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Low-Temperature-Induced Winter Dormancy in a Predatory Stink Bug *Eocanthecona furcellata* (Wolff) in the Subtropics

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Abstract: Insects have developed dormancy mechanisms to survive coldness in winters. The specific forms of winter dormancy, however, vary among different geographical and climatic zones and species. While there is extensive research on winter dormancy in insect pests and parasitoids in temperate zones, our understanding of how predatory insects, such as predatory stink bugs in subtropical regions, cope with cold winters and the specific forms of dormancy they undergo remains limited. The effects of winter temperatures on the population dynamics, development, and reproduction of the predatory stink bug *Eocanthecona furcellata* in the subtropics were investigated through greenhouse and laboratory experiments. *E. furcellata* exhibits two distinct peaks in population distribution throughout the year: one in April–May and another in October–November. Interestingly, the proportions of adults show an opposite pattern to the population dynamics, with the highest proportions of adults observed during the winter and summer seasons, when temperatures are the lowest and the highest, respectively. Laboratory studies showed that *E. furcellata* reared at lower temperatures (16 °C, 18 °C, and 20 °C) experienced prolonged development and higher mortality rates for eggs and nymphs compared to higher temperatures (22 °C and 26 °C). Further experiments observed that *E. furcellata* adults reared at 16 °C, 18 °C, and 20 °C entered into winter dormancy, where ovarian development was either completely halted or slowed down. The observed high proportion of *E. furcellata* adults and low proportion of nymphs during the cold winter months align well with the dormancy period. This study sheds light on the underlying mechanisms driving the population dynamics of *E. furcellata* during the subtropical winter. These findings have significant implications in accurately predicting the population dynamics of *E. furcellata*, implementing effective field release strategies, and optimizing cold storage techniques in the context of biological control programs.

Keywords: *Eocanthecona furcellata*; life table; life-history plasticity; seasonal adaptation; predatory stink bug

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1. Introduction

Insects colonizing temperate zones generally respond to seasonal winter cold [1–3], gradual photoperiod decreases [4–6], or food scarcity [7,8] by entering a physiological arrest state termed winter dormancy. Winter dormancy allows insects to overcome unfavorable environmental conditions during their life cycle. Development and other life activities resume once a suitable environment returns [9,10]. It is an effective strategy for insects to maintain natural populations in winter [11,12].

The mechanisms by which insects in tropical and subtropical zones adapt to harsh winter conditions are not well understood. Existing evidence, however, suggests that the presence of physiological traits that differ from those observed in temperate zones may be responsible [13]. For instance, in temperate regions, the southern green stink bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae), undergoes diapause, a state of arrested development, in response to low temperatures and short days [13]; however, in subtropical regions, the abundant food resources allow this insect to transition to different host plants and continue its development and reproduction without entering diapause [14]. Research has also shown that it enters a period of summer quiescence in response to high temperatures in subtropical areas [15]. Due to the shorter variations in day length in subtropical regions, temperature is believed to have a greater influence on insects' life cycles [11]. They may enter summer diapause or estivo-hibernation by responding to hot weather in summer [16,17]. Furthermore, insect adults in these regions may enter different types of winter dormancy depending on the duration and magnitude of winter coldness. Undergoing a deep winter diapause (i.e., completely halted ovarian development) in response to extended low temperature [11,18] and entering quiescence (i.e., reduced activity and ovarian development) as a function of moderately cold or relatively short period of low temperature [11] have been documented. In the latter case, activity and development can be readily reactivated upon an increase of temperature [6,19].

Studies available so far on insect seasonal adaption to adverse environments have focused largely on insect pests and parasitoids [20–24]. Predacious insects that provide important biological and ecological functions in many ecosystems [25] remain understudied by comparison. Given the importance of predators, especially their important roles in controlling pest populations, an understanding of the strategy they use to deal with harsh winter conditions may benefit inundative release of natural enemies in biological control programs, and prediction of their population dynamics in the fields.

The predatory stink bug *Eocanthecona furcellata* (Wolff) (Hemiptera: Pentatomidae) is an important natural enemy to the larvae of many lepidopteran, coleopteran, and hemipteran pests in the tropics and subtropics [26–29]. One generation of *E. furcellata* takes approximately two months in the field. Since both nymphal and adult stages feed on prey, it has potential as a biological control agent for vegetable garden and crop pests, forest pests, and horticultural pests [26–30].

