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Source: The Journal of the Lepidopterists' Society, 64(2) : 91-97

Published By: The Lepidopterists' Society

URL: https://doi.org/10.18473/lepi.v64i2.a4

*Journal of the Lepidopterists' Society*
64(2), 2010, 91–97

# NOTES ON THE STATUS AND ECOLOGY OF *ANAEA TROGLODYTA FLORIDALIS* (NYMPHALIDAE) IN EVERGLADES NATIONAL PARK

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**ABSTRACT.** A 10-year survey was conducted within the pine rocklands of Everglades National Park to study the general status, phenology and natural history of *Anaea troglodyta floridalis* F. Johnson and Comstock. The response of *A. t. floridalis* populations to prescribed fires and hurricane activity within the Everglades was also noted. *Anaea t. floridalis* (n = 242) was encountered throughout the survey period, most frequently during the late fall to early spring. While the species was encountered throughout the pine rocklands of Long Pine Key its annual abundance varied considerably over the survey duration. *Anaea t. floridalis* was readily encountered within recently burned pine rocklands soon after prescribed fires. In addition, the species appeared to recover quickly after various hurricane events in the Everglades.

**Additional key words:** prescribed fire, phenology, conservation, hurricanes, *Forcipomyia, Chetogena*

*Anaea troglodyta floridalis* F. Johnson & Comstock (Nymphalidae) (Fig. 1) has historically occurred throughout the pine rocklands of southern Florida and the lower Florida Keys (Schwartz 1987; Minno & Emmel 1993; Smith *et al*. 1994; Salvato & Hennessey 2003), where it is endemic. However, due to extensive habitat loss across much of its former range *A. t. floridalis* is now largely restricted to the pine rocklands within and adjacent to Everglades National Park (Fig. 2) as well as to Big Pine Key, which is part the National Key Deer Refuge in the lower Florida Keys. Along with habitat loss, use of chemical adulticides for mosquito control and suppression of natural fire regimes have also been suggested as primary factors that have influenced the decline of *A. t. floridalis* (Hennessey & Habeck 1991; Hennessey *et al.* 1992; Emmel *et al.* 1995; Schwarz *et al.* 1996; Salvato 1999, 2001).

In the Everglades, where the threat of further habitat loss or use of chemical pesticides is reduced, the role and frequency of fire remains an important factor influencing populations of *A. t. floridalis* (Salvato 1999). Historically, periodic lightning-induced fires were a vital component in maintaining native vegetation within the pine rockland ecosystem (Loope & Dunevitz 1981; Slocum *et al.* 2003), including *Croton linearis* Jacq. (Euphorbiaceae), the only known hostplant for *A. t. floridalis*. While prescribed fire had been employed as a management tool in the Everglades for several decades, it was only towards the end of the twentieth century that these protocols were adapted to best mimic the timing of lightning-ignited fires and their role in the natural histories of various pine rockland species. Salvato (2003) indicated that the strong flight abilities of *A. t. floridalis* allow the species to disperse in search of *C. linearis* after fires or other disturbances. However, the actual response and recovery time of *A. t. floridalis* to prescribed burns within the pine rocklands has not been studied or documented in greater detail.

Salvato & Salvato (2007) discussed the influence of hurricane and tropical storm activity on several butterfly species within coastal portions of southern Florida. These studies indicated that species richness and abundance returned to pre-storm levels within a year after the disturbances. However, the potential influence of tropical storms on pine rockland species such as *A. t. floridalis* has never been evaluated.

FIG. 1. *A. t. floridalis* at gate 2 in Long Pine Key on 10 February 2007 (Photo: H. L. Salvato).

