



Are gardens effective in butterfly conservation? A case study with the pipevine swallowtail, *Battus philenor*

Jacqueline M. Levy^{1,2,*} and Edward F. Connor¹

¹Department of Biology, San Francisco State University, 1600 Holloway, San Francisco, CA 94132, USA;

²4226 Mt. Taylor Dr., Santa Rosa, CA 95404-6255; *Author for correspondence (e-mail: jlevym@juno.com)

Received 12 December 2003; accepted in revised form 21 June 2004.

Key words: *Aristolochia californica*, *Battus philenor*, Butterfly gardens, Habitat restoration, Lepidoptera

Abstract

Gardens with nectar sources and larval host plants have been proposed to stem the decline in butterfly abundance caused by habitat loss. However, no study has provided evidence that gardens benefit butterflies. We examined the use of natural sites and gardens in the San Francisco bay area by the butterfly, *Battus philenor*. We found that natural sites were more likely to attract adult *B. philenor*, received more oviposition, and had higher juvenile survival than gardens sites. Butterflies were more likely to be present in gardens with established populations of the host plant, *Aristolochia californica*, growing in the sun. *Battus philenor* are unlikely to visit gardens with host plants planted within the past 7 years. Gardens between the ages of 8–40 years received oviposition, but did not always support completion of larval development of *B. philenor*. In gardens with host plants over 40 years of age, *B. philenor* consistently survived from egg to the adult stage. Natural enemy induced mortality of eggs did not differ between garden and natural sites, but overall egg survival was lower in gardens than at natural sites. It is unlikely that gardens serve as ‘refugia’ for *B. philenor* in years when populations in natural sites experience low survival or low fecundity. Even in gardens capable of supporting larvae to maturity, the density of eggs and survival rates were lower than in natural populations of the host plant suggesting that gardens were not optimal habitats. Therefore, without evidence that juvenile abundance and survival rates in gardens matches or exceeds that in natural sites, it is most likely that gardens act as population sinks for *B. philenor*.

Introduction

Traditionally, butterfly gardening has been purely an aesthetic practice to attract a variety of adult butterflies to complement a floral display. However, butterfly enthusiasts and environmental organizations have recently proposed that gardens could serve as a grass-roots approach to habitat restoration by replacing lost natural habitat and serving as corridors for wildlife confined to fragmented patches of habitat (Stokes 1991; Peterson 1996; Marinelli 1998; NWF 2002; Weatherbee 2002; Mikula 2000; NABA 2002).

Early studies of butterflies in gardens assume that butterflies use gardens only to nectar and that they return to oviposit on host plants in natural habitats (Vickery 1995). It has been assumed that the supplemental nectar obtained from gardens might indirectly support butterfly populations (Vickery 1995), since nectar has been shown to be important in egg production (Boggs 1997a, b). Gardens that also provide larval host plants could serve as oviposition sites and permit the successful completion of development from egg to adult. However, if the risk of mortality encountered while using nectar resources or oviposition sites in

gardens is greater than would have been encountered had nectaring or oviposition occurred on plants in natural sites, then the use of gardens is at least likely to not contribute to the regional abundance of butterfly populations, and could potentially result in a net decline in butterfly abundance.

Recent studies and conventional wisdom suggest that habitat patches in urban areas are effective in sustaining butterflies through development (Blair and Launer 1997; Hardy and Dennis 1999; Wood and Pullin 2002; Shapiro 2002). However, thus far no study has investigated the ability of gardens to contribute to the regional abundance or to promote the persistence of butterflies. Although studies have shown that adult butterflies use gardens to nectar, no study has determined if nectaring in gardens increases fecundity or if gardens are capable of serving as oviposition sites and supporting butterflies through all stages of development (Vickery 1994, 1995, 1996, 1998, 1999).

Studies designed to assess the contribution of nectar resources from gardens to butterfly abundance and persistence would require that marked adult female butterflies be followed or repeatedly re-sighted to estimate fecundity and the extent to which they nectar on natural or garden plants. While such a study is conceivable, obtaining sufficient re-sightings of individual butterflies to provide reliable estimates of fecundity and nectaring activity on garden plants is likely to be difficult.