Eocanthecona furcellata adults enter summer diapause in response to unfavorable high temperatures [31]. The overwintering strategies of herbivorous bugs exhibit a wide range of variations depending on environmental conditions. For instance, *N. viridula* and *Piezodorus guildinii* (Westwood) (Hemiptera: Pentatomidae) display different overwintering durations in response to variations in daytime temperatures across different periods and regions [13–15,32]. The invasive pest *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) tends to aggregate and tightly cling to surfaces in dry and cold environments to overwinter, which facilitates subsequent spreading [33,34]. The impact of cold temperatures on the population and development of carnivorous bugs such as *E. furcellata*, however, remains largely understudied. In a preliminary field survey, it was found that the abundance of *E. furcellata* declined in sweet potato farmlands in Guangzhou (Guangdong Province China, the subtropical region) in winter (personal observation). Further observations discovered that the proportion of adults increased in the winter, and these adults had longer longevity compared to those surviving in summer or autumn. A field survey conducted by Lin [24] also suggested that *E. furcellata* might overwinter as adults in fallen leaves, and no nymph was spotted during the winter months. The stimuli inducing *E. furcellata* to overwinter and the causes of the low abundance of nymphs are largely unknown.

In the current study, we first quantified *E. furcellata* population dynamics in a greenhouse setting for 21 months. In particular, the proportion of adults over the survey period was monitored. Secondly, *E. furcellata* development and reproduction and life-table parameters under various temperature regimes were investigated in the laboratory. Thirdly, we quantified ovarian development of *E. furcellata*, by repeatedly dissecting *E. furcellata* females subject to various temperatures. We hypothesized that the development and reproduction (ovarian development) of adult *E. furcellata* would be halted (winter dormancy), and the survival of nymph *E. furcellata* would be reduced when exposed to low temperatures.

2. Materials and Methods

2.1. Study Insects

Eocanthecona furcellata adults were collected from sweet potato, *Ipomoea batatas* (L.) Lam. (Convolvulaceae), grown in an experimental field in South China Agricultural University (Guangzhou, Guangdong Province, China) [35]. They were supplied with larvae of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) or pupae of *Tenebrio molitor* (L.) (Coleoptera: Tenebrionidae) as food. The adults were placed in cylindrical tubes (h = 11 cm, d = 8.5 cm) made of copy paper under 16L:8D (photoperiod), 26 ± 1 °C, and 75% relative humidity. Eggs laid on the paper wall were cut out, and 50–100 eggs were kept and group-reared in plastic Petri dishes (d = 9 cm, h = 1 cm) where a wet cotton ball was placed away from the eggs. Nymphs hatched from eggs were kept in the Petri dishes until the 2nd instar before being transferred into a plastic transparent box (15 × 10 × 6 cm, with wet cotton balls and meshed windows). Nymphs were reared on the same foods as described for adults.

2.2. Population Dynamic of *E. furcellata* in a Semi-Field Greenhouse

Field experiments were conducted in a semi-field greenhouse at South China Agricultural University, Guangzhou, Guangdong Province, China, from 25 March 2018 to 15 December 2019. The greenhouse (8 × 3 × 3 m) was enclosed and covered with fine mesh (mesh hole = 0.25 mm) to prevent invasion of any organisms that might interfere with test insects. The internal temperature of the greenhouse was set to match the ambient external temperature. Wild sweet potato plants (*I. batatas*) had been growing in this greenhouse for a few years and served as a food source for many lepidopteran pests such as *S. litura*, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) and *Agrius cingulata* (Fabricius) (Lepidoptera: Sphingidae), which are all prey for *E. furcellata* in a natural environment. It is also a habitat and an oviposition substrate for *E. furcellata*.

On 25 March 2018, 180 *E. furcellata* nymphs (90 3-instar and 90 5-instar) were released into the greenhouse. The selection of these two life stages was based upon the significant abundance of them in field observations. No *E. furcellata* at any stage was observed prior to the release. The numbers of *E. furcellata* nymphs (i.e., 1- to 5-instar) and adults in the greenhouse were carefully checked 10 d following the initial release (i.e., the first greenhouse survey was conducted on 5 April 2018) and roughly every 10 d thereafter. To be specific, the *E. furcellata* population was monitored around the 5th, 15th, and 25th of every month until 15 December 2019. The upper vegetation layer, the ground, and the walls of the greenhouse were carefully inspected two to three times to ensure that no *E. furcellata* was missed. To guarantee sufficient prey, 200–250 *S. litura* larvae (3–5 instar) were placed on the upper side of sweet potato leaves evenly distributed in the greenhouse every 5 d.

