# Aggregations of *Polistes* Wasps Over-wintering in Artificial Red-cockaded Woodpecker Cavities

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**Abstract -** We document blockage of artificial *Dryobates borealis* (Red-cockaded Woodpecker) cavities by family Sphecidae (mud daubers) and large mixed-species aggregations of wintering *Polistes* (paper wasps) in cavity inserts at Great Dismal Swamp NWR in southeast Virginia. The large aggregations that we encountered are the only known cases of more than 2 paper wasp species cohabitating. Activity of Red-cockaded Woodpeckers within a cluster lessened the likelihood that paper wasps will aggregate in cavities, but not the likelihood that mud daubers will nest in cavities. The moist and saturated soils that predominate our field site may explain why these insects are more abundant compared to drier, upland habitats. Additionally, removal of hardwood trees may increase the breeding season habitat quality for paper wasps that hunt and nest in areas that are more open, while simultaneously limiting potential winter hibernacula habitat, typically found in mature hardwood tree cavities for Red-cockaded Woodpeckers. Common cavity management and translocation techniques may need to be altered to mitigate greater paper wasp and mud dauber activity at Red-cockaded Woodpecker cavity inserts in *Pinus serotina* (Pond Pine) pocosin habitat. We suggest using graduated rubber stoppers rather than screens that fail to exclude insect taxa or conducting translocations prior to the formation of winter aggregations of paper wasps.

## Introduction

*Dryobates borealis* (Vieillot) (Red-cockaded Woodpeckers; hereafter, RCW) are unique in that they excavate cavities exclusively in living trees (Walters and Garcia 2016). This activity often takes several years and can require efforts from multiple generations of RCW before the cavity is complete (Harding and Walters 2004). Once complete, RCW cavities may be used by multiple generations of birds, but trees die due to wind throw, infestations of pine beetles, and fire, so mortality of cavity trees often outpaces rates of cavity creation (Conner and Rudolph 1995, Conner et al. 1991, Harding and Walters 2004). Cavity limitation is a problem exacerbated by a few cavity usurpers (USFWS 2003). Species that usurp active cavities are considered kleptoparasites and can induce cavity abandonment (Kappes 1997). Kleptoparasites are not thought to significantly affect healthy RCW populations, but predator and kleptoparasite control is often necessary in critically small populations (<30 individuals) and areas where RCW are being reintroduced (USFWS 2003).

Most control measures focus on vertebrate kleptoparasites, including other woodpecker species and *Glaucomys volans* L. (Southern Flying Squirrel) (USFWS 2003). However, RCW cavities also support a variety of macroarthropods, including

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*Polistes* spp. (paper wasps) and Sphecidae (mud daubers) (Pung et al. 2000, Walters and Kneitel 2004). Paper wasps and mud daubers will occasionally use RCW cavities during the breeding season, although mud daubers reportedly do not interfere with this species (Conner et al. 1997, Dennis 1971). Paper wasps are known to occupy cavities within which they build nests large enough to exclude RCW, but these wasps are only reported to nest in a small proportion of cavities where they have been observed, although most RCW studies have been limited to populations that primarily use natural cavities (Conner et al. 1997, Dennis 1971, Pung et al. 2000, Walters and Kneitel 2004). Paper wasps wintering in RCW cavities have not been reported in the literature, although these wasps have been encountered in natural RCW cavities during winter in *Pinus palustris* L. (Longleaf Pine) in the North Carolina Sandhills in the 1980s and both natural and artificial cavities in Longleaf Pine and *Pinus taeda* (Lobolly Pine) in central Louisiana during the past decade (J.H. Carter III and J. Goodson, Dr. J.H. Carter III and Associates, Inc., Southern Pines, NC, unpubl. data).