However, it may be feasible to demonstrate that butterfly gardens with larval host plants provide the conditions necessary for gardens to contribute to the local abundance and persistence of butterfly populations. For gardens with larval host plants to contribute to butterfly abundance and population persistence, it is *necessary* that larval host plants in gardens attract adult butterflies and serve as oviposition sites. It is also necessary that eggs laid in gardens hatch, leading to larval feeding and completion of development culminating in the emergence of adults. None of these conditions are *sufficient* conditions to demonstrate that on average gardens serve as net sources of butterflies. The minimally sufficient condition to show that a garden site is a net source of butterflies would be to show that, on average, the marginal probability of an egg surviving that was laid on a host plant in a garden equals or exceeds that of an additional egg

laid in a natural population of the larval host plant (Pulliam 1988; Holt 1997). Density-dependent mortality in natural populations of host plants could create an environment where the risk of mortality to an additional egg laid at the natural site would be greater than had that egg been laid in a garden where egg and larval density and therefore density-related risks of mortality may be much lower. However, estimating the marginal probability of survival of an egg laid in a garden in comparison to an additional egg laid in a natural population of the host plant will also be quite difficult. Such a comparison would require that the density of eggs in natural populations and the density-dependent risks they face at the time an egg is laid be compared to the risks faced by an egg laid in a garden. It would be sufficient but not necessary for the overall survival rate in a garden to equal or exceed that in a natural population of host plants to claim that gardens are net sources of butterflies. A more productive initial approach would be first to determine if larval host plants in garden sites can provide the necessary conditions for gardens to serve as net sources of butterflies, and to determine the attributes of gardens that provide the necessary conditions to serve as net sources of butterflies.

To determine if gardens with larval host plants provide the necessary conditions to serve as potential sources of butterflies, we examined the distribution of all life-history stages of the butterfly *Battus philenor* (pipevine swallowtail) in gardens and in natural populations of its larval host plant (*Aristolochia californica*). We estimated egg abundance and survival rates under different microclimatic conditions in both garden and natural populations of the host plant to determine if larval host plants in gardens serve as sites for oviposition and if mortality risks are similar among garden and natural sites.

Methods

Use and development of B. philenor in gardens and natural sites

We used the pipevine swallowtail, *Battus philenor* (Lepidoptera: Papilionidae) as our test species. Although *B. philenor* is not rare, it has declined in

abundance (Hafernik and Reinhard 1995) and is popular among butterfly gardeners. In California, female pipevine swallowtails lay eggs exclusively on *Aristolochia californica*.

To determine if gardens with larval host plants contribute to the abundance and persistence of butterflies, we examined the distribution of all life-history stages of *B. philenor* in gardens and in natural populations of its larval host plant (*Aristolochia californica*). We selected garden and natural populations of *A. californica* without prior knowledge of their use by *B. philenor*. We defined natural sites by the presence of naturally occurring populations of *A. californica*, and garden sites by the presence of planted populations of *A. californica*. We endeavored to ensure that garden and natural sites varied widely in their attributes. Natural sites were located in riparian, oak woodland, and redwood forest habitats. Garden sites were located in botanical gardens, schools, and at private residences. In 2001, we selected nine natural and nine garden sites in Sonoma and San Francisco Counties. In 2002, we expanded the study area to include 11 natural and 23 garden sites in Alameda, Contra Costa, Marin, Napa, San Francisco, and Sonoma Counties.

All natural and garden sites were monitored weekly from March through mid-July 2001 and 2002 for the presence of all butterfly life-history stages. We visited all sites, except sites on private property, which were monitored by volunteers. We trained all volunteers to use the same techniques and communicated frequently with volunteers to insure consistent and accurate data collection. To determine which life-history stages were present (e.g., egg, early-, mid-, and late-instar larvae, and adults) we visually inspected foliage of *A. californica* and observed adult butterflies nectaring or on the wing. Each site was observed for a minimum of 15 min each week, although in most weeks the observation period lasted over an hour. Juvenile stages were easily detectable within a 15 min observation period. However, adult butterflies that pass through a garden only briefly could have been missed. If any juvenile stage was detected, then we inferred that all prior life-history stages and adults had also been present. To test the hypothesis that garden and natural sites were equally likely to have each life-history stage, we applied Fisher's Exact Test to data on the presence and absence of each life-history stage (Zar 1999).

