Species Composition of Cutworm (Lepidoptera: Noctuidae) Larvae in South Central Washington Vineyards

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ABSTRACT The major grape (Vitis spp.)-growing areas of Washington were surveyed during 2003–2007 to determine the cutworm species present as larvae in vineyards during spring when grape buds and young shoots were vulnerable to cutworm (Lepidoptera: Noctuidae) damage. We sampled vineyard floors during daytime, vines at night because cutworms are active at night, and vines during the day. In total, 1,003 larvae were collected and 650 were reared to adults and identified. Twenty-five species were found: 22 on the ground, eight on vines at night, and two on vines during the day. Almost 75% of the cutworms on vines at night were Abagrotis orbis (Grote) and 19% were Agrotis vetusta Walker. The spotted cutworm, Xestia c-nigrum (L.), and the redbacked cutworm, Euxoa ochrogaster (Gueneé), were reported previously to be the major cutworm pests of grapes in Washington, but only four X. c-nigrum and no E. ochrogaster were collected. Abagrotis orbis larvae were collected on grapes at night from mid-March to late April. Adults emerged in the laboratory in mid-May, and they were present during the summer. Agrotis vetusta larvae were collected on grapes from 1 to 30 April. This species had a long prepupal period during the summer, followed by a pupal stadium of ≈3 wk. Mean adult emergence was in early August. Both species were univoltine, with mating and egg laying during the fall followed by overwintering as small larvae.

KEY WORDS cutworm, grape, Noctuidae, Abagrotis orbis, Agrotis vetusta

Larvae of the spotted cutworm, Xestia c-nigrum (L.), and the redbacked cutworm, Euxoa ochrogaster (Gueneé), have been reported to cause most of the cutworm (Lepidoptera: Noctuidae) damage to grape (Vitis spp.) buds during the spring in south central Washington (Cone et al. 1990). However, no extensive survey has identified the cutworm species present in vineyards. Cutworms potentially can cause significant economic damage by reducing yield, which results from the bud injury (Wright and Cone 1980). Vineyards are most susceptible to cutworm injury from approximately late March to early May, depending on the weather, when grape buds are swelling or the shoots are small. An additional reason for conducting a survey was the substantial expansion of the grape growing area in Washington from 14,183 ha in 1992 (USDA 1992) to 25,294 ha in 2002 (USDA 2007), which may have affected the abundance and species composition of vineyard-inhabiting noctuids. We surveyed vineyards in the major grape-growing region of south central Washington during springs 2003–2007, to collect and identify the larvae of cutworms on the ground and on the vines.

Materials and Methods

Ground Sampling. Cutworm larvae residing on vineyard floors during the daytime (≈0900–1600 hours) were sampled in 2003 and 2004 by delineating 40-cm-diameter circle under a vine near the trunk or in the center between the rows, searching through the top 7–10 cm of soil and leaf litter, and collecting all cutworms found. Samples were taken 10 vines apart in a row, alternating between rows and centers between rows. Sampling continued for 1 or 2 person-hours per vineyard. Four vineyards were sampled each for two person-hours three times at ≈2-wk intervals from 1 April to 2 May 2003. Three of these vineyards were 10–15 km northwest to northeast of Prosser, Benton Co., WA, and the other vineyard was ≈5 km south of Richland, Benton Co., WA. One vineyard had Concord grape, Vitis labrusca L., and the others were planted with wine grape, Vitis vinifera L., varieties. Sixteen wine grape vineyards and one Concord vineyard located in the Yakima valley from north of Prosser to south of Yakima and one wine grape vineyard ≈35 km north of Sunnyside, Yakima Co., were sampled in the same manner once per season from 8 to 23 April 2003 for 1 person-hour each. Also, 25 plastic pitfall traps (7.5 cm in diameter by 9 cm in depth) were placed in each of the vineyards that were sampled for 2 h. They were placed in the vineyards on 28 March and emptied weekly until 2 May.

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In 2004, the four vineyards sampled for 2 h in 2003 were sampled again for 2 h each starting on 22 March and ending on 21 April. These vineyards were sampled three times each during the season at \( \approx 2 \) wk intervals. Another 33 vineyards (six Concord and 27 wine grape) that were located in the same general area as in 2003 were sampled once from 29 March to 15 April for 1 h each. No pitfall traps were set out in 2004.

