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## THE TAXONOMY, LARVA AND ECOLOGY OF *AGROTIS BUCHHOLZI* (NOCTUIDAE) WITH A NEW SIBLING SPECIES FROM NORTH CAROLINA

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**ABSTRACT.** *Agrotis buchholzi* is one of four Lepidoptera species believed to be endemic to the New Jersey Pine Barrens. It occurs primarily in recently burned or exceptionally xeric or sterile areas where its sole larval foodplant, *Pyxidanthera barbulata* (Diapensiaceae), occurs in openings in the shrub layer. Adults can be quite common locally. There are two broods approximately two months apart with the first starting about late May. Hibernation is as prepupal larvae in the sand. The larva is similar to that of other species of *Agrotis*. Adults are very active and feed but their natural food sources are not known. A sibling species, ***Agrotis carolina*, new species**, is closely associated with *P. barbulata* in southeastern North Carolina. Its range resembles that of another endemic, *Hemipachnobia subporphyrea*. The combined ranges of these two *Agrotis* are very similar to those of an unnamed *Cyclophora* (Geometridae) and *Spartiniphaga carterae* Schweitzer (Noctuidae) and their habitats commonly overlap in both states. Fire is a crucial factor in forming and maintaining habitat for all of these species. *A. buchholzi* may become imperiled because of a decline of wildfires. *A. carolina*, but not *A. buchholzi*, is thriving in habitats maintained by prescribed burns.

**Additional key words:** Sand plains, bivoltine, larval hibernation, *Agrotis obliqua*, *Agrotis stigmata*, monophagy.

Since its description very little has been published about the habitat and nothing about the life history of *Agrotis buchholzi* (Barnes & Benjamin) (Noctuidae) and its foodplant has not been reported. Forbes (1954) knew this species only from the two types from Lakehurst, New Jersey and indicated (correctly) that their dates suggested two annual generations. Franclemont (1956) reported the collection of the first substantial series, and his collection contained (as of 1974) 34 collected from 31 July to 15 August, 1955 and 19 collected 28 May to 10 June, 1956. Several collections have a few specimens taken by Otto Buchholz, Fredrick Lemmer and Joseph Muller, all vicinity of Lakehurst, but only Franclemont had encountered it in numbers. The late J. W. Cadbury III had a specimen from Browns Mills (now in Schweitzer coll.) which extended the range southwest into adjacent Burlington County.

More recently one of us (TLM) collected a specimen near Atsion, Burlington County, on 25 May 1976, but DFS failed to encounter it at nearby Batsto during

intensive collecting from 1969 to 1977. In 1977 James Madenjian collected 46 specimens on the West Pine Plains east of Chatsworth and a few about nine miles to the west in Lebanon State Forest, both in Burlington County, during field work for his master's thesis at Rutgers University, where a few specimens currently reside. Most of his specimens were discarded. During late May and early August 1980 DFS found the species to be comparably abundant at the West Pine Plains site. Other records in the 1980's (all DFS and/or W. J. Cromartie) were from a burn scar near Atsion, another near Papoose Branch and an unburned site in the East Pine Plains, all in Burlington County, and at the Lakehurst Naval Air Station in Ocean County. In 1994 DFS collected several on the approach zone of Atlantic City International Airport, Egg Harbor Township in northern Atlantic County, New Jersey, increasing the known range to parts of three counties. That small population may originally have been a bit disjunct and is quite isolated now. Another was taken about 3 km to the south by Thomas Hupf in 2000, ap-

parently a stray from the 1994 site as no intervening foodplant is known. In 1994, 1995 and 1996 DFS located enormous populations in the Impact Area at Fort Dix Military Reservation, in Ocean County, with 47 being taken in two blacklight traps the night of 12 August 1994 alone. Lesser numbers were taken on several other nights in June and August. The known distribution thus encompasses parts of three contiguous counties. It could turn up in extreme eastern Camden County a few kilometers west of Atsion.

Although the Pine Barrens region has always been mapped by botanists to include a much larger area (e.g., Stone 1911, Harshberger 1917, McCormick 1970), habitat for *A. buchholzi* and most other specialized Pine Barrens Lepidoptera is very limited south of the Mullica River, becoming more so because of the elimination of large scale fires and development in eastern Atlantic County. Contiguous large tracts of true pine barrens habitats are confined to the region from about Lakehurst to Batsto. *Pyxidanthera barbulata* Michx., the food plant reported below, is scarce in Cumberland County (e.g., Moore 1989) and infrequent, usually in small numbers, in most of Atlantic County, having disappeared from former stations around Pomona since the 1970's probably because of lack of fire (W. J. Cromartie pers. com. to DFS).

#### LIFE HISTORY OF *AGROTIS BUCHHOLZI*

**Phenology.** *Agrotis buchholzi* has two broods with adults present for about two to three weeks each year between 15 May and 15 June; and for a similarly short period between about 17 July and 15 August. Adults are nocturnal and fly almost exclusively before midnight in both broods. They have not been observed at dusk.

**Adult behavior.** Captive adults are extremely active and alert even when disturbed in the daytime. They are also very active at collecting sheets. They apparently do not live more than a week. Adults are difficult to get in perfect condition as they quickly become battered and worn, apparently from moving rapidly through fallen pine needles, cinders, twigs, dead leaves and ashes. The moths are best collected at lights.

Adults do feed, and occasionally the summer brood adults come to sugar bait. Spring brood adults avidly nectar from *Leiophyllum buxifolium* Berg. (Ell.) blossoms in captivity, and would usually have easy access to this and a variety of other flowering low shrubs in the field. However, we have not found any on flowers at night. Summer brood adults would usually not have access to flowers but might be able to locate rotting or damaged berries of Ericaceae. Adults readily accept honey or maple syrup solutions and overripe fruit in confinement.