Here we report 4 species of paper wasps overwintering in large mixed-species aggregations within a relatively large proportion of artificial RCW cavity inserts and the blockage of cavities with mud dauber tubes, such that a RCW could not peck off tubes as reported by Conner et al. (1997). We initially encountered aggregations of wasps within cavities during a nocturnal translocation on 7 November 2018 at Great Dismal Swamp National Wildlife Refuge (GDS-NWR).

## Methods

GDS-NWR is the northernmost of the large, humid swamp forests within the southeastern United States and one of the largest remaining on the Coastal Plain. GDS-NWR is positioned on a low, poorly drained, flat marine terrace 4.5–7 m asl. The swamp is a forested palustrine wetland where the dominant pines are *Pinus serotina* Michx. (Pond Pine) and Loblolly Pine, similar to sites in northeastern North Carolina that support RCW (Carter and Brust 2004). Since 2015, we have attempted to establish a breeding population of RCW within GDS-NWR by translocating 34 birds from source populations to recruitment clusters on the refuge (Watts et al. 2020). Initially, recruitment clusters included 4 artificial cavity inserts installed in 13 different clusters. Since 2015, the number of cavities at each cluster have fluctuated due to cavity mortality, installation of replacement cavities, and creation of natural cavities by RCW. At the time of the study, 11 clusters included 4 artificial cavities, 1 cluster included 3 artificial cavities, and 1 cluster included 3 artificial cavities and 1 natural cavity in a Pond Pine. RCW were captured after they enter roost cavities within source populations, transported to GDS-NWR and placed in cavity inserts in the recruitment clusters, and released the following morning. We have conducted these translocations between mid-September and mid-November.

Between 8 August and 17 October 2018, we prepared 16 cavity inserts for receiving birds by removing debris and covering the entrances with 2 overlapping metal screens of different mesh sizes (~1 $cm^2$, ~1 $mm^2$) to exclude vertebrate kleptoparasites. Wasps were not observed in any cavities during preparation. While attempting to place translocated RCW into the artificial cavities on 7 November, however, wasps were discovered in 4 of the cavities, forcing us to place birds in alternate cavities.

Following these encounters, we inspected all cavities at the 13 clusters within GDS-NWR for wasp aggregations between 9 January 2018 and 25 February 2019 using a SN-3464 peeper camera (see Luneau 1999) attached to a 50-ft linesman's hot pole (model E 50; Hastings, Hastings, MI). Any wasps encountered in the cavities were removed using a battery-powered vacuum cleaner (model DCV517B; Dewalt, Baltimore, MD) fitted with a vacuum hose ~2 cm in diameter. We inserted the vacuum hose through the cavity entrance and sucked wasps into the vacuum reservoir. We used a paint stirrer and untwisted wire clothes hanger to facilitate vacuuming by scraping these tools against the inside walls of the cavity. Each cavity cleaning took ~30 min, resulting in removal of ~90% of the wasps. Our total number of wasps is a minimum estimate, as we were unable to remove 100% of wasps from any cavity, and the removal process destroyed some wasps. We emptied wasps from the vacuum reservoir into a hand-sewn mesh bag (Agfabric INRone0050WF0_F; Wellco Industries Inc., Corona, CA). We used Super Cold aerosol spray (MG Chemicals, Burlington, ON, Canada) to facilitate the transfer from vacuum reservoir to mesh bag when temperatures were >15 °C and wasps were more active, then placed the mesh bags into a cooler with ice blocks. We stored the wasps in a freezer at -20 °C and identified them to species according to MacDonald and Deyrup (1989) and Buck et al. (2012) using color markings, forewing length, and relative size of gastral terga. We randomly selected a subsample of 10 wasps (if available) for each species present in each cavity and sexed them by the number of antennal segments and presence of a stinger.