Determining the importance of site attributes

To determine if site attributes were useful in predicting use by butterflies, we estimated the attributes of each site and fitted logistic regression models to data on the presence and absence of each life-history stage. We estimated the area of *A. californica* present at each natural and garden site by measuring the horizontal and vertical coverage of the vine. For garden sites, we used the number of years since *A. californica* was planted as an estimate of the age of the site. Since we had no information on the age of natural patches of *A. californica*, we adopted the convention to define the age of natural sites to equal the age of the oldest planted site included in our study (80 years). Based on the size of the vines of *A. californica*, the area of coverage and its slow growth rate, most natural patches are probably older than 80 years. However, this convention should make our estimates of the magnitude of the effect of site age and the age at first occupancy to be underestimates. Isolation distances of each garden to the nearest known natural population of *A. californica* were estimated using GPS and ARCVIEW GIS. The surrounding habitat matrix was characterized as rural, agricultural, suburban, or urban. We examined the correlations between site attributes and built separate models for highly correlated predictor variables. We estimated the predicted age of sites when first occupied by each life-history stage of *B. philenor* and the 95% reverse confidence intervals on these estimates of age at initial occupancy using 1000 bootstrapped replications of the logistic regression model of occupancy on site age.

The role of microclimate

To determine if females prefer to oviposit in sunny locations, we made weekly estimates of the average number of eggs/m² of *A. californica* foliage growing in the sun and shade at four natural and four garden sites over a 12-week period in 2002. Each site had *A. californica* in both sun and shade and had received oviposition the previous year. Using two-factor repeated-measures ANOVA, we tested for differences in oviposition rates between sun and shade locations and between garden and natural sites. At each site we recorded temperature

and light intensity in the sun and shade at 4-h intervals using data loggers with temperature and light sensors.

Factors influencing egg survival

We estimated egg survival by determining the fate of eggs in marked egg masses at each site. Because larvae do not leave their natal shoot until the second or third instar, reliable estimates of egg survival can be obtained. We used an independent samples *t*-test to compare egg survival rates between the garden and natural sites that received oviposition. In 2002, to test for microclimatic effects on egg survival, we marked 10 egg masses each in the sun and shade at four garden and four natural sites. To determine the effects of natural enemies on egg survival, half of the egg masses were covered with fine mesh bags (0.5 mm mesh) to exclude natural enemies (e.g., parasitoids and both invertebrate and vertebrate predators) and half were left uncovered. Egg masses were monitored weekly and the number of eggs and first instar larvae recorded. Three of the four garden sites received no oviposition on foliage in the shade, so we could not compare microclimate effects between garden and natural sites. To test for differences in egg survival rates and natural enemy mortality between garden and natural sites, we used a two-factor repeated-measures ANOVA with data from the sun locations only. To determine if egg survival and natural enemy effects differ between sun and shade, we used a two-factor repeated-measures ANOVA on the data from the natural sites.

Results

Adult *B. philenor* visited and oviposited in a smaller proportion of garden sites than natural sites during both years of study. In 2001, adults visited only one of nine garden sites surveyed ($p = 0.11$, 95% confidence interval (CI) [0.0025, 0.2]) as opposed to eight of nine natural sites ($p = 0.89$, 95% CI [0.21, 0.9]). In 2002, adults visited all 11 natural sites ($p = 1.0$, 95% CI [0.21, 1.0]), but only eight of 23 garden sites ($p = 0.35$, 95% CI [0.130, 0.375]). All natural sites visited by

adults received oviposition ($p = 1.0$, 95% CI [0.21, 1.0]) as did 75% of the garden sites ($p = 0.75$, 95% CI [0.179, 0.778]). Eggs hatched wherever deposited, but larvae did not survive to the last instar in all sites. The proportion of sites that received oviposition that had larvae complete development was higher in natural sites than in garden sites, 90.9% (95% CI [0.237, 0.917]) and 75% (95% CI [0.122, 0.714]) respectively. For both years, all life-history stages were more likely to be found in natural sites than in garden sites (Fisher's Exact Test: $p < 0.001$). Egg and larval densities were also 27 and 30% higher in natural than in garden sites, respectively.

