

BANISTERIA

A JOURNAL DEVOTED TO THE NATURAL HISTORY OF VIRGINIA

ISSN 1066-0712

Published by the Virginia Natural History Society

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RESEARCH ARTICLE

OBSERVATIONS ON THE BEHAVIOR, BIOLOGY, AND DISTRIBUTION OF THE EASTERN HERCULES BEETLE, *DYNASTES TITYUS* (LINNAEUS) (COLEOPTERA: SCARABAEIDAE; DYNASTINAE) IN VIRGINIA

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Editor: T. Fredericksen | Received 24 July 2020 | Accepted 2 August 2020 | Published 9 August 2020

<https://virginiannaturalhistorysociety.com/banisteria/banisteria.htm#ban54>

Citation: Bunch, J. and A. V. Evans 2020. Observations on the behavior, biology, and distribution of the Eastern Hercules Beetle, *Dynastes tityus* (Linnaeus) (Coleoptera: Scarabaeidae; Dynastinae) in Virginia. *Banisteria* 54: 31–43.

ABSTRACT

The New World genus *Dynastes* reaches its northernmost extent in the United States with two species, *Dynastes grantii* and *D. tityus* (Linnaeus), the latter of which is widespread in eastern United States, including Virginia. Notes on the biology and distribution of *D. tityus* in Virginia are presented, along with observations on their feeding and mating behaviors on green ash trees (*Fraxinus pennsylvanica* Marshall) in Southampton County during the summer of 2019. The apparent dependence on ash trees of both species of American *Dynastes* that occur north of Mexico for attracting and locating mates is briefly discussed in light of their possible endangerment due to the ever-expanding range of the invasive Emerald Ash Borer, *Agilus planipennis* Fairmaire.

Keywords: *Agilus*, *Apis*, conservation, Emerald Ash Borer, *Panopoda*, *Vanessa*, *Xyloryctes*.

INTRODUCTION

Species of the New World *Dynastes* are among the largest of all beetles. The males are easily recognized by the long, forward-projecting pronotal horn, while the unarmed females bear a single tubercle on the frons. The genus was recently revised by Huang (2017), who recognized 15 species distributed from northern South America northward to the United States, as well as a few islands in the Caribbean. The validity of several Central and South American “forms” recognized as valid species has been questioned by some workers (Ratcliffe & Cave, 2017).

Dynastes is postulated to have originated in South America and the lineages that produced the North American taxa originated after the closure of the Panama Isthmus 3.5 Mya (Huang, 2016). The Transverse Volcanic Belt and the Sierra Madre del Sur funneled dispersing ancestors of North American *Dynastes* both westward and eastward (Ratcliffe & Cave, 2017). Today, the genus reaches its northernmost extent in the United States with two species. *Dynastes grantii* Horn is a montane species that occurs in southwestern Utah, Arizona, western New Mexico, and south to northern Mexico, while *D. tityus* (Linnaeus) is primarily a lowland species that is widespread in eastern United States from New York south to Florida, west to southeastern Kansas, Oklahoma, and eastern Texas (Huang, 2017; Ratcliffe & Cave, 2017).

Dynastes tityus is a very distinctive (Fig. 1) and widespread species in Virginia. Ratcliffe & Cave (2017) recorded following counties and independent cities: Accomack, Albemarle, Alexandria, Amelia, Amherst, Arlington, Bedford, Botetourt, Brunswick, Buckingham, Chesterfield, Culpeper, Emporia, Fairfax, Falls Church, Fauquier, Franklin, Halifax, Hanover, Henrico, Loudon, Louisa, Lunenburg, Lynchburg, Madison, Manassas, Martinsville, Montgomery, Nelson, New Kent, Newport News, Northampton, Page, Pittsylvania, Portsmouth, Powhatan, Prince Edward, Prince George, Prince William, Rappahannock, Richmond (city), Roanoke (city), Rockingham, Tazewell, Virginia Beach, Westmoreland, Williamsburg, and Wise. To these we add the counties and cities of Campbell, Chesapeake, Cumberland, Danville, Essex, Fairfax, Frederick, Fredericksburg, Gloucester, Goochland, Greenville, Isle Of Wight, King George, King William, Mathews, Orange, Patrick, Petersburg, Pulaski, Roanoke (county), Salem, Scott, Shenandoah, Smyth, Spotsylvania, Stafford, Suffolk, Surry, Sussex, Warren, Warrenton, Washington, York (iNaturalist.net, 2020), and Southampton (personal observation).