We used logistic regression to assess the influence of RCW activity at the cluster level on the likelihood that wasps would aggregate in cavities. If a RCW occupied at least 1 cavity at any given cluster, the cluster was considered "active". The presence/absence of wasp aggregations and mud dauber tubes were treated as response variables in separate tests. We used likelihood ratio tests to compare goodness of fit between the models that included RCW activity at the cluster (active/inactive) as a fixed effect and models that did not include RCW activity as a predictor (i.e., intercept-only models). We report the Nagelkerke $R^2$ (Nagelkerke 1991), RCW activity effect size, standard error, and $P$-value for the logistic regression. All data analyses were performed in the R platform (R Core Team 2020) using the 'lme4' package (Bates et al. 2015).

## Results

Of 51 cavities, 13 inserts in Pond Pines were used by RCW, 15 supported wasp aggregations (12 inserts in Pond Pine, 3 in Loblolly Pine), 9 contained mud dauber tubes (including 6 that also supported wasp aggregations), 3 were filled with cobwebs, 1 contained a passerine nest, and 16 were empty.

Among 15 cavities with paper wasps, we did not remove or count paper wasps that were aggregating within 4 cavities that were blocked by mud dauber tubes to such a degree that a RCW could not enter the cavity. Mud dauber tubes filled these cavities from the top to the bottom of the cavity and from the back of the cavity to the cavity entrance. Additionally, we did not remove or count paper wasps that dispersed away from 1 cavity prior to our last collection attempt (9 Apr 2019). We collected 3249 wasps of 4 species (*Polistes exclamans* Viereck [Guinea Paper Wasp], *P. metricus* Say [Metricus Paper Wasp], *P. fuscatis* (Fabricious) [Northern Paper Wasp], *P. dorsalis* (Fabricious)) from the remaining 10 cavities (Table 1). All cavities supported the same 2 wasp species (*P. exclamans, P. metricus*), and most cavities supported simultaneous occupation by 4 species (Table 1). All wasps in our subsample were female.

RCW activity at the cluster level ($n = 13$) was an important predictor for occurrence of paper wasp aggregations (likelihood ratio $\chi^2 = 1.42$, df = 1, $P < 0.001$), but wasps were less likely to be found in cavities within active RCW clusters (logistic regression: $R^2 = 0.35$, Effect Size = -3.06, SE = 1.09, $P = 0.005$). RCW activity at the cluster level was not a statistically significant predictor for occurrence of mud dauber tubes ($\chi^2 = 2.86$, df = 1, $P = 0.09$) and, although mud daubers were less likely to be found in cavities within active RCW clusters, this difference was also not statistically significant ($R^2 = 0.09$, Effect Size = -1.35, SE = 0.86, $P = 0.12$).

## Discussion

The proportion of cavity inserts that were occupied by paper wasps and the degree to which cavities were filled with mud dauber tubes at our study site were both greater than has been reported in other RCW populations. Artificial inserts compose a greater proportion of the cavities at our site than at most RCW study areas because the population at GDS-NWR is only recently established, so we do not have any evidence that either paper wasps or mud daubers favor artificial cavities over natural cavities. We believe that paper wasps and mud daubers may be more common at our study site compared to other more traditional RCW habitats because it is located in a wet environment.

Table 1. Minimum estimates of the total number of 4 *Polistes* spp. (paper wasps) collected from 10 cavity inserts at 4 clusters in Great Dismal Swamp National Wildlife Refuge, VA.

| Cluster | Tree | *P. exclamans* | *P. metricus* | *P. fuscatis* | *P. dorsalis* | Total |
|---|---|---|---|---|---|---|
| C2-3 | 120 | 301 | 5 | 1 | 0 | 307 |
| C3-1 | 34 | 34 | 61 | 2 | 2 | 99 |
| C3-1 | 32 | 65 | 10 | 2 | 2 | 79 |
| C3-1 | 31 | 655 | 30 | 3 | 14 | 702 |
| C3-2 | 111 | 196 | 7 | 0 | 0 | 203 |
| C3-2 | 112 | 227 | 3 | 0 | 0 | 230 |
| S2-4 | 131 | 265 | 161 | 9 | 4 | 439 |
| S2-4 | 130 | 371 | 253 | 48 | 22 | 694 |
| S2-4 | 132 | 149 | 36 | 6 | 5 | 196 |
| S2-4 | 133 | 170 | 79 | 18 | 33 | 300 |
| Total | | 2433 | 645 | 89 | 82 | 3249 |