**Foodplant and larval behavior.** In 1980 DFS obtained eggs from two females, as had Franclemont previously. No suitable foodplant was found although some larvae fed on a species of *Hudsonia* (Cistaceae) but were promptly poisoned by it. In 1988 we found all of over 100 species of plants, including a somewhat wilted piece of *Pyxidanthera* and several grasses, to be unacceptable. By the end of the 1988 field season it was obvious to DFS that *Agrotis buchholzi* could be obtained consistently by placing light traps in large concentrations of *Pyxidanthera barbulata*. Thus it seemed obvious that either this plant or an abundant associate, such as *Leiophyllum buxifolium*, would prove to be the larval foodplant.

On 4 August 1989, five worn females were collected alive from three 15-watt blacklight setups on the Lakehurst Naval Station by DFS and Thomas Breden. All five were fed the next day and placed in sealed plastic boxes with foliage of the above three plants. All females laid some eggs, two of them a substantial number. Most eggs were laid 6 to 9 August. The majority of eggs were placed on the foliage or stems of the *Pyxidanthera* but some were placed on paper or on the *Leiophyllum*. Eggs hatched on about the seventh day after oviposition and the first few larvae were found to feed readily on fresh *Pyxidanthera*, but not at all on *Leiophyllum*, *Hudsonia* or *Xerophyllum* (Liliaceae). Herbaceous dicots were not tried this time because most *A. buchholzi* habitats are composed almost entirely of woody species and lichens, sometimes with grasses or sedges present.

Cuttings of *Pyxidanthera* remained fresh for over two weeks in plastic containers; larvae were left undisturbed except to add new foliage and to make observations. One group of eggs was transferred to potted *Pyxidanthera* before hatching and larvae allowed to feed on this for about a month until the foodplant was severely defoliated by the third instars. Larvae were thereafter all placed in sealed plastic containers and fed fresh cuttings as needed. Cuttings were sometimes stored in a refrigerator for up to two weeks before use. The potted plant was covered with thin muslin, but this was probably an unnecessary precaution as the larvae showed no tendency to climb.

Once feeding commenced, larvae were very sluggish and usually remained hidden in accumulated frass. The frass appeared to be quite sticky and became mixed with sand grains forming piles adhering to the foliage or stems of the foodplant. By the third instar, larvae on foliage actually touching the sand tended to hide in the upper most sand grains while not feeding and some others often moved to the base of the plants or the soil rather than remain among their frass. Later instars became more subterranean and the last two in-

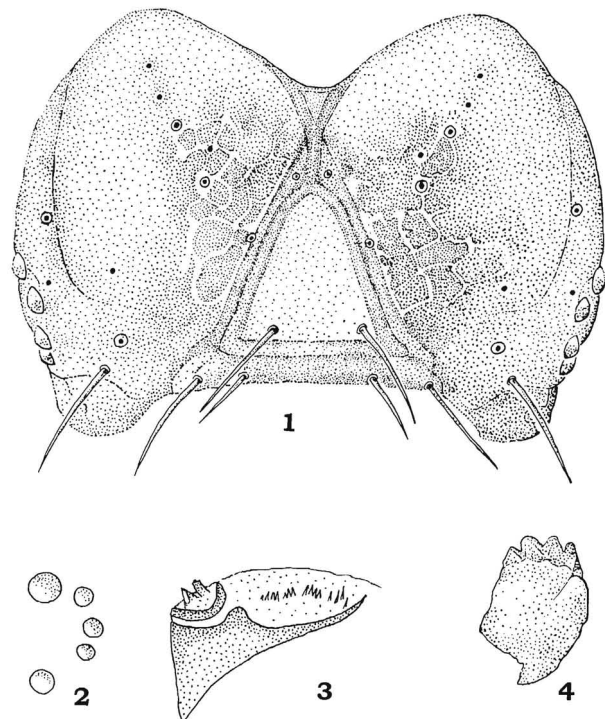
stars emerged from the soil only to feed. Feeding was almost always at night except during cold weather in October when diurnal feeding was observed.

Although cuttings of *Leiophyllum* and several Ericaceae were frequently added with the foodplant when feeding the older larvae, these plants and the grass *Calamovilfa brevipilis* were never eaten. On 13 September 1989 DFS collected a single third instar larva on *Pyxidanthera* near Atsion. It is virtually certain that the larvae feed exclusively on this plant.

Reared *A. buchholzi* larvae reached full size outdoors by early to mid October, but continued to feed for a few more weeks. First brood larvae obviously mature faster since the second brood adults appear within two months of first brood adults. All of 65 larvae (from two females) counted on 15 September reached maturity. However, 10 died in late October or November, probably from a pathogen. By 10 November, all survivors appeared to have completed feeding and most were apparently in an early pre-pupal condition. Most had formed cells in the moist sand, but sometimes appeared briefly at the surface. The containers holding the hibernating larvae were placed in a thick styrofoam box, and buried in peat moss and left outside on a sheltered porch. December of 1989 proved to be the coldest December on record in the region and when seasonable conditions returned at the end of the month the peat was frozen and all but six of the 50 larvae were dead. These six were removed to a refrigerator until 8 March 1990. Three appeared at the surface later that month and formed new pupal cells at the surface. All three pupated in April and eclosed in mid May. They did not feed after November.

According to McCabe (1981) the related *A. stigmosa* Morrison [as *Agrotis volubilis* Harvey] also diapauses as a mature larva by late summer and overwinters in that state. He too had difficulty overwintering the larvae. Crumb (1956) reported a prolonged spring and summer larval diapause in *A. venerabilis* Walker, a common species in grassy places with adults in early autumn.

The apparent monophagy of *A. buchholzi* is unusual, but not unique, for the group of genera (including *Euxoa*) combined as *Agrotis* by Forbes (1954). The undescribed *Mesembragrotis* illustrated by Handfield (1999) is monophagous in New Jersey on flowers and ripening seeds of the grass *Calamovilfa brevipilis*. *Richiaacclivis* (Morrison), which is similar in genitalia, adult and larval appearance, phenology and behavior, is also a specialist on flowers and seeds of a grass, *Panicum virgatum* L. at least in New Jersey (DFS). Our larvae of *Trichosilia manifesta* (Morrison) accepted only oaks but apparently become more polyphagous after hibernation (Crumb, 1956), when oak is unavailable.