Logistic regression models for each life-history stage indicated that only site age and foliage area were useful in predicting the presence of *B. philenor*. Neither isolation distance nor any of the matrix type variables entered any of the regression models. These models predicted adults to be present in gardens over 7 years old; eggs and early instar larvae in gardens over 17 years old; and last instar larvae in gardens over 40 years old (Figure 1). The lower rates of visitation to and oviposition in garden sites appear to arise primarily because garden plantings of *A. californica* comprised fewer individual plants that, because of their young age (less than 10 years), were smaller in size than plants in natural populations. As a result, garden plantings had less foliage ($51 \pm 24 \text{ m}^2$ foliage area) for oviposition and larval feeding than did natural sites ($661 \pm 257 \text{ m}^2$ foliage area). No gardens planted within the last 5 years received adult visitation or oviposition.

Microclimate was important in oviposition site choice. Sunny patches within sites were warmer and received more illumination than shady patches (mean light level difference: 3.03 lumens, paired $t = 3.47$, $df = 7$, $p = 0.005$; mean temperature difference: 4.58 °C, paired, $t = 3.84$, $df = 7$, $p = 0.003$). Females preferred to oviposit on foliage of *A. californica* growing in the sun. Egg densities were higher in the sun than in the shade ($F_{1,6} = 13.13$, $p = 0.01$, Figure 2a). Of the eight sites used to examine the effects of microclimate, three received no oviposition in the shade. Furthermore, the two gardens that were visited by adults, but rejected as oviposition sites, had no *A. californica* growing in the sun unlike the gardens that received oviposition.

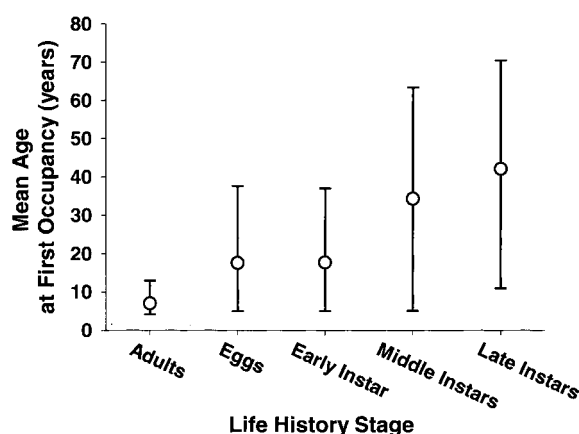


Figure 1. Predicted age (number of years post-establishment) of a population of the host plant when first occupied by various life-history stages of *B. philenor*. Circles represent the bootstrapped estimates of the mean ages at initial occupation and bars represent the 95% empirical bootstrapped reverse confidence intervals. Note that adults are predicted to begin to visit and oviposit approximately 7 and 17 years post-establishment, respectively, but that *B. philenor* is not predicted to be able to successfully complete development at sites younger than 40 years of age.

Egg and larval survival was lower in garden sites than in natural sites. The average egg survival rate was 23.5 and 17.6% lower in garden than in natural sites in 2001 and 2002, respectively (Fisher's method for combining probabilities: $\chi^2 = 10.81$, $df = 4$, $p = 0.029$). Rates of mortality from natural enemies did not differ between garden and natural sites (Figure 2b). Patterns of occurrence of larvae among sites also suggest that larval survival rates are slightly lower in garden than in natural sites. Of the six garden sites that received oviposition in 2002, only four had larvae survive to the last instar. In contrast, 10 of 11 natural sites had larvae complete development. No garden established within the past 10 years with less than 5 m² of *A. californica* growing in the sun was able to support larvae to maturity. Logistic regression models predicted that no garden with *A. californica* planted within the last 40 years or with less than 185 m² of foliage would support survival from egg to the last larval instar.

Discussion

We found no evidence that butterfly gardening, as currently practiced, is useful in the conservation of *B. philenor*. Although some garden sites attracted butterflies and provided the conditions necessary for the completion of larval development, overall,

gardens were less likely to attract and support *B. philenor* than natural sites.