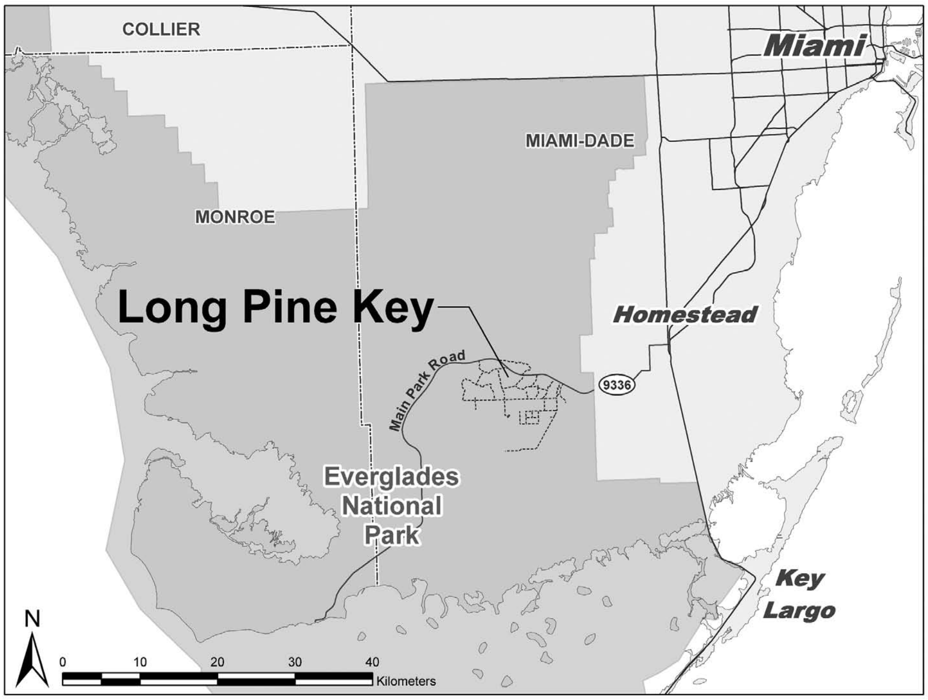


FIG. 2. Location of Long Pine Key within Everglades National Park and southern Florida.

This paper describes our ongoing population monitoring of *A. t. floridalis* within the Everglades and examines phenology, parasitism, and response to hurricane activity, as well as the possible influence of prescribed fires on the abundance of this species.

## METHODS

A survey transect was established at the gate 4 nature trail in the Long Pine Key (LPK) portion of the Everglades to evaluate the seasonal phenology and annual abundance of *A. t. troglodyta*. The transect was 400 m in length and 5 m in width (0.2 ha) and occurred within pine rockland habitat with evenly distributed amounts of hostplant and followed the parameters outlined in Hennessey & Habeck (1991) and Salvato (1999). Monthly survey data were collected to identify seasonal peaks in *A. t. floridalis* abundance. A variety of ecological factors (including, parasitism, predation, weather) was examined to evaluate variability in annual *A. t. floridalis* abundance throughout the study. To help determine general *A. t. floridalis* distribution elsewhere within LPK, additional, similarly proportioned transects (n = 3) were established during 2004 in areas where the species had been historically reported (gates 2, 8, and 10) (Fig. 3). Although additional time was also spent surveying other pine rocklands within LPK to access *A. t. floridalis* activity outside our primary study sites, many areas with habitat suitable for the species were not monitored or only infrequently visited. Therefore obtaining an overall population density for *A. t. floridalis* in LPK was not an objective in these studies. The general abundance and natural history of another pine rockland-occurring butterfly, *Strymon acis bartrami* (W. Huntington & Comstock) (Lycaenidae), was also studied during this survey and these data are discussed elsewhere (Salvato and Salvato, in press).

Surveys were conducted monthly from January 1999 to December 2008. Sampling dates occurred on warm, clear days when temperatures (minimum 23°C) were considered sufficient for butterflies to be flying. Adult butterfly abundance was determined on each sampling date by visually observing and recording the number of butterflies seen. Monthly visits to transects occurred at approximately 4-week intervals which reduced the likelihood of encountering the same individuals on consecutive sampling dates. From 1999 to 2003 each sampling date included approximately 3 to 4 hours of field time (between 08:00–12:00 h). From 2004 onward field time increased to approximately 9 hours (between 08:00–17:00 h) on each sampling date to accommodate the additional study sites.