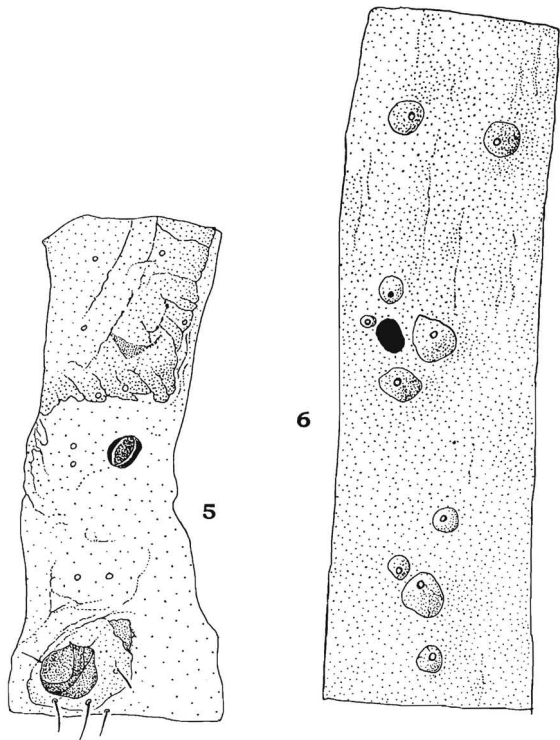


FIGS. 1–4. *Agrotis buchholzi* larval head features. 1, Head, frontal aspect (most head setae worn or broken off). 2, Ocellar arrangement, lateral view. 3, Hypopharyngeal complex. 4, Mandible, oral face. All larvae reared ex ovis on *Pyxidanthera* from Naval Air Station near Lakehurst, New Jersey.

**Larval description of *Agrotis buchholzi*.** First instars were not examined in detail. They had no obvious pattern and moved in the looping fashion typical for first instar Noctuidae. Second and third instars were slightly reddish with little pattern other than ill-defined dorsal and lateral pale lines. Virtually all patterns were lost by the penultimate instar and the older larvae were a rather uniform blackish brown much like the caterpillar of *A. stigmosa* illustrated by McCabe (1981). There appeared to be six instars, but close observation of young larvae was difficult and the number of instars was not established with certainty.

The diapausing prepupal larvae were preserved after they died. This made for less than pristine preserved larvae with considerable erosion and breakage of setae. Consequently, not all setal bases had their setae intact and, therefore, are not represented in the illustrations.

**Last (sixth?) instar larva.** General: The average head width (as viewed from the face) 2.1 mm; average total body length (head to tail, natural resting posture) 25.1 mm; abdominal prolegs present on 3rd through 6th and 10th segments; setae simple; crochets a unioordinal mesoseries; spiracle A8 0.33 mm high on average ( $n = 10$ ). Coloration (living material): Head with a brown pavement pattern towards front of face only. Body brown-black with a conspicuous lateral series of black spots, two on each segment, comprising the spiracle and the L1 pinaculum. Head capsule (Fig. 1): Epicranial suture 0.27 mm long; height of frons 0.97 mm; second adfrontal (Af2) anterior and 1st adfrontal (Af1) posterior to apex of frons; coronal punctures Aa, pa, pb, and 3 ultraposterior (2 visible in frontal aspect) present as illustrated. Hypopharyngeal complex (Fig. 3): spinneret shorter than labial palpus, apex lacking setae; stipular seta (S) at an-



FIGS. 5–6. *Agrotis buchholzi* larval body segments. 5, Prothorax, semidiagrammatic (most body setae worn or broken off). 6, First abdominal segment. All caterpillars reared ex ovis on *Pyxidantha* from the Naval Air Station near Lakehurst, New Jersey.

terodorsal region of prementum; distal region of hypopharynx bears numerous very fine spines, followed by a single row of 14–15 large spines that extend to the posterior apex of prementum. Mandible (Fig. 4) with inner ridges indistinct, lacking basal tooth. Prothorax (Fig. 5): cervical shield well sclerotized; subdorsal setae (SD1 & SD2) on the shield; prespiracular setae (L1 & L2) and subventral setae lacking pinaculi. First abdominal segments (Fig. 6): subventral setae (SV1 & SV3) approximate; L1 posterior to spiracle; SD2 anterodorsal to spiracle; spiracle 0.31 mm high. Ab2–6 with 3 subventral setae; SD2 setal base anterior to spiracle. Ab7&8 with only 1 seta in subventral group. Tarsal claws are without a basal tooth. The hind coxae are approximately the femur length apart. Crochets a uniordinal mesoseries. Actual crochet counts were not practical because of the state of preservation. Material examined. Ten specimens, Lakehurst Naval Air Station, Ocean County New Jersey, 6 December 1989, from ova of female collected and determined by D. F. Schweitzer.

*Agrotis buchholzi* larvae differ from *A. stigmosa* (see McCabe 1981) as follows: head coronal puncture (pb) out of line with setae P2 and P1; the L1 pinaculus, on the first abdominal segment, less than half its width from the pinaculus L2 (this distance is twice L1's width in *A. stigmosa*) and the SV3 pinaculus well formed and near to SV1.

Multiple rearings of *A. venerabilis* have shown variability in the size of the L1 pinaculus. If this holds for *A. buchholzi* it could affect the apparent distance between it and the L2 pinaculus. If run through Crumb's keys, *A. buchholzi* appears closest to *A. gladiaria*, but Crumb (1956) did not have the related *A. obliqua* as its larva is unknown.

**Relationships.** *Agrotis buchholzi* fits in a group that includes *A. obliqua* (J. B. Smith) (Fig. 10). These moths are all very similar in appearance and male and female genitalia, although the latter typically has the orbicular dark throughout, unlike the lighter ring seen in *A. buchholzi*. The food plant of *A. obliqua* has not been established, but it occurs in the absence of Diapensiaceae. The polyphagous *A. volubilis*, *A. stigmosa* and *A. venerabilis* are also morphologically close to these three. *Agrotis buchholzi* also has a sibling species, previously treated in collections as a southern disjunct, which we consider distinct.