The lower rates of visitation by adults to and oviposition in garden sites appear to arise primarily because garden sites have a smaller area of host plant cover than natural sites. It is possible some gardens were not visited because their size, degree of isolation, and location within an urban/suburban matrix render them unlikely to be detected by foraging adults. While we did not find that isolation or the character of the surrounding habitat matrix was useful in predicting patterns of visitation and oviposition, our sample size was small. However, the high vagility and longevity of *B. philenor* adults argues that most populations of *A. californica* should be detected (Rausher 1978). Some garden sites were visited by adults, but rejected as oviposition sites. We observed females on numerous occasions to alight on several shoots before returning to the initial shoot to oviposit. Such behavior may provide females with information on host-plant quality and/or quantity, and therefore a basis for rejecting a site. Such site rejection behavior, combined with a lower probability of visiting garden sites could account for the lower density of eggs that we observed in garden sites. Rausher (1980) reported that in Texas female *B. philenor* discriminated between two host plant species, which supports the idea that information obtained when searching for oviposition sites

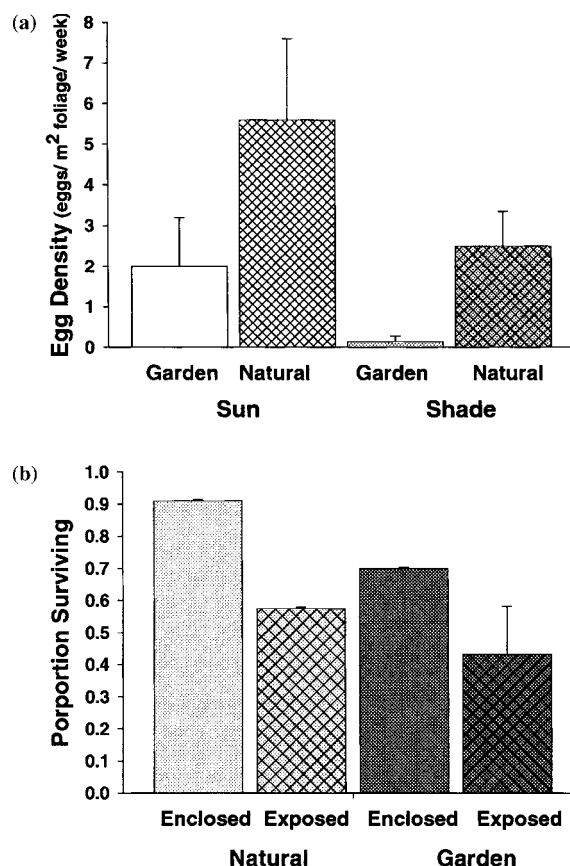


Figure 2. Densities and survival rates of *B. philenor* eggs. (a) Effects of ambient sunlight on oviposition preference. Mean density of *B. philenor* eggs on *A. californica* in the sun and shade in garden and natural sites. Vertical lines depict ± 1 SE. (b) Survival rates of *B. philenor* eggs in garden and natural sites in the presence and absence of natural enemies. Vertical lines depict ± 1 SE.

provides a basis for host plant and possibly site rejection.

The most important attributes of gardens necessary to attract and support the development of *B. philenor* include the abundance and age of the host plant, and the microclimate of the garden. An abundant supply of established *A. californica* plants growing in the sun is essential to attract adults. Abundant nectar resources and proximity to an established population of *A. californica* appear to be less important, or even of no consequence at all. A visual assessment of floral resources near each site indicated that all garden sites had abundant floral resources in comparison to natural sites. However, we found no evidence that the greater variety and quantity of nectar resources found at garden sites increased the probability of visitation by *B. philenor*. Each of the

garden sites, regardless of whether or not it received visitation or oviposition, had a much greater variety and quantity of nectar resources than did the natural sites. However, despite the high floral densities and prolonged flowering period in gardens, adult visitation was lower in gardens than natural sites.

The survival rates of *Battus philenor* eggs were higher in natural than in garden sites. However, because egg mortality caused by natural enemies did not differ between garden and natural sites, natural enemies cannot account for the observed differences in egg survival rates. Exactly why egg survival is lower in gardens is not clear. Garden sites receive supplemental watering throughout the growing season including the oviposition period. It is conceivable that sprinkler irrigation may evaporatively cool eggs, slowing development and

increasing the exposure of eggs to pathogens (Smittey et al. 1995), or potentially dislodge eggs from leaves leading to mortality (Connor and Taverner 1997).

Examination of the patterns of occurrence among sites of juvenile life-history stages also suggests that larval survival rates are slightly lower in garden than in natural sites. Of the six garden sites that received oviposition in 2002, only four had larvae survive to the last instar. In contrast, in 2002, 10 of 11 natural sites had larvae complete development.