Night Sampling. Because cutworm larvae feed nocturnally, we sampled five vineyards, all wine grapes, near Prosser at night in 2004. The vineyards were sampled by searching with flashlights for cutworms on the vines starting about an hour after sunset (\( \approx 1930 - 2000 \) hours) and continuing to \( \approx 2130 \) hours. Four vineyards were sampled for 3 person-hours each and one vineyard for 5 person-hours. Each vineyard was sampled once from 7 to 20 April.

After 2004, we sampled vineyards only at night for 1 person-hour each from \( \approx 1 \) h after sunset (\( \approx 1900 - 2000 \) hours) until \( \approx 2330 \) hours at the latest. In 2005, sampling started on 7 March and ended on 27 April. The four vineyards sampled for 2 h in the ground survey were sampled every week for 8 wk. Nineteen other vineyards, all wine grapes, located in the Walla Walla area, Walla Walla County; the Paterson area, Benton County; and in the Yakima valley were sampled once per season. In 2006, we sampled for 6 wk from 27 March to 3 May. The same four vineyards sampled multiple times in 2005 were sampled again three times each at \( \approx 2 \) wk intervals. Seven wine grape vineyards were sampled two times each \( \approx 2 \) wk apart, and 10 wine grape vineyards were sampled once during the season. The vineyards were located generally in the same locations as in 2005 but vineyards in the Mattawa area, Grant Co., were sampled for the first time. In 2007, we sampled one wine grape vineyard three times, 13 wine grape vineyards two times each, and five vineyards (two wine grape and three Concord) once each from 13 March to 25 April. Vineyards that were sampled multiple times were sampled \( \approx 2 \) wk apart. The areas sampled were the same as in 2006. After 2004, the sampling start time, air temperature and soil temperature at approximately the 5 cm depth were recorded.

**Vine Sampling during the Daytime.** To determine whether some cutworm larvae remained on the vines during the day, we sampled one vineyard per day during daytime on 8 and 15 April 2004 and on 17 and 27 April 2007. Each vineyard was sampled for 1–2 person-hours by examining the bark, especially under loose, rough bark.

**Cutworm Rearing.** Cutworm larvae cannot be identified to species with certainty, so they were reared to adults in the laboratory on artificial diet (Multiple Species Diet, Southland Products Inc., Lake Village, AR) at \( \approx 27^\circ C \) under continuous lighting. In 2003, a layer of diet \( \approx 1 \) ml in depth was poured into 35-ml plastic cups after mixing. One larva was added to each cup after the diet had cooled and solidified and lids with punched holes were attached to the tops. Larvae were transferred to cups with fresh diet when needed. The pupae were transferred to 100-ml plastic cups with wooden sticks \( \approx 7 \) cm in length for the newly emerged moths to climb for wing unfolding and expansion. Starting in 2004, some of the larvae were reared in 100-ml plastic cups with pet bedding (Forest Floor Bedding, Zoo Med Laboratories, San Luis Obispo, CA) \( \approx 1–2 \) cm in depth and a 1-cm\(^3\) piece of diet. From 2005, this substrate material was replaced with coconut fiber (Coco Life Brik, Coconut Palm Resources, Inc., Hillsboro, OR) because of cost and local availability. The cups were covered with tulle netting (http://www.joann.com) fastened with rubber bands. When the larvae pupated, a strip of paper \( \approx 21.5 \) by 6 cm was inserted around the inside wall of the cup to provide a climbable surface where the moths could unfold and expand their wings. Gender of the most abundant species was determined by examining the pupae. A chi-square test for equal proportions (PROC FREQ, SAS Institute 1985) was done to determine whether sex ratios were significantly different from 1:1. Moths were pinned and identified using published keys and descriptions (Lafontaine 1987, 1998) and comparisons with previously identified specimens. Voucher specimens are deposited at the Irrigated Agriculture Research and Extension Center, Washington State University, Prosser, WA.