### *Agrotis carolina* Schweitzer & McCabe, new species

(Figs. 7–9, 14, 16, 18, 19)

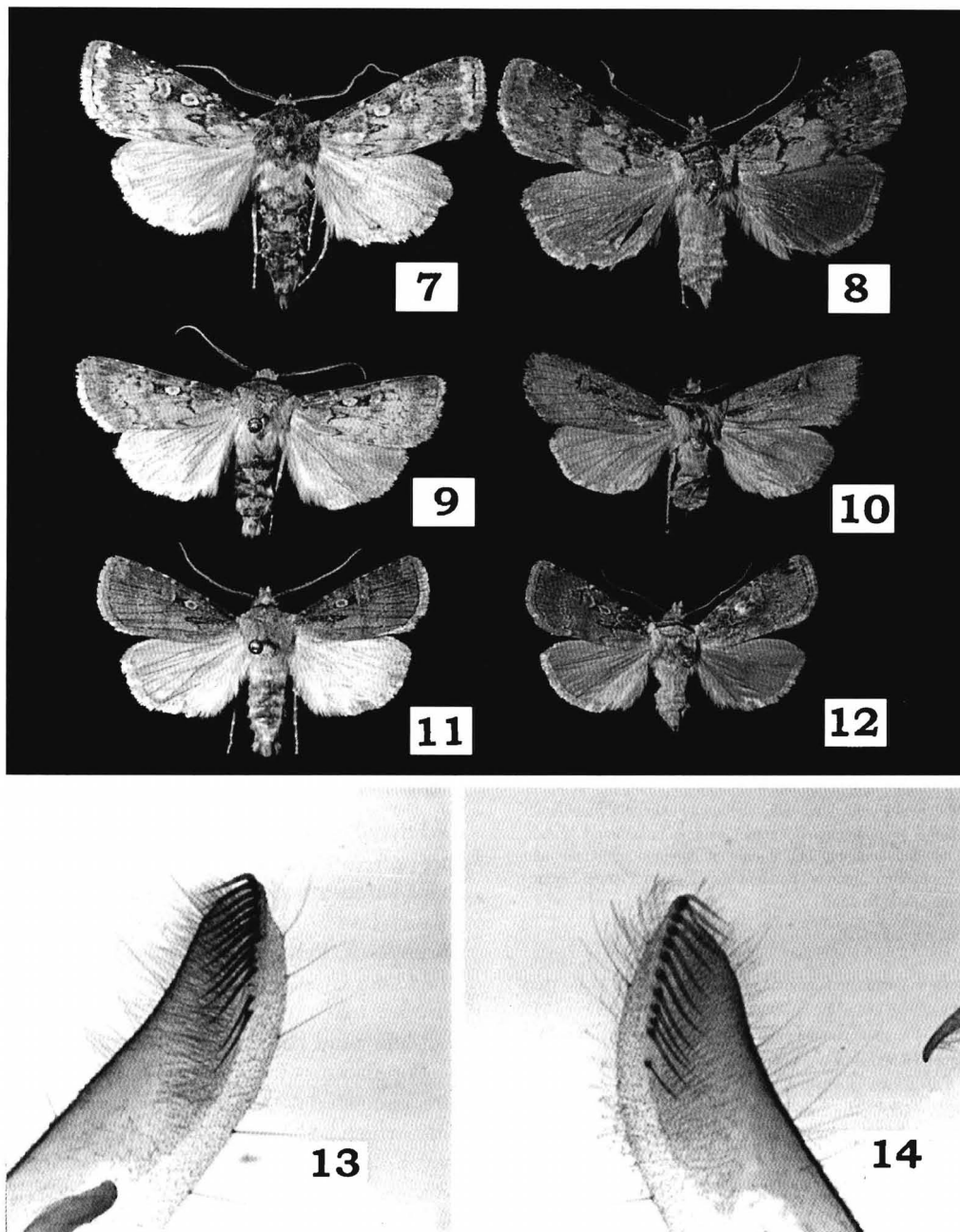
**Adults:** Male and female similar (Figs. 7, 8). Vertex of head a reddish brown; frons and tips of palpi light brown; antennae subpectinate; tegulae with a black band; patagia with silvery gray scales, lighter than disk; abdomen untufted; wings violet gray with an line wavy, bowed out considerably below fold, with subtle pinkish cast to basal area in fold; orbicular round, reniform kidney shaped, region between orbicular and reniform and costa darker; median line usually present though sometimes lacking; pm line dentate, evenly excurved; terminal line a broken series of black spots; fringe concolorous with ground; wing expanse (spring brood) = 32–38 mm (n = 55, average = 34 mm), second brood wing expanse = 26–30 mm (n = 9, average = 29 mm).

**Male genitalia** (Figs. 14, 16, 18): Valves nearly parallel-sided, bluntly pointed (Fig. 16). Harpe present, length about half width of valve, bluntly rounded and directed slightly towards outside. Cucullar spines loosely spaced, with room enough for additional spine between many bases (Fig. 14). Everted vesica with chitinized basal band (Fig. 18). Remainder of vesica an elongate tube, slightly curved, and swollen towards end.

**Female genitalia** (Fig. 19): Ovipositor lobes short, unmodified. Anterior apophyses extend half way to branch of appendix bursa. Ductus bursa nearly twice length of anterior apophyses. Corpus bursa a long tube with swollen apex. Appendix bursa much longer, narrow, coiled once upon itself, with gradually swollen apex. Ductus seminalis issues from apex of appendix bursa. The lengthy appendix bursa coils inwardly over itself. This is evident when the bursa is inflated in alcohol and was sketched at this stage in the dissection. The appendix bursa had to be accurately "arranged" in the thicker mounting medium.

**Holotype:** Male, North Carolina, Brunswick Co., vic. Supply, Green Swamp Preserve, dry savanna, 12 April 1991, S. Hall & D. Schweitzer.