On each sampling date *C. linearis* (n = 100) was inspected at the gate 4 transect to monitor for *A. t. floridalis* larval activity. *Croton linearis* was not regularly monitored for larvae on the remaining transects, however larval activity, when observed at these locations, was noted.

During two periods (November 2007 to April 2008 and November to December 2008) we conducted weekly monitoring of *A. t. floridalis* larvae at gate 4 to more accurately measure larval development. Only larval activity was monitored during these additional survey dates.

Throughout the study prescribed burns (n = 6) were administered on burn units within the study area at gate 4. In such instances *C. linearis* was observed to note general recovery time post-burn as well as duration until the plants were used by *A. t. floridalis* for reproduction. In addition, adult *A. t. floridalis* abundance was evaluated during the 6 months prior to and following each prescribed burn event. Following Hurricanes Irene (1999), Katrina (2005) and Wilma (2005) we monitored the response of *A. t. floridalis* to storm influence.

## RESULTS

Figure 4 indicates the number of adult *A. t. floridalis* observed during 1999 to 2008 in LPK at gate 4 only, based on twelve monthly sampling dates annually. The highest number of adult *A. t. floridalis* observed at gate 4 during a survey year was 54 individuals during 1999. In subsequent years the total number of adult *A. t. floridalis* varied greatly at gate 4, ranging from 4 (2005) to 37 (2004).

A total of 206 adult *A. t. floridalis* were recorded at gate 4 over the 10-year survey period. Table 1 reviews observations of *A. t. floridalis* (n = 36) at gates 2, 8 and 10 during 2004 to 2008. Adult *A. t. floridalis* were observed during every month of the year, but the majority of observations occurred from late fall to early spring (Fig. 5). Throughout the survey period a similar number of adult *A. t. floridalis* were observed during the months prior to and following each of the six prescribed burns administered at gate 4 (Fig. 6).

The number of *A. t. floridalis* larvae found over the duration of the study varied, but was generally low. As with adults, larval *A. t. floridalis* were encountered throughout the year, but were reduced during the summer months, with no larvae observed during July. Table 2 reviews *A. t. floridalis* larval observations at gate 4 annually over the duration of the study. The cryptic nature of *A. t. floridalis* larvae made the species difficult to locate and it is likely that a considerable number of individuals were overlooked during sampling dates.

During two periods (November 2007 to April 2008 and November to December 2008) we monitored larval activity weekly at gate 4. Of these larvae (n = 19), approximately 37 % (n = 7) reached the 5th instar with