2.3. Development and Reproduction of *E. furcellata* in the Laboratory

Findings from the preceding studies of population dynamics of *E. furcellata* in the greenhouse suggested that *E. furcellata* adults might enter diapause or quiescence in winter. To test this hypothesis, the development and reproduction of *E. furcellata* adults under different temperature regimes were examined. Since a previous study showed that photoperiod (i.e., 8L:16D, 12L:12D, and 16L:8D) did not induce diapause in any *E. furcellata* stage [35], the effects of photoperiod were not investigated in this study.

The average winter temperature in Guangzhou ranges from 15 to 20 °C, so five constant temperature levels (i.e., 16 °C, 18 °C, 20 °C, 22 °C, and 26 °C) were tested, and 26 °C was set as control. The photoperiod in all treatments was 10L:14D (a photoperiod close to that in Guangzhou in winter months). One hundred (100) newly hatched eggs were placed in a Petri dish (d = 9 cm, h = 1 cm) with a wet cotton ball and put into each incubator with the temperature set at 16 °C, 18 °C, 20 °C, 22 °C and 26 °C. The rearing (or handling) of eggs, nymphs, and adults followed the methods described above. The Petri dishes were checked daily, and the developmental time of the egg, each 1st–5th instar nymph, pre-oviposition, and the number of *E. furcellata* surviving to the next stage were recorded. Newly emerged adults under the same temperature were paired (8, 20, and 19 pairs at 20 °C, 22 °C, and 26 °C, respectively) and then reared together in a cylindrical tube (see above) at their respective temperature. The daily number of eggs laid and the total eggs throughout the pair's life were recorded.

2.4. Ovarian Development of E. furcellata and Dormancy

The preceding study showed that *E. furcellata* eggs or nymphs were not able to survive at 16 °C or 18 °C, and surviving females at 20 °C did not lay eggs (Table 1). Furthermore, although newly emerged females or males reared at 26 °C were able to survive 2–3 months at 16 °C and 18 °C, females did not lay any eggs, and males did not enter any form of dormancy with normal development of testes and male accessory glands (unpublished data). These observations suggested that temperatures $\leq$ 20 °C trigger *E. furcellata* female winter dormancy (no ovarian development or reduced ovarian development).

Table 1. Developmental times (mean ± 1SE d) of *E. furcellata* eggs under five temperature regimes in the laboratory.

Temperature (°C)	Egg (d) [5]	Nymph (d) [5]	Pre-Oviposition (d) [5]	Adult Longevity (d) [4,5]
16 [1]	--	--	--	--
18 [2]	20.53 ± 0.19 a (32) [6]	--	--	--
20 [3]	17.73 ± 0.05 b (88)	44.06 ± 0.32 a (18)	--	63.00 ± 0.44 a (17)
22	13.79 ± 0.04 c (95)	31.28 ± 0.14 b (67)	28.55 ± 2.61 a (20)	68.24 ± 2.52 a (63)
26	6.45 ± 0.11 d (98)	12.21 ± 0.26 c (72)	13.89 ± 1.35 b (19)	39.05 ± 2.34 b (63)

[1] Eggs subject to 16 °C could not hatch and died in less than a month (judging by dryness and discoloration); [2] eggs under 18 °C hatched, but none survived to the 2nd nymphal instar; [3] adults reared at 20 °C did not lay eggs; [4] data of female and male longevity were pooled; [5] different lower-case letters within the same column denote significant differences among treatments at α = 0.05 level (Tukey's test); [6] sample size.