**Paratypes** (68—all North Carolina, approximately a 3:1 male to female ratio): (6) Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 11 June 1991, 12 April 1991, S. Hall & D. Schweitzer; McCabe slides 2567, 2663, 2664, 2879; (3) Brunswick County, 2 mi. SW Boiling Springs Lakes, 28 June 1994, J. B. Sullivan, R. Broadwell, & B. Smith; (1) Brunswick County, MOTSU, Intersection of firebreaks 32 & 34, 11 April 1994, J. B. Sullivan, R. Broadwell, & B. Smith; (23) Carteret County, Millis Savannah, 34.45.19N–76.59.23W, 29 March 1998, T. McCabe, McCabe slide 3721; (18) Onslow County, Camp Lejeune, 4 April 1995, S. Hall; (3) Pender County, 3.2 mi. N. Maple Hill, Angola Creek Preserve, 13 April 1991, S. Hall & D. Schweitzer, McCabe slide 2568; (8) Pender County, Holly Shelter, Old Rd./BJ Rd., 5 April 1995, S. Hall.

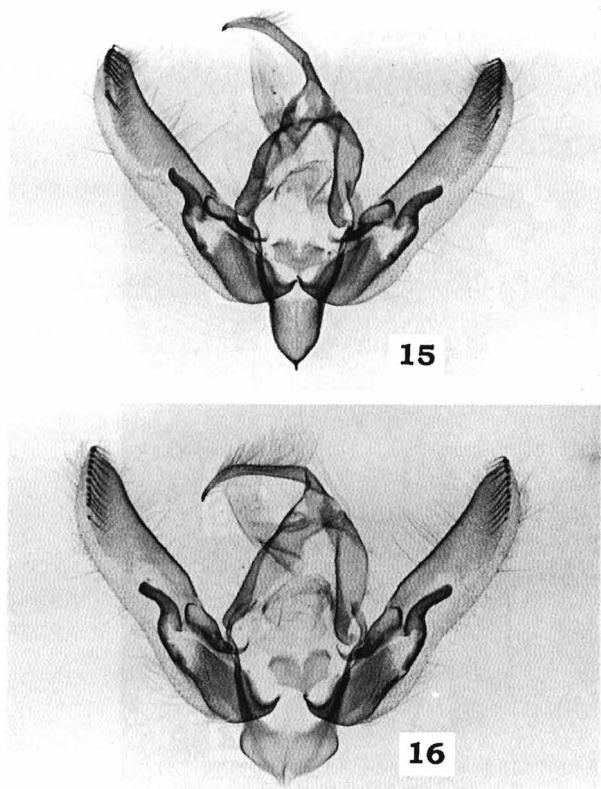


FIGS. 7–14. Adults. **7**, *Agrotis carolina*, first brood male, **Holotype**, North Carolina (Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 12 April 1991, S. Hall & D. Schweitzer). **8**, *Agrotis carolina*, female, North Carolina (Pender County, 3.2 mi. N. Maple Hill, Angola Creek Preserve, 13 April 1991, S. Hall & D. Schweitzer). **9**, *Agrotis carolina*, second brood, North Carolina (Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 11 June 1991, S. Hall & D. Schweitzer). **10**, *Agrotis obliqua*, female, Labrador (Lower Brook, 55.15.52–60.52.29, 15 July 1993, J. Bopp). **11**, *Agrotis buchholzi*, male, New Jersey (Ocean County, Fort Dix impact area, 12 August 1994, D. Schweitzer). **12**, *Agrotis buchholzi*, female, New Jersey (Ocean County, Lakehurst N.A.S., ex ovis, reared late April, ecl. 2 June 1990, D. Schweitzer). FIGS. 13–14. Cucullar spines. **13**, *Agrotis buchholzi* (same data as Fig. 15). **14**, *Agrotis carolina* (same data as Fig. 16).

**Deposition of type material.** Holotype male is deposited in the US National Museum of Natural History, Washington, D.C. Paratypes are in that collection, the New York State Museum, the Schweitzer collection, the Sullivan collection and the McCabe collection.

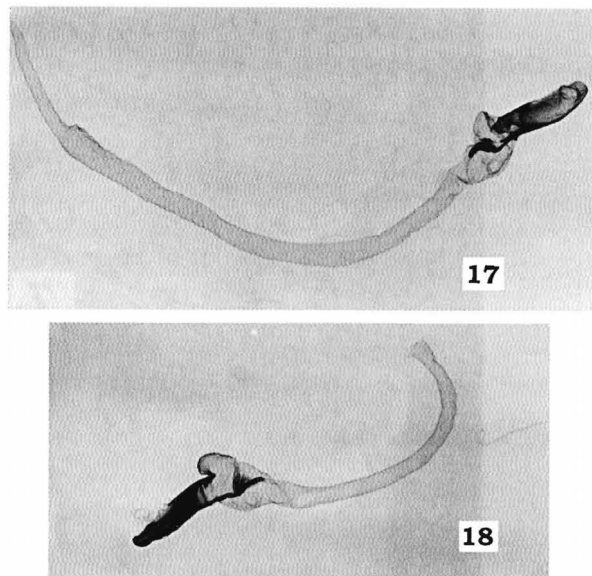
**Diagnosis.** *Agrotis carolina* resembles a large version of *A.*

*buchholzi* (34 mm vs. 27 mm for first brood, 29 mm vs. 27 mm for the second brood). Size and distribution will allow easy determination, although almost all adults are paler and much more strikingly marked than *A. buchholzi* or *A. obliqua*. *Agrotis obliqua* (Fig. 10) occurs in boreal habitats and typically has the orbicular dark throughout. The morphological differences between *A. carolina* and



FIGS. 15–16. Male genitalia. **15**, Valves of *Agrotis buchholzi*, McCabe slide 2569, New Jersey (Ocean County, Lakehurst N.A.S., 4 August 1989, D. Schweitzer. **16**, Valves of *Agrotis carolina*, McCabe slide 2663, North Carolina (Brunswick County, Green Swamp Preserve, 11 June 1991, S. Hall).