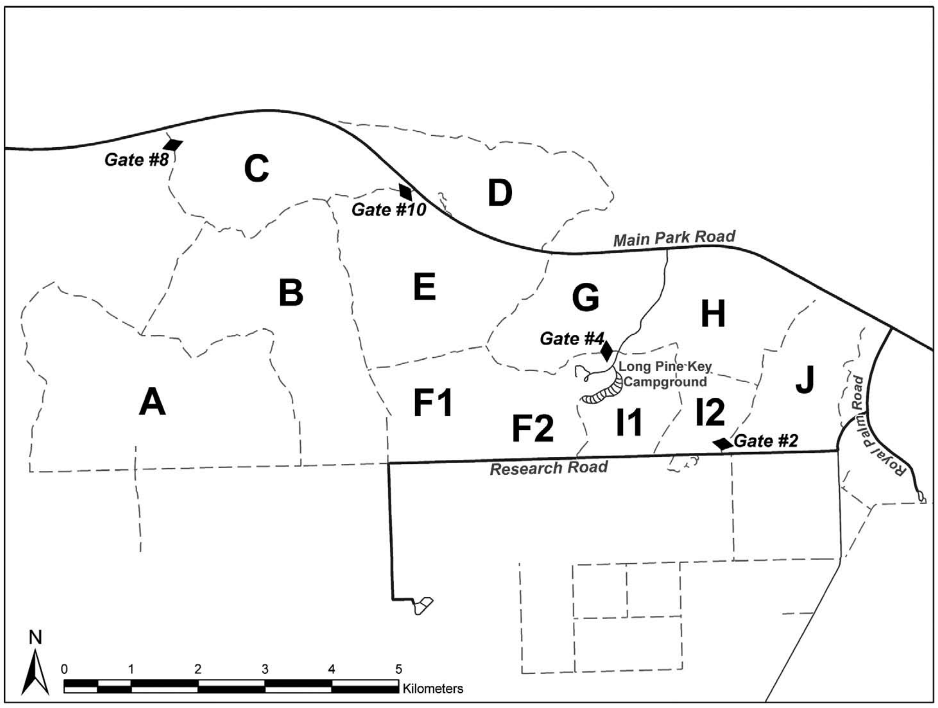


FIG. 3. Locations of the study areas at gates 2, 4, 8, and 10 and the burn units within Long Pine Key.

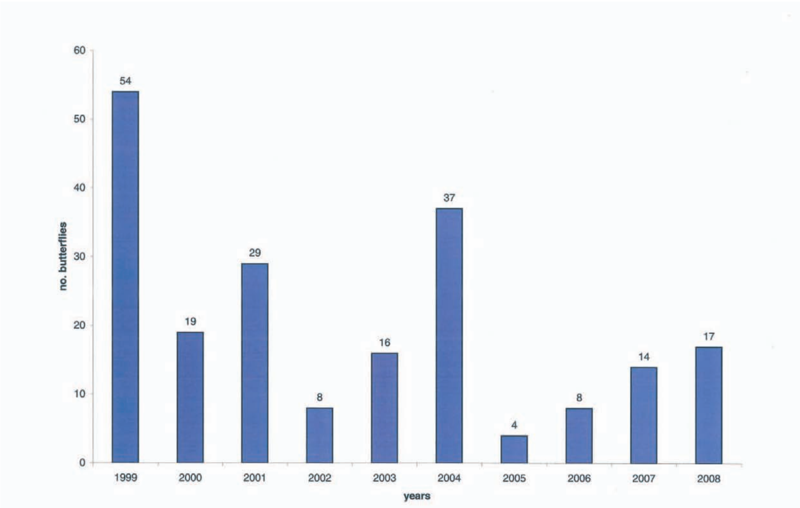


FIG. 4. The number of adult *A. t. floridalis* observed annually during 1999 to 2008 in Long Pine Key at gate 4, based on 12 months of sampling each year.

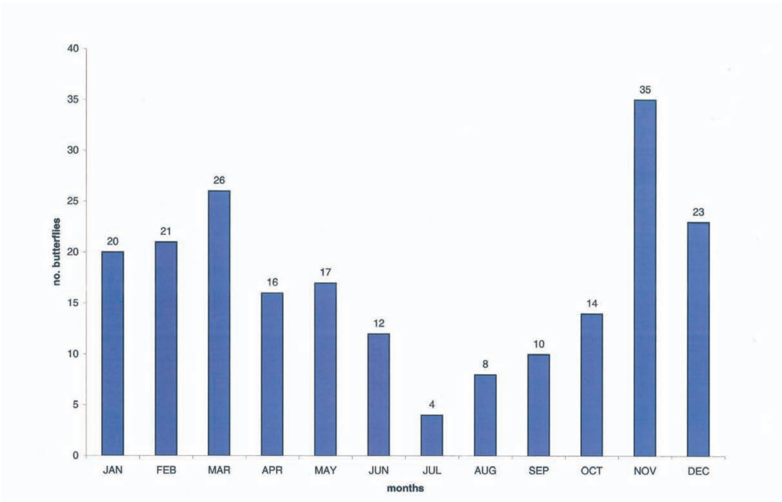


FIG. 5. The number of adult *A. t. floridalis* observed monthly during 1999 to 2008 in Long Pine Key at gate 4, based on 12 months of sampling each year.

