host–parasitoid interaction. The use of different values of the host growth rate in the Lotka–Volterra model allows describing the overall trend of unstable dynamics characterizing the host–parasitoid interaction, although specific oscillations are lost. In particular, the simulated behavior shows that the presence of the parasitoid *P. bliteus* provides a significant reduction of the *G. brimblecombei* host even at very low level of pest, according to the collected data. On the other hand, the host is not driven to the extinction even when the population size of the parasitoid overtakes the population size of the host. The performed analysis allows highlighting some interesting features of the parasitoid influence on the growth of the host population that could be usefully exploited in biological control programs. A significant growth in the host population can be achieved in optimal environmental conditions following low values in the winter period. However, both the collected data and the simulated results show that the increasing of the host is associated with the parasitoid growth that provides a severe reduction of the host population. Moreover, further significant growth (i.e., after the summer period) of the host population does not appear after the first one, in contrast with the case of parasitoid absence. The comparison between the observed data before and after the occurrence of the parasitoid suggests that the parasitization causes a 64% reduction of the host population. Even though this is an approximate value, it confirms the usefulness of the application of biological control tools to reduce the host population. Despite the simple definition of the prey–predator Lotka–Volterra model, the proposed approach shows that it is a useful basis to model the very complex *G. brimblecombei*–*P. bliteus* host–parasitoid interaction. The proposed model also provides some insights into the effect of the parasitoid activity on the host population that are hard to evaluate in natural environment. In the overall context, it is to further investigate the influence that the presence of a strong attack of *T. peregrinus* can have against both host and parasitoid (Laudonia and Sasso 2012, Suma et al. 2014).

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