Synthesis

Even in the gardens capable of supporting larvae to maturity, the density of eggs and survival rates were lower than in natural populations of the host plant, suggesting that these gardens were not optimal habitats for *B. philenor*. Dispersal from an optimal site and use of a suboptimal site, when oviposition sites and foliage for larval development are limited and when juvenile mortality is density dependent, must be evident for suboptimal garden sites to be considered a source habitat for butterflies (Pulliam 1988). However, egg densities and foliage consumption in natural populations do not suggest that oviposition and feeding sites are limited. There is also no evidence to suggest that higher densities are associated with increased egg mortality in natural sites. Therefore, without evidence that juvenile abundance and survival rates in gardens matches or exceeds that in natural sites, it is most likely that gardens act as population sinks for *B. philenor*. Furthermore, the common practice of introducing eggs and larvae from natural populations into garden sites without adequate foliage in an appropriate microclimate is likely to be a net drain on natural populations.

Efforts by conservation organizations to promote butterfly gardening have been successful. The growing interest in butterfly gardening has inspired neighborhoods to landscape with the intention of conserving butterflies and the National Wildlife Federation (NWF) to designate 13 entire towns as Wildlife Habitats™ (Swezey and Cohoon 2002, S.D. Portnoy, pers. comm.). A garden that contains plants and other landscape features that supply food, water, shelter, and breeding sites for animals can receive certification

from NWF, but the requirements for certification are not specific to the needs of individual species.

However, our results suggest that the establishment of small individual gardens is more likely to serve to decrease the regional abundance of *B. philenor*, than to increase their abundance. Therefore, further promotion of butterfly gardening as a tool for aiding in the conservation of *B. philenor* should be suspended. We also question the indiscriminate promotion of butterfly gardening as a benefit to other butterfly species until gardens can be designed with knowledge of the specific needs for microclimate and resource plants of the species targeted for conservation.

It is possible that individual gardens with sufficiently large plantings of host plants in appropriate microclimates could contribute to the regional abundance of some butterfly species. However, most home gardens are not large enough to accommodate the needs of *B. philenor* (185 m² of foliage area). For *B. philenor*, habitat restoration involving a network of large, nearby gardens might provide adequate resources to support oviposition and survival rates similar to natural populations. However, species of butterflies that are extremely rare or have more complex life histories are unlikely to use or thrive in gardens (e.g., ant tended Lycaenids, etc.). Butterfly gardening might be most successful if used to augment populations of those species that have experienced a regional decline, but are not threatened, and that have more rapidly maturing host plants than does *B. philenor*.

To determine the value of gardens in the conservation of butterflies, further studies including several species of butterflies that vary in regional abundance, in degree of host plant specialization, and in host plant growth rates will be necessary. Such studies would be feasible given the enthusiastic participation of volunteers to monitor the presence and survival rates of several species of butterflies. Butterfly gardens typically contain a variety of host and nectar plants and their owners are often eager to discover means of attracting and sustaining more butterflies.

Until now there have been no studies examining the value of gardens in butterfly conservation. As efforts to create gardens for butterflies continue, it is essential that assessments of the use and survival of butterflies in gardens occur as well. Otherwise, we will remain ignorant of the role that gardens

might play in butterfly population dynamics as well as the attributes of gardens that make them a potential resource for butterflies.

Acknowledgements

We acknowledge support from the Graduate Student Council in Biology at San Francisco State University, the Xerces Society, and the Garden Club of America. We thank the following volunteers: M. Abbot, M. and K. Angell, J. Barry, M. Bennett, B. Groce, C. Cloak, J. Cook, L. Coster, C. and W. Culp, G. Dodson, D. Ford, L. Hallberg, V. Hanelt, C. Harrison, L. Hazen, E. Insley, J. Kennedy, S. Levinson, L. Lozier, T. Meikle, B. Montgomery, B. Preston, M. Quenzer, M. Sproul, C. Vellutini, A. Webster, A. Weishaar, H. Wilbur, E. Woodriff, and G. Wright. We also thank the Sonoma County Parks Department, California State Parks Department, Bouverie Audubon Preserve, D. and G. White, UC Berkeley Botanical Garden, East Bay Regional Parks, San Francisco Zoo, and Strybing Arboretum for allowing access to their properties. This manuscript benefited from comments by John Hafernik.