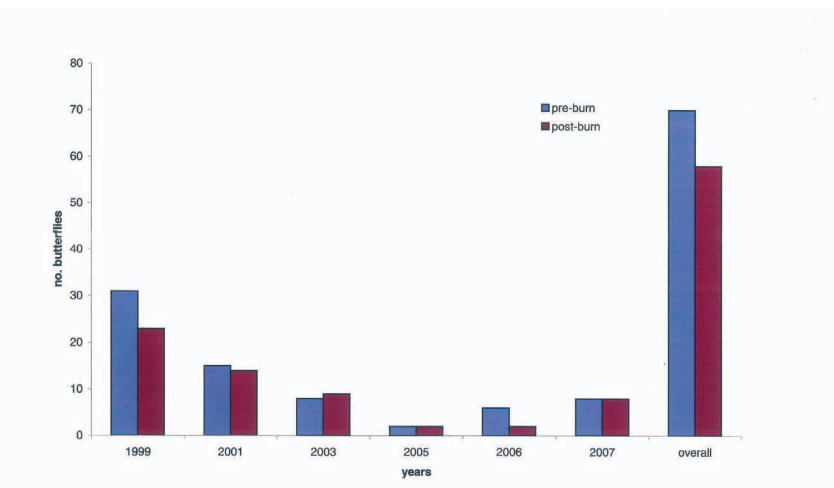


FIG. 6. Indicates the number of adult *A. t. floridalis* observed at 6 months prior to (pre-burn) and 6 months following (post-burn) Rx fire events at gate 4 within Long Pine Key.

the remainder disappearing (n = 9) or being parasitized (n = 3) prior to the 3rd instar.

## DISCUSSION

Hennessey & Habeck (1991), Emmel *et al.* (1995) and Salvato (1999) identified LPK as one of the last major strongholds for *A. t. floridalis* within its remaining range. During the first year of the present study *A. t. floridalis* was abundant within the Everglades. However, throughout the remainder of the study the number of *A. t. floridalis* encountered annually was generally lower and varied considerably, possibly due to a number of ecological factors.

*Anaea t. floridalis* eggs have been shown to experience a high level of mortality from parasitic trichogrammid wasps within LPK and throughout the species' range (Hennessey & Habeck 1991; Salvato & Hennessey 2003). Caldas (1996), Muyshondt (1974), DeVries (1987) and Salvato & Hennessey (2003) each indicated high parasitism rates from tachinid flies for larvae of *Anaea* or similar genera. Salvato & Hennessey (2003), Salvato & Salvato (2008) and Salvato *et al.* (2008) summarized the numerous known arthropod parasitoids and predators specific to *A. t. floridalis* eggs and later stages.

During two periods (November 2007 to April 2008 and November to December 2008) we monitored *A. t. floridalis* larval development weekly and found that most had disappeared prior to the 3rd instar stage. In three instances larval parasitism was documented, once by a biting midge *Forcipomyia* (*Microhelea*) *fuliginosa* (Meigen) (Ceratopogonidae)(Salvato *et al*. 2008) and twice by a fly, *Chetogena scutellaris* (Wulp) (Salvato *et al*. 2009). Early instar *A. t. floridalis*, as with similar genera, construct frass chains on the hostplant for use in avoiding some types of predation when not feeding (Salvato & Salvato 2008). Such behavior may also increase their exposure to rainfall. Caldas (1996) found high levels of early instar mortality due to rainfall for *Fountainea ryphea* (Cramer). However in our studies the majority of larvae were encountered during the dry season, which limited potential risks from rain. Forys *et al.* (2001) found high mortality among immature *Papilio cresphontes* Cramer from predation by the red imported fire ant (*Solenopsis invicta* Buren) and suggested other butterflies in southern Florida might also be influenced. Although *S. invicta* occurred increasingly within our study sites, we did not observe it in direct association with *A. t. floridalis*. While detailed data on *A. t. floridalis* larval development were only collected for a small part of our survey period, it does suggest that larval mortality from parasitism and other factors may contribute to the annual variability encountered. Additional studies are needed to monitor *A. t. floridalis* in the field from egg through eclosion to more reliably gauge types and levels of mortality experienced by the early stages of the species.

