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FOOD HABITS OF PACIFIC MARTEN FROM SCATS IN SOUTH-CENTRAL OREGON

RANDALL J WILK AND MARTIN G RAPHAEL

ABSTRACT—Quantifying prey taken by Pacific Marten (*Martes americana caurina*) helps to understand local habitat requirements of the species. We collected 250 scat samples associated with at least 53 marten in a salvage-logged Lodgepole Pine (*Pinus contorta*)-Bitterbrush shrub (*Purshia tridentata*) forest in south-central Oregon. The frequency of occurrence of food items included 98.0% mammals, 36.0% arthropods, 23.2% birds, 9.2% plants, 2.0% hares and rabbits, and 0.8% reptiles. Among mammals, 72.4% were vole-sized and 47.2% squirrel-sized. Chipmunks (*Neotamias* spp., 27.6%) and ground squirrels (*Spermophilus* spp., 28.0%) had the highest occurrence by size group, respectively. Frequency varied little between summer and winter. Male marten preyed on a greater proportion of mice (*Peromyscus* spp.) than females, especially in summer, and in winter females preyed on a greater proportion of voles (*Microtus* spp.) than did males. Female marten also preyed on a greater proportion of birds in winter than did males, whereas males had a greater proportion in summer. We compare our findings with a concurrent study in northeastern Oregon and discuss the importance of slash piles from the indirect evidence in the frequently logged forest type to help inform habitat management of the species and prey.

Key words: forest carnivore, Lodgepole Pine, *Martes americana caurina*, *Microtus*, *Myodes*, *Neotamias*, Pacific Northwest, *Peromyscus*, *Pinus contorta*, *Spermophilus*

Laboratory examination of scat contents of forest predators such as Pacific Marten (*Martes americana caurina*; hereafter marten) provides information on diet that is important to understanding habitat relationships for the species and its prey (Cumberland and others 1997; Bull 2000). Food habits of marten in the Pacific states may be more diverse than elsewhere (Zielinski and others 1983; Martin 1994; Bull 2000). For example, in the east-central Cascade Range, Washington, arthropods (bees, ants, wasps, and beetles) occurred most often in marten scats (Newby 1951), whereas in north-eastern Oregon, vole-sized mammals dominated (Bull 2000). To our knowledge, these are the only published studies on the Pacific Marten for these states. We

present findings of contents of marten scats as indicators of their feeding habits in a south-central Oregon location and forest type where information has not been previously reported, and compare results with the northeastern (NE) Oregon study (Bull 2000), which paralleled our study.

Our study was located on the Fremont-Winema National Forest, east of the Cascade Range crest northeast of Chemult, Oregon (Jones and others 1996). The approximate Winema center is at latitude 42.929°, longitude -121.153° (Google Earth imagery date, 31 December 1969, accessed 19 September 2016); general elevation was approximately 1700 m. Forest cover was dominated by climax Lodgepole Pine (*Pinus contorta*)-Bitterbrush shrub (*Purshia tridentata*) forest, and higher hills on that pumice plateau supported Ponderosa Pine (*P. ponderosa*), Sugar Pine (*P. lambertiana*), Western White Pine (*P. monticola*), White Fir (*Abies concolor*) and Red Fir (*A. magnifica*) (Franklin and Dyrness 1988). Mean annual temperature at that period (1997) was 5.3°C ($\bar{x}$ January min. = -11.1°C, and $\bar{x}$ July max. = 28.2°C). Mean annual precipitation was 0.68 m with 4.2 m snow accumulation (Raphael and Jones 1997). Salvage logging following beetle damage occurred during the study, with some removal of down wood and snags and a large accumulation of slash piles for a habitat-manipulation study that was not implemented (Jones and others 1996; Katnik and others 1996). The area has been described at multiple scales from remotely-sensed data (Shirk and others 2014).

Each sample contained ≤ 10 scats per collection event, mostly from capture sites, dens, and rest sites discovered during radio-tracking research (Jones and others 1997; Raphael and Jones 1997; Holyan and others 1998; Shirk and others 2014) between January 1993 and September 1998. We used standard methods to process contents and identified items from guard hairs and bones using available keys (Maser and Storm 1970; Brunner and Coman 1974; Korschgen 1980) and reference collections of potential

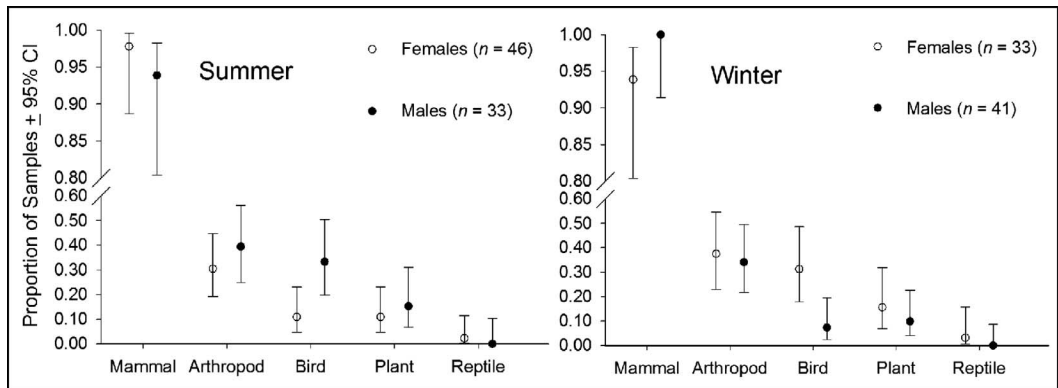


FIGURE 1. Proportion of Pacific Marten scat samples in general taxonomic classes, collected in spring–summer (summer) and autumn–winter (winter), 1993 to 1998 in south-central Oregon. Significant differences occur for birds between sexes in both seasons, and in each sex between seasons. See Table 1 for details.

prey. It was not always possible to accurately count the number of items in each sample, so we used frequency of occurrence (FO; the percentage of samples in which an item occurred) to describe composition (Klare and others 2011).