References

- Blair R.B. and Launer A.E. 1997. Butterfly diversity and human land use: species assemblages along an urban gradient. *Biol. Conserv.* 80: 113–125.
- Boggs C.L. 1997a. Dynamics of reproductive allocation from juvenile and adult feeding: radiotracer studies. *Ecology* 78: 192–202.
- Boggs C.L. 1997b. Reproductive allocation from reserves and income in butterfly species with differing adult diets. *Ecology* 78: 181–191.
- Connor E.F. and Taverner M.P. 1997. The evolution and adaptive significance of the leaf-mining habit. *Oikos* 79: 6–25.
- Hafernik J.E. and Reinhard H. 1995. Butterflies by the bay: winners and losers in San Francisco's urban jungle. *Am. Butterflies* 3: 4–11.
- Hardy P.B. and Dennis R.L.H. 1999. The impact of urban development on butterflies within a city region. *Biodiv. Conserv.* 8: 1261–1279.
- Holt R.D. 1997. On the evolutionary stability of sink populations. *Evol. Ecol.* 11: 723–731.
- Marinelli J. 1998. *Stalking the Wild Amaranth: Gardening in the Age of Extinction*. Henry Holt and Company, New York.
- Mikula R. 2000. *The Family Butterfly Book: Projects, Activities, and a Field Guide to 40 Favorite North American Species*. Storey Books, Pownal, VA.
- NABA. 2002. *Butterfly Gardens & Habitats*. North American Butterfly Association, Morristown, NJ. <<http://www.naba.org>>, July 16, 2004.
- National Wildlife Federation. 2002. *Backyard Wildlife Habitat*. National Wildlife Federation, Reston, VA. <<http://www.nwf.org/backyardwildlifehabitat/>>, July 16, 2004.
- Peterson R.T. 1996. *Your Backyard Wildlife Year: How to Attract Birds, Butterflies, and Other Animals Every Month of the Year*. Rodale Press Inc., Emmaus, PA.
- Pulliam R. 1988. Sources, sinks, and population regulation. *Am. Nat.* 132: 652–661.
- Rausher M.D. 1978. Search image for leaf shape in a butterfly. *Science* 200: 1071–1073.
- Rausher M.D. 1980. Host abundance, juvenile survival, and oviposition preference in *Battus philenor*. *Evolution* 34: 342–355.
- Shapiro A. 2002. The Californian urban butterfly fauna is dependent on alien plants. *Biodiv. Res.* 8: 31–40.
- Smithey D.R., Bauer L.S., Hajek A.E., Sapio F.J. and Humber R.A. 1995. Introduction and establishment of *Entomophaga maimaiga*, a fungal pathogen of gypsy moth (Lepidoptera: Lymantriidae) in Michigan. *Environ. Entomol.* 24: 1685–1695.
- Stokes D.W., Stokes L.Q. and Williams E. 1991. *The Butterfly Book: An Easy Guide to Butterfly Gardening, Identification, and Behaviour*. Little, Brown and Company, Boston.
- Swezey L.B. and Cohoon S. 2002. Gardening for wildlife: your landscape can be a sanctuary for birds, butterflies, and other lovely creatures. *Sunset November*: 77–80.
- Vickery M. 1994. Butterfly conservation national garden butterfly survey. *Butterfly Conserv. News* 59: 26–28.
- Vickery M.L. 1995. Gardens: the neglected habitat. In: Pullin A.S. (ed.), *Ecology and Conservation of Butterflies*. Chapman & Hall, London pp. 123–134.
- Vickery M. 1996. The garden butterfly survey 1995. *Butterfly Conserv. News* 62: 25–27.
- Vickery M. 1998. Garden butterfly survey 1997. *Butterfly Conserv. News Spring 1998*: 26–28.
- Vickery M. 1999. Garden butterfly survey 1989. *Butterfly Conserv. News Spring/Summer 1999*: 24–26.
- Weatherbee. 2002. *Gardening for Butterflies*. National Audubon Society, New York. <<http://magazine.audubon.org/backyard/backyard.html>>, July 16, 2004.
- Wood B.C. and Pullin A.S. 2002. Persistence of species in a fragmented urban landscape: the importance of dispersal ability and habitat availability for grassland butterflies. *Biodiv. Conserv.* 11: 1451–1468.
- Zar J.H. 1999. *Biostatistical Analysis*, 4th ed. Prentice-Hall Inc., Upper Saddle River, NJ.