TABLE 1. Observations of adult *A. t. floridalis* at gates 2, 8 and 10 during 2004 to 2008 in Long Pine Key.

| area | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|
| gate 2 | 2 | 3 | 5 | 9 | 9 |
| gate 8 | 1 | 0 | 0 | 3 | 0 |
| gate 10 | 0 | 0 | 0 | 4 | 0 |

*Anaea t. floridalis* is multivoltine and maintains numerous overlapping broods throughout the year (Baggett 1982; Worth *et al.* 1996; Salvato & Hennessey 2003). Several species of nymphalid butterflies are known to enter a state of reproductive diapause in response to unfavorable climatic conditions or during periods of reduced hostplant availability or quality (Opler & Krizek 1984; Jones 1987; Braby 1995; Kemp 2001; Hill *et al.* 2003; Barron *et al.* 2004). Smith *et al.* (1994) indicated that under dry conditions *A. t. portia* F. remains dormant in the pupal stage for several months. Pozo *et al.* (2008) encountered *A. t. aidea* Guérin-Meńeville throughout the year in Central America but found it much more abundant during the rainy season. Opler & Krizek (1984) believed that *A. t. floridalis* might enter diapause during the drier winter months. Salvato (1999) reported that *A. t. floridalis* occurred throughout the year on Big Pine Key with no apparent diapause period. Our studies within LPK found *A. t. floridalis* to be most abundant from late fall to early spring and infrequent during the summer months (Fig. 5), suggesting the species may respond to higher summer temperatures or other seasonal factors by entering diapause during these months. We found no correlation between annual precipitation levels in the Everglades and *A. t. floridalis* abundance, as the species was abundant during years of both above- and below-normal rainfall. In addition, throughout the majority of this study *C. linearis* availability did not appear to be a limiting factor within the study area.

We encountered similar adult *A. t. floridalis* densities pre- and post-burn throughout the study period (Fig. 6), suggesting the species may be able to quickly re-colonize pine rocklands following a fire. Surveys conducted shortly after burns often found adult *A. t. floridalis* actively exploring the recently burned locations in search of new hostplant growth. In most instances *C. linearis* returned to the burned parts of our study sites at one to three months post-burn. The earliest we encountered signs of *A. t. floridalis* reproduction within a recently burned location was on 2 September 2006 when we observed a female *A. t. floridalis* ovipositing on resurgent *C. linearis* within the northern portion of gate 4 at approximately six weeks post-burn. However this was our only observation of *A. t. floridalis* reproduction within a burned area so soon after a fire. Throughout the majority of this study our observations indicate that oviposition and larval activity increased at about three to six months post-burn. This suggests there may be some lag time between hostplant resurgence and compatibility with *A. t. floridalis* re-colonization.

Following burn events *A. t. floridalis* was also frequently encountered in adjacent pine rocklands, or in non-hostplant bearing portions of the survey sites (such as hardwood hammock), indicating the species will disperse in search of reproductive opportunities, new territories or perhaps food sources when resources in a select area are limited (Salvato & Salvato 2008). On 7 February 2004 we observed two male *A. t. floridalis* traversing hardwood hammock on the northern side of gate 4. During this encounter both individuals displayed (opening and closing their wings while perched within approximately 1 to 5 m of each other) and jousted (twirling up in the air together) before ultimately continuing eastward along the gate 4 trail. During the fall of 2007 we encountered *A. t. floridalis* (n = 4) dispersing through gate 10, an area of pine rockland with sparse hostplant; these individuals stopped to feed at pine sap and then proceeded southeast towards gate 4. On 15 November 2008 we observed a freshly emerged male *A. t. floridalis* taking nectar from *Bidens alba* (L.) DC. within a weedy disturbed area over 1.6 km (1 mile) from *C. linearis* bearing pinelands. Adult *A. t. floridalis* were frequently observed feeding on the sap of *Pinus elliottii* Engelm. (Pinaceae), *Sideroxylon salicifolia* (L.) Lam. (Sapotaceae) and *Lysiloma latisiliquum* (L.) Benth. (Fabaceae) throughout the study area.