In 2004, we tested three different rearing methods for cutworm survival: the 35-ml cups with diet as described above (21 larvae); the 100-ml plastic cups described above with 1–2 cm of peat moss and 1 cm\(^3\) of diet (22 larvae); and 100-ml cups with 1–2 cm of the Forest Floor Bedding and a 1-cm\(^3\) piece of diet (19 larvae). All treatments had one larva per cup. Statistical differences among treatments were tested by the Mantel—Haenszel chi-square test (PROC FREQ, SAS Institute 1988).

**Results.**

We collected 1,003 cutworm larvae in total during our survey. One hundred sixty seven died as larvae (cause unknown), 69 died as pupae (cause unknown), 108 (10.77%) were parasitized, 659 were reared to adults, and 650 were identified to species (12 adults were not identified because of shriveled wings, and three dead pupae were identified by dissection). Twenty-five species were represented in the samples (Table 1). One hundred eighty seven larvae in 22 species were found on the ground, 445 larvae in eight species were found on the vines at night, and 18 larvae of two species were found on vines during the day. Seventeen species were found only on the ground, three were only on vines, and five were found in both locations (Table 1). Most of the species on the ground were found in low numbers: only six species were represented by >10 larvae (Table 1). *Abagrotis orbis* (Grote) (previously known as *Abagrotis barnesi*; Rings 1972, Lafontaine 1998) and *Agrotis vetusta* Walker dominated the cutworm population on the vines at night, accounting for >93% of the cutworms found (Table 1). We collected 17 *Abagrotis orbis* and one X. c-nigrum from under the loose bark of vine trunks or cordon during the day. Seventeen larvae were caught.
in pitfall traps: one Agrotis vetusta, one Euxoa albipennis (Grote), four Euxoa messoria (Harris), three Euxoa olivia (Morrison), and eight Euxoa septentrionalis (Walker).

Agrotis orbis larvae were first found about two weeks before Agrotis vetusta (Table 2). The rearing data showed that Agrotis orbis development was rapid with mean adult emergence on 14 May. In contrast, Agrotis vetusta had a prolonged prepupal period, not pupating until ≥84 d after collection with mean adult emergence on 2 August (Table 2). The pupal stadia of the two species were similar. Males outnumbered females in both Agrotis orbis (191 [54.57%] to 159 [45.43%]) and Agrotis vetusta (61 [56.48%] to 47 [43.52%]), but the proportions were not significantly different from equal (Agrotis orbis: χ^2 = 2.926, df = 1, P = 0.087, n = 350 and Agrotis vetusta: χ^2 = 1.815, df = 1, P = 0.178, n = 108).

Larval mortality differed significantly between the three rearing methods: Mantel–Haenszel χ^2 = 5.704, df = 1, P = 0.017. Larvae in the 35-ml cups with only diet had 42.86% mortality, larvae in 100-ml cups with peat moss had 18.18% mortality, and the larvae in the 100-ml cups with pet bedding had 10.53% mortality.

The number of cutworms we collected varied considerably during 2003–2007 when we sampled vines at night for the whole cutworm season. The numbers collected per year were 276 in 2005, 37 in 2006, and 189 in 2007. Percentage parasitism varied from 3.09 to 14.86% during 2004–2007. One species of Diptera was reared from the collected cutworms: Tachinidae, Panzeria sp. probably ampelius Walker. The other parasitoids were hymenopterans in the families Braconidae (Meteorinae, Meteorus sp.; Microgastrinae, Cotesia sp. and Microplitis sp.) and Ichneumonidae (Banchinae, Campopleginae, and Ichneumoninae).

The air temperatures recorded in vineyards during night samplings in which at least one cutworm was found averaged 8.4°C (range, 2–15°C). The soil temperatures averaged 14.7°C (range, 4–26°C).

Agrotis orbis was more common than Agrotis vetusta in every grape-growing area that we sampled at night. We collected 96 Agrotis orbis and six Agrotis vetusta in the Mattawa area, 33 Agrotis orbis and four Agrotis vetusta near Paterson, 109 Agrotis orbis and 0 Agrotis vetusta near Richland, 14 Agrotis orbis and 0 Agrotis vetusta near Walla Walla, and 80 Agrotis orbis and 74 Agrotis vetusta in the Yakima Valley.