To put the above hypothesis to the test, 400 newly emerged (i.e., <1 d old) adults (female:male = 1:1) reared at 26 °C were paired and kept in separate cylindrical tubes (see above) before being transferred to incubators with the temperature set at 16 °C, 18 °C, and 20 °C, respectively (photoperiod = 10L:14D). As such, there were 200 cylindrical tubes (pairs) for each temperature regime. Meanwhile, 400 adults (female:male = 1:1) reared at 26 °C all the time were similarly set as a control. Twenty females that had not oviposited were randomly selected from each temperature regime 30, 40, 50, 60, and 70 d following onset of the experimentation and dissected in 70% NaCl solution under a microscope. Developmental stages of ovaries were determined based on the number of oocytes in vitellarium [30] (Figure 1a–d). Females with ovaries at stage I, II, III, and IV after 30 d and without oviposition within 70 d were regarded as being in winter dormancy. Females oviposited within 30 d were not dissected and were considered to be normally developed. The proportion of normally developed dormant females were computed from the remaining undissected females.

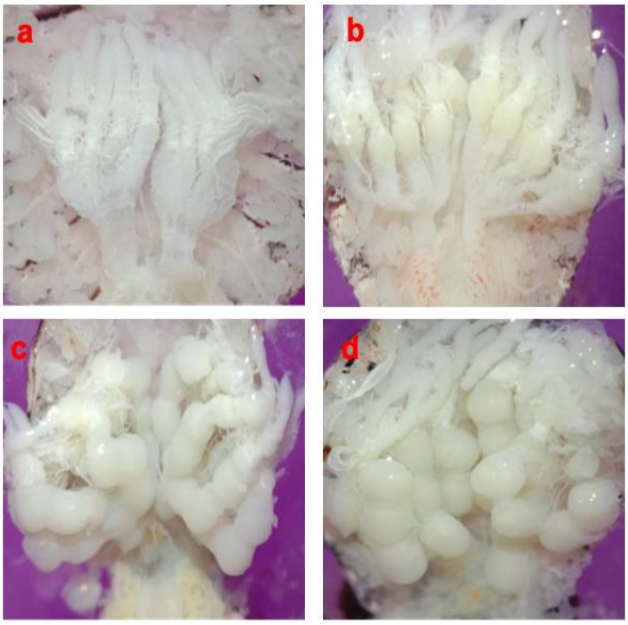

Figure 1. Stages of ovarian development of *E. furcellata*. (**a**) Stage I: transparent, no oocyte in the vitellarium; (**b**) stage II: 1–3 oocytes in each vitellarium; (**c**) stage III: >3 oocytes in each vitellarium; (**d**) stage IV: one or more matured eggs.

2.5. Statistical Analyses

All data analyses were conducted with R 4.0.3 software [36]. Normality and variances of data were assessed using Shapiro–Wilk tests and Levene's test, respectively. The nymph and adult developmental times, duration of pre-oviposition, and adult longevity were analyzed by using Kruskal–Wallis tests, since the data violated the normality assumption. Tukey's HSD test was used for comparing means among multiple treatments after rejecting the overall null hypothesis of no difference at the $\alpha = 0.05$ level. The life history raw data of *E. furcellata* reared at different temperatures were analyzed based on the age-stage life table [32,33].

The age-stage specific survival rate (s_{xj}, the probability that a *E. furcellata* will survive to age x and stage j), the age-stage specific fecundity (f_{xj}, the mean number of offspring produced by a female of age x), the age-specific survival rate (l_x, the probability of a newly laid egg surviving to age x), and the age-specific fecundity (m_x, the mean fecundity of individuals at age x) were calculated. We calculated l_x and m_x as:

$$l_x = \sum_{j}^{k} s_{xj} \tag{1}$$

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}} \tag{2}$$

where k is the number of stages. The net reproductive rate (R_0) was calculated as:

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \tag{3}$$

The mean generation time (T) was calculated as:

$$T = \frac{\sum x l_x m_x}{R_0} \tag{4}$$

The intrinsic rate of increase (r_m) was calculated as:

$$r_m = \frac{\ln R_0}{T} \tag{5}$$

and the finite rate of increase (λ) was calculated as:

$$\lambda = \mathrm{e}^{r_m} \tag{6}$$

A linear mixed-effects model was fit to the number of dormant *E. furcellata* females in response to temperature (five levels: 16 °C, 18 °C, 20 °C, 22 °C, and 26 °C) (function *lme* from package "nlme"). Temperature (as a factor) was the fixed factor, and time (i.e., sampling period at 30, 40, 50, 60, and 70 d) was the random factor. Normality (checked by function *qqPlot* from package "car") and variance homogeneity (checked by function *plot.lme* from package "nlme") were all met. If the overall null hypothesis that no significant difference among the temperatures rejected at α = 0.05, multiple mean comparison was adjusted using Tukey's HSD (function emmeans from package "emmeans").