Figure 1. Male eastern Hercules beetle, *Dynastes tityus* (Linnaeus). Fort Eustis, Newport News. (Photo by Arthur V. Evans)

Elytral base color change has been noted in both living (Manee, 1915; Prokop, 1969; Ritcher, 1966; Sun et al., 2017) and pinned specimens of *D. tityus* (Fattig, 1933). The reversible elytral color change in living beetles shifts from yellow-green in a dry state to deep brown in a wet state, reflecting varying degrees of water absorption (Sun et al., 2017). During periods of high humidity, water replaces air inside the voids of the elytra's spongy internal structure composed of laminated chitin and protein.

Females lay their eggs during the month of August in large cavities at or near the base of several species of hardwood trees, especially mature oaks and other hardwoods, and occasionally pines with trunk diameters of 1–1.5 meters (Wray, 1959; Glaser, 1976; Harpootlian, 2001). Crumbling heartwood and other woody debris within these cavities are utilized as food for the developing larvae (Fig. 2).



Figure 2. Larvae of *Dynastes tityus*. James River Park System, City of Richmond. (Photo by Arthur V. Evans)

Oviposition sites with substantial accumulations of woody debris may be used by multiple females over several years before the food supply is depleted (Glaser, 1976). Several similar cavities with either narrow or broad entrances located in central Virginia (City of Richmond, Caroline and Hanover counties) were readily identified as being occupied by developing *Dynastes* larvae by the presence of the distinctly flattened and rectangular fecal pellets (Fig. 3) measuring about 10 mm in length.



Figure 3. Fecal pellets of larval *Dynastes tityus*. Fort A. P. Hill, Caroline County. (Photo by Arthur V. Evans)

Under artificial conditions, the first instar larvae hatch within a week from elongate, white to yellowish eggs and take about two years to reach adulthood, but may require as many as three years to complete their development in the wild (Glaser, 1976). Pupation occurs in late summer within oval, thick-walled cases constructed of the larva's fecal pellets and surrounding woody debris. Adults eclose from the pupa (Fig. 4) in about a month, but remain inactive with their pupal cases until the following summer (Ratcliffe & Cave, 2017). For example, in the aftermath of a severe weather event (Tropical Storm Gaston in September of 2004), Evans found a single pupal case in the hollowed-out base of a toppled oak in Joseph Bryan Park in Richmond. The case was brought indoors and partially opened to reveal a fully developed female that remained within the case until April, 2005 and died in February of 2006. She was kept on a diet of various soft fruits (bananas, cantaloupe, nectarines, and peaches) and a 50% solution of maple syrup and water. Outdoors, *D. tityus* is reported to feed on tree sap and decaying apples, figs, peaches, pears, and plums (Manee, 1915; Cartwright, 1976; Ratcliffe & Cave, 2017). In captivity, adult *D. tityus* live about 6–23 months (Krell & Krell, 2015).

Adult males and females are typically encountered at lights at night, especially from June through August. Individuals and mating pairs are found on the slender limbs of ash trees where they scrape off the bark and feed on sap (Manee, 1915; Cartwright, 1976). Cartwright (1976), based on observations made nearly 50 years previously, recalled that he "... glanced upward into a small ash tree and discovered more beetles all over the tree, clinging to limbs up to an inch and a half in diameter. The tree was about 15–20 feet tall. Each beetle, its legs wrapped around the limb, appeared to be pushing a small ball of excelsior, feeding on the sap of the inner bark. When handled, the male gave off a strong, characteristic, penetrating odor".



Figure 4. Male pupa of *Dynastes tityus*. James River Park System, City of Richmond. (Photo by Arthur V. Evans)

The establishment of the invasive Emerald Ash Borer, *Agrilus plannipes* Fairmaire (Coleoptera: Buprestidae), in Virginia and elsewhere in North America threatens the survival of all species of ash. Thus, information on the distribution and biology *D. tityus* is essential for their conservation, especially with regards to recognizing the dependence of the adults on ash for attracting and locating mates.