Discussion

This survey provides compelling evidence that larvae of Agrotis orbis and Agrotis vetusta dominate the cutworm species found on grapevines in south central Washington. Larvae of two species formerly considered to be the major cutworm pests of grapes (Cone et al. 1990) occurred in low numbers (X. c-nigrum) on vines or were absent (E. ochrogaster). Relatively large numbers of X. c-nigrum were caught in pheromone traps in south central Washington vineyards in 2006 and in acetic acid plus 3-methyl-1-butanol-baited traps (Landolt 2000) in 2002–2004 (L.C.W. and D.G.J., unpublished data). Landolt (2000) and Landolt and Hammond (2001) found that X. c-nigrum was com-

Table 1. Cutworms found in south central Washington vineyards during spring from 2003 to 2007

| Species | Common name | Total identified | Found on ground | Found on vines at night | Found on vines during daytime |
|---------|-------------|-----------------|----------------|------------------------|-----------------------------|
|         |             | No. | % | No. | % | No. | % |
| Abagrotis orbis | (Grote) | None | 350 | 1 | 0.53 | 332 | 74.61 | 17 | 94.44 |
| Abagrotis reedi | Buckett | None | 7 | 1 | 0.53 | 6 | 1.35 | 0 | 0 |
| Agrotis cetusta | Walker | Old man dart* | 108 | 24 | 12.83 | 84 | 18.88 | 0 | 0 |
| Autographa californica | Speyer | Alalfa looper | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Diocrea trifidi | Hufnagel | Clover cutworm | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Euxoa albipennis | (Grote) | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Euxoa atomaris | (Smith) | None | 6 | 2 | 1.07 | 4 | 0.90 | 0 | 0 |
| Euxoa catenula | (Grote) | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Euxoa hollemanni | (Grote) | None | 10 | 10 | 5.35 | 0 | 0 | 0 | 0 |
| Euxoa infusta | (Walker) | None | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Euxoa messoria | (Harris) | Darksided cutworm | 14 | 14 | 7.49 | 0 | 0 | 0 | 0 |
| Euxoa olivia | (Morrison) | None | 57 | 55 | 29.41 | 2 | 0.45 | 0 | 0 |
| Euxoa rockburnei | Hardwick | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Euxoa septentrionalis | (Walker) | None | 41 | 41 | 21.93 | 0 | 0 | 0 | 0 |
| Euxoa subandera | Lafontaine | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Euxoa tessellata | (Harris) | Striped cutworm | 6 | 6 | 3.21 | 0 | 0 | 0 | 0 |
| Felthia jaculifera | (Guene) | Dingy cutworm | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Lacinipolia pensilis | (Grote) | None | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Nocta concs Hüber | None | 9 | 0 | 0 | 9 | 2.02 | 0 | 0 |
| Parabagrotis exercitationis | (Morrison) | None | 1 | 1 | 0.53 | 0 | 0 | 0 | 0 |
| Platyperigea extima | (Walker) | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Platyperigea montana | Bremer | None | 2 | 2 | 1.07 | 0 | 0 | 0 | 0 |
| Protorthodes curtica | (Smith) | None | 15 | 15 | 8.02 | 0 | 0 | 0 | 0 |
| Spaelotis clandestina | (Harris) | W-marked cutworm | 5 | 0 | 0 | 5 | 1.12 | 0 | 0 |
| Xestia c-nigrum | (L.) | Spotted cutworm | 4 | 0 | 0 | 3 | 0.67 | 1 | 5.56 |