3. Results

3.1. Population Dynamic of *E. furcellata* in a Semi-Field Greenhouse

The 21-month-long seasonal survey showed a bimodal *E. furcellata* population distribution in a year (Figure 2). The first mode started in March, peaked in April, and ended in May (Figure 2). The second mode started in September, peaked in October, and ended in November (Figure 2). The population density sharply declined in mid-July, late November 2018, and mid-September 2019, and only adults were found during these periods (Figure 2). The proportions of adults showed an opposite pattern to population dynamics: proportions of adults during these peak population times were lower (Figure 2). The adult population exhibited a consistent distribution pattern during specific time periods. For instance, from late June to late July 2018 (summer), early December to late January 2018 (winter), mid-August to mid-September 2019 (autumn), and mid-November to mid-December 2019 (winter), the proportion of adults remained at 100%.

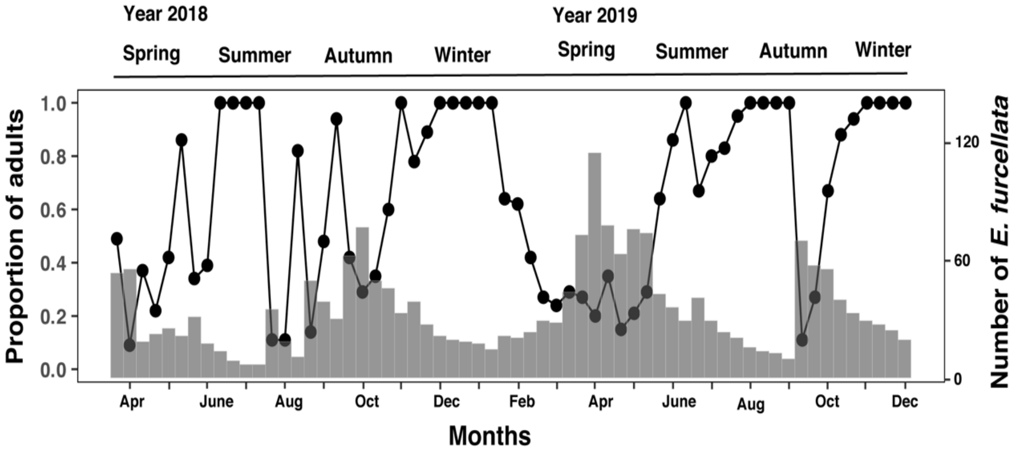

Figure 2. Seasonal population dynamic of the proportion of *E. furcellata* adults (black circles and solid line) and *E. furcellata* (nymphs and adults) abundance (bars) in a semi-field greenhouse from 5 April 2018 to 15 December 2019.

3.2. Development and Reproduction of *E. furcellata* in the Laboratory

No eggs subject to 16 °C survived to the 1st instar nymph, while eggs under 18 °C hatched, but none survived to the 2nd nymphal instar (Table 1). Increasing rearing temperature significantly shortened egg developmental time (χ^2 = 293.91, *df* = 3, $p < 0.001$), nymphal duration (χ^2 = 130.09, *df* = 2, $p < 0.001$), and pre-oviposition period (χ^2 = 19.31, *df* = 1, $p < 0.001$) (Table 1). Adult longevity under 20°C and 22°C did not statistically differ from each other, but both were longer than that under 26°C ($\chi^2 = 63.49$, $df = 2$, $p < 0.001$) (Table 1).

Eocanthecona furcellata reared at 16 °C, 18 °C, and 20 °C could not complete a life cycle, and life table parameters were not calculated (Table 2). Population parameters of *E. furcellata* were affected by different temperature regimes (Table 2). The net reproductive rate (R_0), finite rate of increase (λ), and intrinsic rate of increase (r_m) of *E. furcellata* reared at 22 °C were lower than those at 26 °C (Table 2). However, the mean generation time (T) of *E. furcellata* reared at 22 °C was longer than that of *E. furcellata* reared at 26 °C (Table 2).

Table 2. Life table parameters of *E. furcellata* population reared at five temperature regimes in the laboratory.