Wet soils are a scarce resource in dry upland RCW habitats, and both flying insect taxa prefer to be near water (Brockmann 1980, Nelson 1971, Strassman 1979). The moist or saturated soils in conjunction with artificial RCW cavities apparently provide ideal conditions for paper wasps, as the aggregations we encountered are larger than others reported in North America. Most winter aggregations of paper wasps are monospecific and include fewer than 100 individuals (Gibo 1972, 1980; Hunt et al. 1999; Rau 1930), although tropical paper wasps sometimes form larger aggregations during a dry-season diapause (González et al. 2002, 2005). To our knowledge, the aggregations we have documented at GDS-NWR are the only reported cases in which more than 2 species cohabitate.

In addition to the wet environment found at GDS-NWR, paper wasps may also form large mixed-species aggregations at our study site because the majority of mature hardwoods were mechanically removed to create habitat suitable for RCW. The more open habitat found in the GDS-NWR following tree removal may be more suitable for *P. exclamans* and *P. fuscatis*, which both depend upon prey located in habitats that are more open (Rabb 1960), and *P. metricus,* which prefers areas that are more open for nesting (Reed and Vinson 1979). In addition to the greater habitat suitability that the more open landscape may provide paper wasps, the dense mixed-species aggregations of wasps present in artificial cavity inserts in pine trees at GDS-NWR may be a result of resource limitation because of the scarcity of alternative winter hibernacula sites. Natural cavities that could provide suitable winter hibernacula for wasps can often be found in mature hardwoods (Remm et al. 2006), but mature hardwoods were unavailable throughout much of the study site after mechanical removal.

Our discovery of large wintering aggregations of paper wasps in artificial RCW cavities exemplify how managers must adapt to habitat-specific challenges. Unlike upland sites where Southern Flying Squirrels are generally the most common cavity kleptoparasite (Loeb and Hooper 1997; although not in much of Florida [J.J. Kappes Jr., Norfolk Southern's Brosnan Forest, Dorchester, SC, pers. comm.]), mud daubers and paper wasps are the primary cavity kleptoparasites at our study site, requiring regular removal of paper wasps and mud daubers during winter. We did not observe paper wasps in cavities that were recently occupied by RCW, but the loss of cavities likely affects established birds at our site if they must unexpectedly search for replacement cavities. Pine trees at wet environments like the GDS-NWR are more prone to snapping from wind throw than at drier upland sites, especially if hardwoods are mechanically removed (Carter and Brust 2004). Between 2015 and 2018, 15 of 66 cavity trees (23%) were lost at GDS-NWR. Following such events, RCW without available alternative cavities may be forced to open-roost on trunks and branches of trees, where they may be more vulnerable to inclement weather and certain predators (Hooper and Lennartz 1983).

Limited availability of cavity trees may also affect the likelihood of translocation success. More frequent cavity inspections and maintenance may be warranted in wet environments such as that found at GDS-NWR. Prior to translocations, graduated rubber stoppers can be inserted into cavity-insert entrances after cleaning. These stoppers are more effective at excluding paper wasps, which can apparently crawl through bark crevices to pass underneath screens. Alternatively, we recommend conducting translocations before wasps move to hibernacula, which was first observed at our study area in 2018 on 7 November. Temperatures beforehand did not reach freezing, but did include several days after 17 October when they dropped just below 3 °C (NOAA Suffolk Airport), which is cold enough to induce torpor in some species of paper wasps during winter (Rau 1942). Additional investigation may further explain environmental cues that may trigger wasps moving to hibernacula.

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