*Common name refers to moth.
Table 2. Phenological and rearing statistics of cutworms found in south central Washington vineyards during spring from 2003 to 2007

| Species                  | Date of first collection | Date of last collection | Days from collection to pupation Mean (±SEM) | n   | Days in pupal stage Mean (±SEM) | Date of adult emergence Mean (±SEM) |
|--------------------------|--------------------------|-------------------------|---------------------------------------------|-----|---------------------------------|------------------------------------|
| *Abagrotis orbis* (Grote) | 13 March                 | 27 April                | 12.37 ± 0.19                               | 345 | 20.62 ± 0.09                    | 14 May ± 0.41                      |
| *Abagrotis reedi* Buckett | 13 March                 | 18 April                | 12.29 ± 1.19                               | 7   | 18.29 ± 0.92                    | 8 May ± 5.27                       |
| *Agrotis cettusa* Walker | 1 April                  | 30 April                | 83.77 ± 1.41                               | 108 | 23.92 ± 0.28                    | 2 Aug. ± 2.36                      |
| *Autographa californica* Speyer | 5 April              | 5 April                 | 2.00                                        | 1   | 12.00                           | 19 April                           |
| *Dicerca trifoli" Hufnagel | 2 April                  | 2 April                 | ND                                         | 1   | ND                              | 19 April                           |
| *Euxoa albipennis* (Grote) | 4 April                  | 30 April                | 71.50 ± 1.50                               | 2   | 24.50 ± 1.50                    | 22 July ± 13.00                    |
| *Euxoa atomaris* (Smith) | 17 March                 | 15 April                | 121.17 ± 6.13                              | 16  | 19.33 ± 0.80                    | 26 Aug. ± 7.79                     |
| *Euxoa cataena* (Grote) | 2 April                  | 6 April                 | 95.50 ± 29.50                              | 2   | 23.50 ± 0.50                    | 2 Aug. ± 32.00                     |
| *Euxoa hollemanni* (Grote) | 5 April                  | 19 April                | 134.63 ± 11.58                             | 8   | 22.50 ± 1.10                    | 11 Sept. ± 9.54                    |
| *Euxoa infusta* (Walker) | 29 April                 | 29 April                | 13.00                                       | 1   | 16.00                           | 28 May                             |
| *Euxoa messoria* (Harris) | 6 April                  | 30 April                | 63.43 ± 4.35                               | 14  | 20.43 ± 0.85                    | 12 July ± 5.33                     |
| *Euxoa olivia* (Morrison) | 25 March                 | 29 April                | 127.39 ± 2.56                              | 57  | 21.14 ± 0.32                    | 6 Sept. ± 2.42                     |
| *Euxoa rockburnei* (Harrison) | 29 April               | 29 April                | 30.50 ± 10.50                              | 2   | 15.50 ± 5.50                    | 14 June ± 5.00                     |
| *Euxoa separtentinalis* (Walker) | 25 March               | 2 May                   | 40.28 ± 3.41                               | 39  | 24.21 ± 1.31                    | 18 June ± 3.38                     |
| *Euxoa subantera* Lafontaine | 18 April               | 29 April                | 30.50 ± 4.50                               | 2   | 25.00 ± 3.00                    | 24 June ± 13.00                    |
| *Euxoa tessellata* (Harris) | 5 April                  | 29 April                | 16.50 ± 1.36                               | 6   | 16.83 ± 1.56                    | 23 May ± 4.47                      |
| *Felthia jaculifera* (Gaeneue) | 12 April                | 12 April                | 78.00                                       | 1   | 21.00                           | 20 July                            |
| *Lacenipolia pensilis* (Grote) | 25 March                 | 25 April                | 68.00                                       | 1   | 22.00                           | 24 July                            |
| *Noctua comes* Hũbner | 13 March                 | 26 April                | 10.78 ± 0.85                               | 9   | 20.36 ± 0.53                    | 10 May ± 4.82                      |
| *Parabagrotis exsirvtigna* (Morrison) | 17 April               | 17 April                | 0*                                          | 1   | 11.00                           | 25 April                            |
| *Platyperigea extima* (Walker) | 19 April                | 19 April                | 4.00 ± 0.00                                | 2   | 1.350 ± 0.50                    | 5 May ± 0.50                       |
| *Platyperigea montana* Bremer | 1 April                  | 5 April                 | 12.50 ± 2.50                               | 2   | 6.50 ± 0.50                     | 23 April ± 4.50                    |
| *Prothodes curtica* (Smith) | 5 April                  | 19 April                | 31.53 ± 2.61                               | 15  | 64.53 ± 3.21                    | 22 July ± 2.24                     |
| *Spaelotis clandestina* (Harris) | 13 April                | 21 April                | 10.60 ± 0.93                               | 5   | 15.80 ± 0.66                    | 13 May ± 2.80                      |
| *Xestia c-nigrum* (L) | 11 April                 | 17 April                | 8.50 ± 1.32                                | 4   | 14.25 ± 0.63                    | 9 May ± 4.87                       |

ND, no data.
*a* Collected as pupa.