MATERIALS AND METHODS

The initial discovery of *D. tityus* at the study site occurred during the summer of 2018 when the senior author noticed a male Hercules beetle scraping bark on an ash limb during the day, with a moth feeding on the exposed sap along beside him. Returning to the site that evening, that same a male beetle was observed still scraping the bark and surrounded by Red-lined Panopodas, *Panopoda rufimargo* (Hübner) (Lepidoptera: Erebidae) (Fig. 5).

Following are the observations made during the summer of 2019 by the senior author in Sedley, Southampton County (36.82964° N, -76.98842° W), located in the southeastern Virginia Coastal Plain. The soil type is sandy loam, and the ground is slightly elevated from a stream that's approximately 150 feet (45.7 meters) away, providing the study site with good drainage. In addition to Green Ash (*Fraxinus pennsylvanica* Marshall), the study site is also populated with Loblolly Pine (*Pinus taeda* L.), Sourwood (*Oxydendrum arboretum* (L.) DC), American Holly (*Ilex opaca* Alton), and River Birch (*Betula nigra* L.), as well as an abundance of Common Greenbrier (*Smilax rotundifolia* L.) and Blueberry (*Vaccinium* sp.).



Figure 5. Male *Dynastes tityus* scraping bark at night while surrounded by Red-lined Panopodas, *Panopoda rufimargo* (Hübner). Sedley, Southampton County. (Photo by John Bunch)

The observations of *D. tityus* began in mid-June of 2019. Observations began daily before 7 AM and continued throughout the day until sometime before or close to dusk. All the beetles were observed on Green Ash bordering a rural backyard. Occasionally individual beetles were identified by their unique elytral markings (see Figures 4-5 in Kim & Brou, 2019). Initial observations were made with the aid of a pair of Minolta Compact 10x23.5 binoculars, but beetles located on bare limbs were easy to spot with the naked eye. Photographs at the site were made with a Sony a58 mounted on a tripod and outfitted with a Sigma DG 70-300 zoom lens. Temperatures were obtained with a lab-grade mercury thermometer manufactured by American Scientific Products. The height off the ground was measured using a 30-foot bamboo pole.

Precipitation was measured by a rain gauge in increments of hundredths of an inch. Rain data was supplied to the Community Collaborative Rain, Hail & Snow Network, sponsored by the National Oceanic and Atmospheric Administration.

RESULTS

The search for beetles began in mid-June 2019. The first beetle, a male, was observed on an ash tree on 29 June at 7 AM at a height of 13 feet above the ground on a limb about 1-1.5 inches in diameter. He had already begun to peel back the bark. This beetle was observed peeling the bark, off and on, throughout day right up until dusk; no other beetles were observed at or near the feeding site. During the week prior to this observation, the days were hot and muggy, with high temperatures ranging from 88°F to 93°F.

The next morning (30 June), the same beetle (confirmed by comparing markings on the elytra with the beetle from the previous day) was still working the bark at the 13' site. Another male (later identified as "WC" based on its unique elytral markings—see details for 6 July) was seen working a limb similar in size at a height of 25 feet. The limb diameter chosen by both males appeared to be most suitable because it allowed them to easily grip the limb with their legs as they worked the bark. The high temperature that day reached 94°F and there was a mid to late afternoon thundershower that produced 0.05 inches of rain.

On 1 July the same two beetles were still in place in their respective locations and there were no changes in their activity from the previous day (30 June). The high temperature on this day was 86°F.

Observations continued to be made throughout the day on 2 July, and as dusk approached, a male beetle was discovered on its back under the 13-foot location and was apparently dying. Comparing this dying beetle with photos taken previously revealed that it was the very first male that was observed back on 29 June at the 13' location. It had been replaced by another beetle. Both this and the remaining male at the 25-foot location continued to engage in bark peeling through 5 July, with no females appearing at either location. Up to this time, the daily progress of these two beetles was monitored before 7 AM and at different times throughout the day until just before dusk. The high temperatures for this period are as follows: 2 July - 93°, 3 July - 94°, 4 July - 95°, 5 July - 91°. An evening thunderstorm on 4 July produced 0.14 inches of rain.