Temperature (°C)	R_0 [1]	r_m [2]	T [3]	λ [4]
16 [5]	-	-	-	-
18 [5]	-	-	-	-
20 [5]	-	-	-	-
22	42.16	0.14	27.00	1.15
26	81.64	0.18	24.02	1.20

[1] Net reproductive rate; [2] intrinsic rate of increase; [3] mean generation time; [4] finite rate of increase; [5] *E. furcellata* reared at 16 °C, 18 °C, and 20 °C could not complete a life cycle and parameters were not calculated.

3.3. Ovarian Development of E. furcellata and Dormancy

Temperature significantly affected the number of dormant females ($F_{4,16} = 133.95$, $p < 0.001$; Figure 3). At 16 °C, female *E. furcellata* experienced developmental arrest in their ovaries (stage I) from day 30 to 70. An increase in temperature to 18 °C triggered partial development in a small proportion of females' ovaries, resulting in 70% and 75% of females entering a dormant state with halted or reduced ovarian development by days 60 and 70, respectively. As the temperature further increased to 20 °C, the percentage of dormant individuals gradually decreased to below 50% after day 50. Notably, when the temperature reached 22 °C and 26 °C, over 80% of the population transitioned into non-dormant adults.

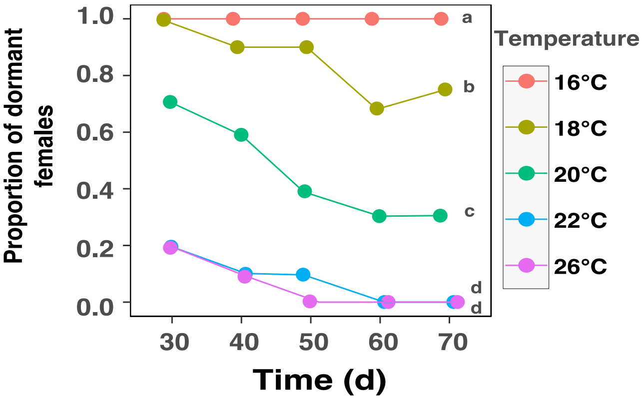

Figure 3. Proportion of dormant *E. furcellata* females in response to temperature (16 °C, 18 °C, 20 °C, 22 °C, or 26 °C) over 70 d. See Methods for statistical analysis. Multiple mean comparison was adjusted by Tukey's HSD. Different lower-case letters next to the temperature lines denote significant difference at $\alpha = 0.05$.

4. Discussion

A combination of greenhouse and laboratory experiments in the present study clearly revealed that *E. furcellata* responds to seasonal winter coldness in the subtropics by entering a reproductive dormant phase. This winter dormancy led to a lower proportion of immature *E. furcellata* but a high proportion of adults in the population. These findings enhance our understanding of how insects adapt to different seasons and have valuable implications in predicting the population dynamics of *E. furcellata* and developing effective biological pest control methods utilizing this predator. The population of the predatory stink bug *E. furcellata* showed a bimodal seasonal distribution in the greenhouse. Its abundance was lower when the air temperature was higher (summer or autumn) or lower (winter). On the contrary, the proportion of *E. furcellata* adults was higher in these periods (surviving *E. furcellata* were almost all adults). The findings of this study are in agreement with a previous study, providing consistent evidence [26]. It is important to note that the findings contrast with those of Chakravarty et al. [37], who observed a positive correlation between temperature and abundance of *E. furcellata* but did not specifically investigate the response of adult insects to temperature variations. The lower abundance of *E. furcellata* in hot seasons such as summer or autumn was due to the occurrence of summer diapause, as previously reported [35]. The underlying mechanism of lower *E. furcellata* nymphal abundance in winter has not been reported prior to the current study. As hypothesized, temperatures ≤20 °C (16 °C, 18 °C and 20 °C) greatly increased nymphal mortality, and surviving adults went into winter dormancy.