*A. buchholzi* include genitalic features as well as habitus. **Male genitalia:** The bases of the cucullar spines in *A. buchholzi* (Fig. 13) are mostly contiguous, those of *A. carolina* (Fig. 14) are typically widely spaced to the extent it would be possible to fit another spine in many of the spaces. A bulbous protuberance, near the basal end of the vesica, is opposite ( $180^\circ$ ) the basal cornutus in *A. carolina* and at more of a right angle ( $270^\circ$ ) to the basal cornutus in *A. buchholzi*. *Agrotis buchholzi* also has an indentation (a “valley”) between the base of the vesica and the origin of the elongate distal portion of the vesica. This indentation is not seen in *carolina*. In ‘perfect’ eversions (some features can not be viewed if the vesica is accidentally pierced or severed short of the final narrowing resulting in a poorly inflated vesica) the most distal portion of the vesica displays a swelling before the final tapering (see Fig. 17). The apex of this swelling does not recurve even as far as the bulbous vesical base in *A. carolina*, but recurves to and through the length of the aedoeagus proper in *A. buchholzi*. Unfortunately this last feature has to be viewed during dissection as the true orientation is distorted by mounting in the viscous mounting medium. **Female genitalia:** *A. buchholzi* is proportionately smaller than *A. carolina* (photos are at the same magnification); appendix bursa swollen abruptly at tip in *A. buchholzi* (Fig. 20) that of *A. carolina* gradually enlarged (Fig. 19). There is a volume distinction as well. The swollen tip of the appendix bursa of *A. carolina* is approximately one third the volume of the bursa. The swollen tip of the appendix bursa of *A. buchholzi* is less than one-



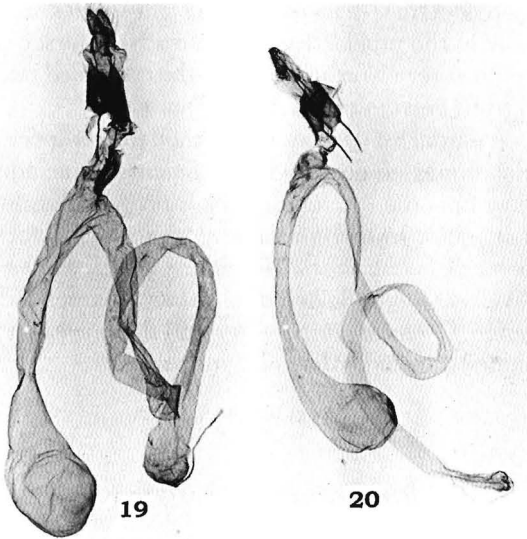
FIGS. 17–18. Aedoeagus. **17**, Everted aedoeagus of *Agrotis buchholzi* (same data as Fig. 15). **18**, Everted aedoeagus of *Agrotis carolina* (same data as Fig. 16).

fifth the volume of the bursa. Very old and worn specimens possess particularly fragile appendix bursae and made for poor and nearly worthless slide mounts.

**Distribution.** We believe that *Agrotis carolina* will prove to be confined to eastern North Carolina or perhaps barely into South Carolina with its apparent foodplant (Radford et al. 1964). We have seen it from Brunswick, Pender, Onslow and Carteret Counties in the Outer Coastal Plain; Stephen Hall (pers. com. 2001) also has taken it in Hoke and Harnett Counties in the fall-line Sand Hills region of the inner coastal plain.

Populations of *A. carolina* in the outer coastal Plain are associated with *Pyxidanthera barbulata* var. *barbulata*, which is the foodplant of *A. buchholzi* in New Jersey. Specimens collected in the sand hills were associated with the endemic variety *brevifolia*, which differs in both its much more xeric sand ridge habitat and in morphology. Neither *Agrotis buchholzi* nor *A. carolina* occurs in the tiny pine barren remnant near Zuni, Virginia that harbors the only significant population of *Pyxidanthera* between New Jersey and North Carolina. This conclusion is based on repeated collecting efforts by both authors and the Virginia Natural Heritage Program.

**Biology of *Agrotis carolina*.** While this species has not been reared it is virtually certain that it feeds on the same plant as *A. buchholzi*, namely *Pyxidanthera barbulata* including variety *brevifolia*. As with *A. buchholzi*, *A. carolina* is taken virtually at will by placing



FIGS. 19–20. Female genitalia. **19**, *Agrotis carolina*, McCabe slide 2568, North Carolina, Pender County, 3.2 mi. W. Maple Hill, Angola Creek Preserve, 13 April 1991. **20**, *Agrotis buchholzi*, McCabe slide 2570, New Jersey, Burlington County, Atsion, 16 May 1985, D. Schweitzer.

light traps at patches of that plant. Unlike *A. buchholzi*, we are not aware of strays taken away from that plant.

Given the longer growing season in southeastern North Carolina one would expect three broods of *A. carolina* with the first two about a month earlier than the corresponding broods of *A. buchholzi* in New Jersey. Indeed there are broods peaking in April and June and an apparently more protracted third brood with dates from 1 August to 14 September (Stephen Hall pers. com. 2001). The first brood starts in late March, a bit earlier than might be expected considering the phenology of the two regions. The flight season of the spring brood of *A. carolina* overlaps substantially with the flowering period for *Pyxidanthera* while *A. buchholzi* flies after the foodplant has flowered. We thus suspect that adult *A. carolina* obtain nectar from the larval hostplant.

#### ECOLOGY OF *AGROTIS BUCHHOLZI*, *A. CAROLINA* AND FOODPLANT

*Pyxidanthera barbulata* is a prostrate mat forming plant of the largely arctic-alpine family Diapensiaceae, with showy flowers appearing in March or April. It grows in gaps in the shrub layer in open pinelands and flourishes for several years after fires on sterile white sands, such as the Atsion soil series in New Jersey. Such soils are generally very dry at the surface, but often, probably nearly always in North Carolina, they are moist just beneath.