The biology and larva of *Abagrotis orbis* were described by Rings (1972). The larva resembles the spotted cutworm except the dark, wedge-shaped dorsal spots on the abdomen are more pronounced anteriorly in *A. orbis*. The larvae of *E. ochrogaster* and *A. cettusa* lack prominent dark spots but the abdomen of both species is reddish or rusty colored dorsally. Phenologically, there are similarities between *X. c-nigrum* and *Abagrotis orbis* and between *E. ochrogaster* and *Agrotis cettusa* with larvae of the former two species appearing on grapevines earlier than the latter two species (Cone et al., 1990 and this study). *Abagrotis orbis* and *Agrotis cettusa* larvae can be separated by the markings on their head capsules: reticulations on *Abagrotis orbis* and spots on *Agrotis cettusa*. Lafontaine (1987) provides characters that can be used to separate the larvae of *Euxoa* and *Agrotis*. In Ohio, 95.5% of *Abagrotis orbis* overwintered as second instars with the remainder in the third instar (Rings 1972). Lafontaine (1998) provides keys to adults and larvae of the genus *Xestia* and *Abagrotis*. *Agrotis cettusa* overwinters as a small larva (L.C.W. and D.G.J., unpublished data). More than 99% of *Abagrotis orbis* and 77.8% of *Agrotis cettusa* were found on vines compared with ground collections (Table 1).

We found *Abagrotis orbis* in all of the regions that we surveyed. *Agrotis cettusa* was not found in vineyards sampled in the Tri-Cities and Walla Walla areas, but it probably occurs there. The majority of species we collected occurred in low numbers and only on the ground. These probably do not pose a threat to grapes, but some species we found on the ground have been reported as climbing cutworms: the dark-sided cutworm, *Euxoa messoria* (Harris) (Marmor et al. 1981); *Abagrotis reedi* Buckett (Lafontaine 1998); and the striped cutworm, *Euxoa tessellata* (Harris) (Lafontaine 1998). We did not find *E. messoria* or *E. tessellata* on vines. *Noctua comes* Hũbner, *Spaelotis clandestina* (Harris), and *X. c-nigrum* were found only on vines (Table 1). Other species collected on vines that have not been reported as climbing cutworms were *Euxoa atomaris* (Smith) and *Euxoa olivia* (Morrison). The first reported collection of the introduced *Noctua pronuba* (L) in Washington was in 2002 from Matton, Yakima Co. (Shepard 2006). We observed a large number of larvae feeding on weeds in a vineyard near Paterson, WA, during one of our night samplings, but no larvae were found on vines. *N. comes* was intro-
duced into British Columbia (Copley and Cannings 2005) and was first collected in eastern Washington on a vine at night in 2005 in a vineyard near the Tri-Cities (Shepard 2006). We found it again in 2006 and 2007, but only in the same vineyard.

Abagrotis orbis and Agrotis vetusta are univoltine, with adults mating and females laying eggs in late summer or fall (Rings 1972; L.C.W. and D.G.J., unpublished data). Abagrotis orbis spends the summer as an adult (Rings 1972). Adults have been collected from mid-April to mid-October (Lafontaine 1998). Agrotis vetusta aestivates as a prepupa. The pupation and adult eclosion dates in Table 2 are based on rearing conditions; field dates may be different. The climate of south central Washington is characterized by hot, dry summers. Delaying mating and egg laying until fall would avoid the low humidity, which would increase egg desiccation and scarcity of food and water for both the adults and new larvae.

Correct identification of cutworm species affecting grape production is critical to development of low-input, biologically based management strategies. Our survey indicates that Abagrotis orbis and Agrotis vetusta are the principal species responsible for economic damage from cutworms in Washington viticulture.

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