In Guangzhou, daily mean air temperature ≤20 °C can last for about 10–50 d (Figure S1 in the Supplementary Material). In such long cold periods, it will be an advantage for *E. furcellata* adults to enter a deep reproductive dormancy (ovarian development was either prevented or reduced, resulting in either the absence of oocytes or a lower number of oocytes occurring in the vitellarium, as shown in Figure 1a–d) because they and their offspring (eggs or nymphs) cannot survive under such low temperatures (Table 1). At 20 °C, however, there is still a high proportion of *E. furcellata* adults showing continued slow development of the ovary, but their egg laying activity is prohibited. This special dormant phase may allow *E. furcellata* to recover and reproduce quickly as soon as the temperature rises above 20 °C because in these regions the cold periods (<20 °C) may not last as long as in temperate regions. This hypothesis was corroborated by the fact that when *E. furcellata* adults reared at 20 °C for more than two months were transferred to 26 °C, they started laying eggs within 15 d after the transfer (unpublished data). The different degrees of dormancy *E. furcellata* used suggest that they can flexibly adjust their metabolisms or developments in response to the fluctuation of winter temperature, maintaining the population above a certain level in the field in winter [11,12,38]. Such a strategy was described as a "bet-hedging" strategy, by which adults lower their current fitness in order to maximize their long-term fitness and population persistence [39,40].

Due to the lack of transfer of dormant females to normal temperatures for further observation, the specific type of dormancy they exhibit, whether it is diapause or quiescence, cannot be definitively determined. The two forms of dormancy, diapause and quiescence, are difficult to distinguish at times because the phenotypic effects of them are quite similar [41,42]. Quiescence, as defined by the literature [41–43], however, is non-diapause dormancy and is characterized by slowed metabolism and an arrest of development or activity under the direct impact of unfavorable environmental conditions; once the stimulus is removed, physiological activity is restored. Here, we found that *E. furcellata* adults with reduced ovarian development at 20 °C had developing ovaries (stage II–stage IV), which differed from *E. furcellata* reared at 16 °C and 18 °C, whose ovarian developments were completely prevented (stage I). However, additional observations are required to judge whether the latter is in a quiescence state or a diapausing state.

The higher mortality of *E. furcellata* nymphs under low temperature may be due to higher freezing points. In previous laboratory experiments, it was observed that nymphs on average had a freezing point 1–2 °C higher than that of adults (Table S1 in the Supplementary Material). The relatively lower freezing points in *E. furcellata* adults may also explain why the surviving proportion of adults was higher in winter in the greenhouse and in other field conditions [26].

Though we did not obtain any population parameters of *E. furcellata* reared at 16 °C, 18 °C, and 20 °C, because *E. furcellata* cannot complete their life cycle at these temperature regimes, the present work provides an alternative method of studying the effects of temperature on the development and reproduction of insects and prediction of the long-term effects of temperature. In addition, the present results may have great implications for mass rearing and cold storage of *E. furcellata* in the laboratory [24,44,45].

Seasonal fluctuation of temperature has important impacts on the population dynamic of *E. furcellata*, a natural enemy of many serious lepidopteran pests in the tropics and subtropics, and *E. furcellata* seems to have evolved to cope with this special hostile factor (mild but not severe cold weather) by entering a reproductive dormant phase in winter so as not to expose their offspring to the fast-changing environments. These studies advance our understanding of the seasonal adaptation of *E. furcellata* and other predatory insects living in the tropics and subtropics, which facilitates their applications for the biological control of pests.

5. Conclusions

This study unveiled the adaptive response of *E. furcellata*, a predatory stink bug, to seasonal temperature fluctuations in subtropical regions. The research demonstrates that *E. furcellata* enters a dormant phase during winter, leading to a decrease in nymph abundance but an increase in the adult population. The ability of adults to undergo reproductive winter dormancy at varying temperature ranges ensures the species' survival and successful reproduction. These findings have practical implications for predicting *E. furcellata* population dynamics and developing effective biological pest control strategies. Moreover, this research deepens our understanding of seasonal adaptation in *E. furcellata* and other similar predator insects in tropical and subtropical regions, thereby facilitating their integration into pest management efforts.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy13102573/s1, Figure S1: Daily mean air temperature in Guangzhou, Guangdong Province, China in 2018 (A) and 2019 (B); Table S1: Freezing points of *Eocanthecona furcellata* (Wolff).

Author Contributions: Conceptualization, Y.Z., J.W. and K.C.; methodology, J.W., Y.Z., Q.L. and K.C.; software, Y.Z. and J.W.; formal analysis, Y.Z., J.W. and K.C.; investigation, Y.Z., Q.L., Z.K. and K.C.; resources, K.C.; writing—original draft preparation, Y.Z. and J.W.; writing—review and editing, K.C.; supervision, K.C.; project administration, K.C.; funding acquisition, K.C. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The datasets analyzed in the present study are available from the corresponding authors on reasonable request.

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