Typical habitats for *A. buchholzi* are usually dwarf pine plains (Forman 1979) and recently burned pitch

pine lowlands. See McCormick (1970) or Forman (1979) for a general description of these communities. Large numbers can also be found around the edges of and to some extent in reedgrass (*Calamovilfa brevipilis*) savannas. Habitats for *A. carolina* include mesic wiregrass savannas, pine flatwoods and other frequently burned open pinelands. All normal habitats for both species can be characterized as fire disclimax coastal plain pinelands although the Atlantic City Airport habitat is maintained by annual winter cutting.

Fire frequencies vary from essentially a prescribed burn every winter at some North Carolina sites (e.g., formerly at Green Swamp) to only two or three wild fires per century in a few New Jersey sites. As a general rule one or more fires per decade will usually be required to maintain most high quality habitats in optimum condition for either species. Andrew Windisch (pers. com. to DFS 2001) suggests a regime of average to moderately severe wildfires at intervals of 10–30 years probably allows both *Pyxidanthera* and *A. buchholzi* to persist indefinitely in the core New Jersey Pine Barrens landscape (see also Windisch 1999). *Pyxidanthera* appeared to be still increasing on the Atsion burn scar in late 1989, over six years after the intense July 1983 fire, and had not declined noticeably by September 1991. By July 2001 it was still common in the more open areas but greatly reduced overall by heavy pine regeneration (DFS pers. obs.). Observations from Fort Dix suggest *A. buchholzi* numbers peak about one to five years after fires. Prescribed burning, as presently practiced in New Jersey, does not create suitable habitat for *A. buchholzi* since the sites involved already have a dense canopy which these light winter fires do not reduce.

There are no direct data on the immediate effects of fires on either *A. carolina* or *A. buchholzi* but both have been collected in numbers in spring following dormant season fires indicating obvious *in situ* survival as would be expected for underground larvae. While few insects from a centimeter below the soil surface to the tree tops would be likely to survive in duff to crown infernos in New Jersey wildfires, direct mortality of overwintering larvae of either *Agrotis* should be very low in most prescribed burns and in less intense wildfires. However, captive *A. buchholzi* larvae moved to the soil surface to pupate by late March (*A. carolina* probably does so in February), which could leave them vulnerable to intense wildfires during the spring fire season.

In addition to direct mortality larvae would starve and/or females be forced to emigrate if fires killed the *Pyxidanthera* foliage. Top kill of this plant was observed in March following winter burns in at least one North Carolina site (DFS pers. obs.), but not at some

others. Top kill is common in New Jersey fires. Most patches resprout after light fires, and light fires may well stimulate germination. Summer fires, which occur in very frequently burned parts of Fort Dix, may burn slowly along the ground surface or through the shrubs and consume only the outer parts of the apparently succulent *Pyxidantha* mats, leaving the centers intact. Larvae in these patches would have good survival. Such fires are not now typical elsewhere in the range of *A. buchholzi*, in part because of accumulation of more fuel between infrequent fires. They may be more typical in *A. carolina* habitats and may also have been more typical in pre-settlement New Jersey. Unburned refugia should always be left in any prescribed burns and are clearly needed with some of the hotter New Jersey wildfires.

**Associated species.** Both of these *Agrotis* occur with other rare and extremely range-restricted Lepidoptera. *Agrotis buchholzi* usually occurs with some or all of the other the Pine Barrens endemics and near endemics. *Crambus daeckellus* Haimbach (Pyralidae) is easily found in its habitats on Ft. Dix and Lakehurst Naval Air Station within five meters of patches of *Xerophyllum asphodeliodes* (L.) Nutt. (Liliaceae) (DFS pers. obs.) but has not been taken elsewhere since before 1960. Two still unnamed *Crambidia* (Arctiidae, Lithosiinae) species described and keyed by Franclemont in Forbes (1960) bring the list of apparent Pine Barrens endemic moths to four species. Both *Crambidia* occur at some *A. buchholzi* sites. One of the *Crambidia* is common and widespread in the region, while the other may prefer habitats similar to those used by *A. buchholzi*.

*Spartiniphaga carterae* Schweitzer (Noctuidae), which is a borer in the grass *Calamovilfa brevipilis* (Torr.) Scribn., and an unnamed geometrid consistently misidentified (e.g., Forbes 1948) as *Cyclophora* or *Cosymbia culicaria* (Guenée)<sup>1</sup>, which apparently feeds mostly on *Leiophyllum*, have ranges similar to the combined range of *Agrotis buchholzi* and *A. carolina* and are often microsympatric with them. *Agrotis buchholzi* was collected in the same light trap sample as a paratype of *Abagrotis cryptica* LaFontaine (known from only two specimens from the New Jersey Pine Barrens and one from Michigan). The now severely imperiled venus flytrap cutworm, *Hemipachnobia subporphyrea* (Walker), is essentially endemic to the eastern part of the range of *A. carolina*. With four and two respectively New Jersey and North Carolina appear to lead eastern US states in terms of endemic

Lepidoptera species. A total of eight species are found only in the pinelands of southern New Jersey and/or southeastern North Carolina—the combined ranges of *Agrotis buchholzi* and *A. carolina*.

A partial list of other uncommon to rare species that sometimes co-occur with *A. buchholzi* includes the now imperiled *Atrytone arogos arogos* (Boisduval & LeConte), *Hesperia attalus slossonae* (Skinner), *Hypomecis buchholzaria* (Lemmer), *Heterocampa varia* (Walker), *Catocala herodias gerhardi* Barnes and Benjamin, *Catocala jair* Strecker, and the previously mentioned unnamed *Mesembagrotis* species.

#### CONSERVATION STATUS

*Agrotis buchholzi* was under review on the Candidate (C2) List of the United States Fish and Wildlife Service under the United States Endangered Species Act as published in the Federal Register on 15 November 1994. Since the range was given as New Jersey and North Carolina, this listing included *Agrotis carolina*. The C2 list was abandoned for political reasons in the mid-1990's and no decision was made on these species.