In June 2005, the southern side of gate 4 (burn unit F2, see Fig. 3) was given a prescribed burn. During late August 2005 Hurricane Katrina passed over the Everglades causing substantial damage from hurricane and tropical storm force winds. The majority of re-sprouting *C. linearis* within the recently burned unit was eliminated and we observed no significant recovery of the hostplant prior to damage brought on by a second hurricane (Wilma), which passed through our study areas during mid-October 2005. Although damaged by storm activity, the unburned northern portions of gate 4 (burn unit G) retained the majority of its *C. linearis* and appeared capable of retaining *A. t. floridalis* activity. However, we did not re-encounter *A. t. floridalis* at gate 4 post-storm until late 2005; this four-month absence represented our longest interval in the survey period without an observation. Conversely, earlier in the survey period (October 1999) Hurricane Irene passed to the north of LPK and had little influence on *A. t. floridalis* abundance at gate 4, with several individuals (n = 8) encountered 1 month after the storm. This suggests post-storm recovery time for *A. t. floridalis* can vary within LPK.

TABLE 2. *Anaea. t. floridalis* larval observations at gate 4 over the duration of the study.

| year | no. larvae |
|---|---|
| 1999 | 13 |
| 2000 | 14 |
| 2001 | 7 |
| 2002 | 2 |
| 2003 | 2 |
| 2004 | 6 |
| 2005 | 1 |
| 2006 | 3 |
| 2007 | 16 |
| 2008 | 11 |

*Anaea t. floridalis* was also documented on a number of our other transects (gates 2, 8 and 10) (Table 1) and elsewhere (gates 3 and 11) in LPK during this study, areas where the species had been reported historically (Hennessey & Habeck 1991; Emmel *et al.* 1995). We also encountered adult *A. t. floridalis* exploring and feeding in non-pine rockland areas on the southeastern border of the Everglades. The seasonality of *A. t. floridalis* within these additional areas was similar to that encountered in our primary study site at gate 4.

Although *A. t. floridalis* was encountered throughout LPK it should be noted that annual abundance of the species at its long established stronghold of gate 4, while variable, appeared to trend downward over the survey duration (Fig. 4). *Anaea t. floridalis* was listed as a candidate species for federal protection on 12 September 2006 based on the continued range-wide decline of the species within the United States. Continued surveys, particularly within pine rockland areas not thoroughly investigated in these studies, are needed to explore the status and population dynamics of *A. t. floridalis* in LPK. Given the imperiled status of *A. t. floridalis* in southern Florida, the conservation and protection of this species requires urgent attention from land managers.

## ACKNOWLEDGEMENTS

We thank Sue A. Perry and the staff at Everglades National Park for permitting and a variety of technical assistance throughout the survey period. We thank Dennis J. Olle for assistance in the field. We thank John V. Calhoun, S. A. Perry, B. G. Scholtens, and two anonymous reviewers for reviewing the manuscript and providing valuable comments. We thank Erik Stabenau for providing climatic data for Everglades National Park. MHS thanks Michael K. Hennessey, J. V. Calhoun, Thomas C. Emmel, Jaret C. Daniels, Kerri A. Schwarz, Richard A. Worth, J. Howard Frank, Dana M. Griffin, III, Lyn A. Atherton, Marc C. Minno, John B. Heppner, Jacqueline Y. Miller, Lee D. Miller and Dale H. Habeck for sharing their insights, knowledge and observations on *A. t. floridalis* at various points during these studies. We thank William L. Grogan Jr. and John O. Stireman III for identification of larval parasites. We also thank Barry Wood for preparing Figures 2 and 3.


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*Received for publication 9 Feb 2009; revised and accepted 11 Jul 2009*