On the morning of 6 July, the male at the 13-foot location had disappeared. A female had joined the male at the 25-foot location and the pair was observed throughout the day. They remained in constant contact with one another, with the female continually peeling bark as the male copulated with her. The peeled away bark was curled, looking as though it had been stripped away with a knife, and consisted of long stringy fibers (Fig. 6). The male was easily identified by markings on its right elytron resembling the letters "WC" that resembled an inscription with a fine tip permanent marker (Fig. 7), hereafter referred to as WC. That same day, a second dead male *D. tityus* was found under the ash trees. That day, the temperature reached 92° F and a thunderstorm late in the day produced 0.16 inches rain.

The following morning (7 July), the mating pair was still together, but had moved about a foot down the limb, stripping the bark as they went. An intense thunderstorm passed over the site later that day, producing 1.46 inches of rain. After the storm, WC disappeared and was not seen for the rest of the day. While copulating, the female always maintained a firm hold on the branch, but WC, grasping only the female, likely lost his grip during the storm.



Figure 6. Male *Dynastes tityus* peeling bark an ash branch. Sedley, Southampton County. (Photo by John Bunch)



Figure 7. Male *Dynastes tityus* with elytral markings resembling ‘WC’ attending a female as she strips bark along an ash branch Sedley, Southampton County. (Photo by John Bunch)

On 8 July, a pair of beetles, including WC, was once again occupying the 25-foot location. Based on comparisons of the elytral markings of female beetles photographed previously at this location over the past two days, WC's mate was a different female. This same morning, an unaccompanied female occupied the 13-foot location and was peeling bark. She remained alone at this location throughout the day, and was gone the next morning. The high temperature for the day was 88°F and there was a brief afternoon thunderstorm that produced 0.08 inches of rain.

At 7 AM the next day (9 July), no beetles were observed at the 13-foot site. At the 25-foot location, there was a mating pair still present, now accompanied by another male (Fig. 8). As the day progressed, the second male confronted WC several times by moving up and down the limb. WC always turned to face the rival male, either remaining over or beside the female at all times. No physical contact between the males was observed. Compared with photos taken the previous day, it appeared that the female on this day was a different individual than the female that accompanied WC the day before. This day was decidedly cooler with the high temperature reaching only 84°F.



Figure 8. Pair of *Dynastes tityus* with another male nearby. Sedley, Southampton County. (Photo by John Bunch)

On the morning of 10 July, only WC remained at the 25-foot location. Throughout the day, the male remained on the branch with some of his legs splayed out, appearing as if he had died in place. However, by the next morning (11 July), he was not only alive and well, but was accompanied by yet another female. To date, based on the photographic record, it appeared that WC had attracted at least four females to this site. The high temperature for 10 July was 91°F,

followed the next day by a high of 94°F and an evening thunderstorm produced 0.54 inches of rain.

No *D. tityus* were observed anywhere on 12 July. The day was sunny, and humid, reaching a high of 90°F. By 7 AM the next day (13 July), WC had returned to the 25-foot location and was near a female. By carefully comparing the photos taken on a daily basis of the females observed through this breeding season, this was female number 5. The pair remained together at the same spot for the entire day. The day was humid and the high temperature was 91°F.

At 6:30 the next morning (14 July), a mating pair of beetles, including WC, were still together at the 25-foot site, along with another male further down the limb. It is not clear whether this female was the same individual observed with WC the day before. By 2 PM that afternoon, both the female and second male were gone. WC was seen running quickly down the limb, possibly in search of the female; this was the first time that any of the beetles were observed moving quickly. By 7 PM that evening, WC was still alone on the branch. The day was humid and the high temperature was 94°F.

A single male was still present at the 25-foot site at 7 AM on 15 July, but his position on the limb made it impossible to see the elytral markings to determine whether it was WC or another beetle. The site wasn't checked again until 8:30 PM that evening and, in the fading light, it was evident that a male beetle was still on the branch. The day was humid and the high temperature was 92°F. At 7 AM the next morning (16 July) it was determined that the lone male at the 25-foot site was WC. A Red Admiral, *Vanessa atalanta* (Linnaeus) (Lepidoptera: Nymphalidae), was observed visiting the stripped bark below and some distance away from the beetle. A video was made of WC raising and lowering his head while wiping the sides of his face or scraping his mouth with the front femora and possibly tibiae. The high temperature for the day was 95°F, with a slight afternoon thunderstorm dropping only 0.07 inches of rain.