At present neither *Agrotis buchholzi* or *A. carolina* are in immediate danger of extinction but given present trends of fire suppression in New Jersey and outright habitat loss and fragmentation in North Carolina, and dependence on fortuitous management practices in both states, neither species can be considered secure. Either could become threatened in the foreseeable future. Very little, if any, non-military land is appropriately managed for *A. buchholzi* and, in the absence of appropriate management, the fire trends discussed below threaten its long-term survival. Both species have extraordinarily small ranges for moths, each being known from only from a single state and three and six counties respectively. *Agrotis buchholzi* is still locally common in the northern half of the New Jersey Pine Barrens in Burlington and Ocean Counties. It does not appear to occupy isolated, largely roadside, patches of the foodplant in Monmouth County or around Batsto in southern Burlington County.

A very substantial portion of the total range of *A. buchholzi* is on lands owned by the State of New Jersey and the United States Military Services. Nearly all of the range of *A. buchholzi* falls under the jurisdiction of the New Jersey Pinelands Commission, which conveys some level of habitat protection but no assurances of management. The Military, The US Forest Service, the state of North Carolina, and The Nature Conservancy own substantial habitats for *A. carolina*. Most of the original habitat for *A. carolina* has been developed

<sup>1</sup>Based on examination of the types in the United States National Museum by DFS.



or converted to agriculture or pine plantations while most of the range of *A. buchholzi* still supports more or less natural, but increasingly fire-suppressed, vegetation.

By far the largest populations (based on numbers in trap samples and extent of optimum habitat) of *A. buchholzi* are on Fort Dix and are maintained by fires from military exercises with some prescribed burning. Recent fire intervals have ranged from less than a year to three years in much of this habitat, with a few parts unburned for five years or longer. Any major curtailment or cessation of military activities on Ft. Dix would be a serious potential threat to *A. buchholzi*, although moderate relaxation of fire frequency (perhaps to two or three per decade) would probably benefit some rare associates, especially *Atrytone arogos arogos*.

Most of the range of *Agrotis buchholzi* is relatively undeveloped, with vast tracts of forest, woodland, scrub and substantial berry farming. Wildfires are responsible for the existence of most remaining habitats for *A. buchholzi* and several other specialized Pine Barrens Lepidoptera. Givnish (1981), Forman and Boerner (1981), Buchholz and Zampella (1987) and Windisch (1999) all document that acreage burned by wildfires has declined in recent decades, and Harshberger (1917) describes a fire swept, cut over, and much less forested region than is present now.

The location in the West Pine Plains where Madenjian and Schweitzer collected *A. buchholzi* in 1977 and 1980 has since closed in noticeably. Parts of the Plains have now not burned for 50–70 years instead of the optimum 5–15 year interval, resulting in closed woody strata of shrubby pines, oaks and heaths, and a marked decline in *Pyxidanthera* and subshrubs such as *Corema conradii* Torr. and *Arctostaphylos uva-ursi* (L.), forbs, and native grasses (Windisch 1999). When fires finally do occur after prolonged (>30–40 years) exclusion they tend to be extremely severe and may reduce or eliminate *Pyxidanthera* plants and seedbanks (Windisch 1999). The increased time between and increased severity of fires are leading to a loss of this plant and its seeds in some areas of the Pine Barrens, even in the core, as well as in peripheral areas (Windisch 1999). Nevertheless, intervening landscapes between major *A. buchholzi* habitats still typically do have some *Pyxidanthera* at least along sand roads and in disturbances, and still experience occasional wildfires on the scale of a few hundred to a few thousand hectares.

While metapopulation dynamics are almost certainly deteriorating, females have been collected about one and three kilometers out of habitat and so do disperse. Metapopulations probably still function except in eastern Atlantic County. Metapopulation collapse is

very possible in the next few decades without appropriate management practices or an increase in moderate intensity wildfires. Since wildfires occasionally affect thousands of hectares (maximum single fire recorded about 38,000 hectares in April–May 1963), *A. buchholzi* could become quite imperiled by any major range contraction or fragmentation which would leave it at risk of having a single hot fire burn all of its habitats simultaneously.

*A. carolina* is more widespread (at least six counties in two separate areas) but its major habitats are within a matrix of a much more intensively developed and agricultural (including pine farming) landscapes and the foodplant is much more localized than in New Jersey. *P. barbulata* variety *barbulata* is currently considered as uncommon (S3) by North Carolina Natural Heritage Program and the endemic Sand Hills variety *brevifolia* is considered Endangered (S1). At present all major habitats with the foodplant that have been checked still have the moth. However, it was not found at two small previously fire-suppressed remnant *Pyxidanthera* sites in Weymouth Woods State Natural Area in Moore County, within 20 kilometers of the Ft. Bragg population (Stephen Hall pers. com. May 2001). Large tracts probably supporting metapopulations on thousands of hectares of habitat exist, including in the Croatan National Forest, some military lands such as Camp Lejeune, Fort Bragg, and MOTSU, Green Swamp Preserve, and Holly Shelter State Gamelands, but most or all are probably functionally isolated from others.

*Agrotis carolina* and its habitats are being perpetuated by current prescribed burning practices, usually dormant season burns, on actively managed state and private conservation lands as well as by combined accidental and prescribed fires on military lands. Tree cover in these habitats tends to be naturally sparse. Perhaps selective thinning combined with prescribed burns would restore *A. buchholzi* habitats in New Jersey.

We recommend that managing agencies for lands harboring *Agrotis buchholzi* or *A. carolina* cooperate with future investigators, including amateur collectors, to the extent practical. Both species generally occupy habitats of hundreds to thousands of hectares and are among the more numerous Noctuidae in them and so are obviously not at risk from ordinary collecting methods. It is specifically recommended that where collecting permits are required on certain state or federal lands, they be made readily available with minimum restrictions other than reporting requirements. Reports from collectors would provide useful updates on the status of *A. buchholzi* and *A. carolina* and repeated failures to find these easily sampled moths would be a good indicator of declines. The only known

population of either species that might be small enough to be vulnerable to occasional blacklight trapping is the isolated one near Atlantic City Airport and current inventory efforts there (by DFS) aimed at other taxa avoid its limited habitat during the flight season.

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