By 7 AM the next morning (16 July), based on unique markings seen on the elytra, a sixth female joined WC at the 25-foot site. A European Honeybee, *Apis mellifera* Linnaeus (Hymenoptera: Apidae), visited the exposed tree sap next to the mating pair. By 10:30 AM the female had left and WC appeared, once again, to be searching for her by moving up and down the small limb. At 5 PM, no *Dynastes* were in evidence and this is the last day that WC was observed. The high temperature for the day was 97°F. No beetles were observed on 18 July and the temperature for that day reached 96°F.

Observations continued daily through 31 July and the last live Hercules beetle of the summer was seen on 19 July. The day was very hot with a high temperature of 96°F. 20 July through 31 July showed high temperatures ranging from 79° (heavy rain date of 23 July) to 100°. During the observational time period addressed in this paper ranging from mid-June through 31 July, males and females were only observed at the 13-foot and 25-foot sites and in no other places in the trees. From 20 July to 4 September, four more dead male *Dynastes tityus* were found on the ground under the stand of green ash trees (20 July, 6 and 15 August, 4 September). Over the course of the study period, a total of six dead male beetles were found, while no dead females were ever encountered. Additional ash trees in the vicinity were searched, but no sites other than the 13-foot and 25-foot locations were found.

DISCUSSION

As far back as the summer of 2001, the senior author and his wife noted a strong scent on hot, humid nights that was likened to blueberries. With lots of *Vaccinium* growing in the immediate vicinity, it was simply assumed that these plants were the source of the odor. However, when handling one of the dead males encountered in this study, Bunch noted the same blueberry scent on his fingers. Manee (1915) and Cartwright (1976) both noted that males gave off a strong odor that has been variously characterized as disagreeable, penetrating, and/or pungent. It is possible that males produce this odor to attract females, but this hypothesis needs testing.

The larvae of both species of *Dynastes* in the United States are generalist feeders on dead wood, especially that of hardwoods. However, the adults appear to be dependent on ash (*Fraxinus*) as a means of attracting and locating mates, with courting males peeling back bark and chewing into the cambium of living ash branches (Manee, 1915; Menke & Parker, 1988; Bouchard, 2014; Wagner & Todd, 2016; personal observation). The wounds created by these beetles leave distinctive scars that remain visible on living for several years (personal observation). We are not aware of any published accounts of bark peeling or mating by either species taking place on any trees other than ash. Whether or not female are attracted to the odors produced by the males, volatiles produced by ash wounds resulting from beetle feeding, or a combination thereof is unknown and certainly worthy of further investigation.

Recently, both species of *Dynastes* in the United States, along with 96 other insect herbivores dependent on various ash species, were considered at risk of high endangerment as a direct result of the environmental damage caused by the invasive Emerald Ash Borer (EAB), *Agilus planipennis* Fairmaire (Wagner & Todd, 2016). All North American species of ash appear susceptible to the wood-boring activities of their larvae and, while not currently known in the West, EAB is widespread in the East where they have killed tens of millions of trees (United States Department of Agriculture, Animal and Plant Health Inspection Service, 2020); since 2008, EAB has become established throughout most of Virginia (Virginia Department of Forestry, 2020).

The loss of ash threatens *D. tityus* and another Virginia dynastine scarab *Xyloryctes jamaicensis* (Drury) thought to be an ash specialist as a larva (Ratcliffe & Cave, 2017). If both *D. tityus* and *X. jamaicensis* are wholly dependent on ash during any part of the life cycle, then both species are at risk of significant population reductions or extirpation if ash is reduced or eliminated from parks and forests. The potential negative impacts of the Emerald Ash Borer on these and other ash specialists in Virginia requires further study.

ACKNOWLEDGEMENTS

Brett Ratcliffe (University of Nebraska State Museum, Lincoln, Nebraska) and Ron Cave (University of Florida's Indian River Research and Education Center, Fort Pierce, Florida) generously provided us with their distributional and temporal data for *D. tityus* in Virginia. Wade Harrel introduced Evans to the tree hole ecology of these beetles 20 years ago. Paula Evans read an early draft of the manuscript. Curt Harden and Kal Ivanov critically reviewed the penultimate draft and offered numerous helpful comments, corrections, and suggestions.

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