We assigned samples to a season based on collection date: summer, from 21 March to 20 September; winter, from 21 September to 20 March; and unknown. The dates during 5 of the 6 y of our study were comparable to the NE Oregon marten study (summer, 18 April to 14 October; winter, 15 October to 17 April), although our study had 8 additional samples in 1998, 1 y following the NE study. We also fixed 3 microscope slides from a random sample of 45 scats to identify the presence of hypogeous fungi.

We used 95% confidence interval (CI) overlap rules to compare pairs of independent means of scat contents. Rules for P -values are as follows: if CIs touch or very slightly overlap, $P \approx 0.01$; if the gap between arms is approximately $\frac{1}{3}$ the length of a single arm, $P \approx 0.001$; and if the gap is larger, $P < 0.001$. For overlap to about $\frac{1}{2}$ the length of an arm, $P \approx 0.05$; so for the area between slight overlap to $\frac{1}{2}$ arm length, $P \leq 0.05$ (Cumming 2009). For fixed N s, the error bars are asymmetrical when P is closer to 0 or 1. We used exploratory software for CIs to compute and display proportions (Cumming 2012) and to report them as percentages. Significant results in the text include the CI as a range with the P -value.

We collected 250 scats from 22 females and 31 males, with 97 samples from marten of un-

known sex. Overall, 98.0% of scats contained remains from 26 mammal species, followed by arthropods, birds, plant material, and reptiles. In general, we observed no differences in the FOs of items within the 5 groups between summer and winter (Table 1). However, 61.2% of the total scats had collection dates for marked individuals ($n = 153$), and with this filter, we found seasonal differences in the FO of bird remains between females and males (Fig. 1).

By FO, the majority of scat samples contained vole-sized (CI = 67–78%) and squirrel-sized mammals (41–53%), which were proportionally different ($P < 0.01$) (Table 1). However, between-season proportions were not different within each size group (Table 1). The FO of *Microtus* spp. in female marten scats in winter (21.2%, 11–38%) was significantly greater than in male scats (4.9%, 1–16%) ($P \approx 0.05$). *Peromyscus* spp. FO in male marten scats in summer (24.2%, 13–41%) was greater than in female scats (4.3%, 1–15%) ($P < 0.05$), and overall, the FO in male samples (17.6%, 11–28%) was greater than in female samples (6.3%, 3–14%) ($P \approx 0.05$).

The FO of both vole- and squirrel-size prey in our study was greater than in the NE Oregon study (vole = 60–66%, $P < 0.01$; squirrel = 26–31%, $P < 0.001$) conducted by Bull (2000). Differences in occurrence of vole-sized prey were mainly due to proportions of chipmunks (*Neotamias* spp.) that were 10 times greater than in the NE Oregon study, and ground squirrels (*Spermophilus* spp.) in squirrel-sized samples, which were nearly absent in the NE Oregon study. In the NE Oregon study, identifications

TABLE 1. Frequency of occurrence (%) of items found in scat samples from radio-collared Pacific Marten in south-central (SC, this study) and northeastern Oregon (NE, Bull 2000). This table is closely formatted after Bull (2000) to facilitate direct comparisons.

	Summer		Winter		All year ¹	
	SC	NE	SC	NE	SC	NE
MAMMALS						
Shrew <i>Sorex</i> spp. ²	1.1	4.9	1.1	6.4	1.2	4.7
Fossorial mammal	1.1	—	3.2	0.4 ³	1.6	0.2 ³
Bat <i>Myotis</i> spp.	—	—	—	0.2	—	0.1
Chipmunk <i>Neotamias</i> spp. ⁴	22.7	6.5	23.2	0.6	27.6	2.7
N. Pocket Gopher <i>Thomomys talpoides</i>	14.8	3.9	5.3	2.0	10.0	2.6
Great Basin Pocket Mouse <i>Perognathus parvus</i>	2.3	—	—	—	1.2	—
Western Harvest Mouse <i>Reithrodontomys megalotis</i>	1.1	—	—	—	0.4	—
Deer Mouse <i>Peromyscus</i> spp.	12.5	10.4	12.6	8.4	14.4	7.8
Red-backed Vole <i>Myodes</i> spp. ⁵	9.1	30.3	6.3	19.4	6.0	24.6
Heather Vole <i>Phenacomys intermedius</i>	11.4	—	11.6	—	16.4	—
Vole <i>Microtus</i> spp.	23.9	50.2	15.8	9.6	16.8	27.4
Undetermined vole (microtine)	4.5	12.4	14.7	11.0	11.2	12.7
Sagebrush Vole <i>Lemmyscus curtatus</i>	—	—	1.1	—	0.4	—
Common Muskrat <i>Ondatra zibethicus</i>	1.1	—	—	—	0.4	—
W. Jumping Mouse <i>Zapus princeps</i>	2.3	—	—	—	0.8	—
Undetermined cricetid	2.3	—	4.2	—	2.8	—
Total vole-sized prey	67.0	83.1	70.5	46.1	72.4	62.7
Undetermined squirrel	10.2	11.1	15.8	24.4	13.6	17.3
N. Flying Squirrel <i>Glaucomys sabrinus</i>	3.4	2.6	2.1	7.2	2.0	4.3
Squirrels <i>Tamiasciurus</i> spp. ⁶	1.1	2.9	2.1	3.0	2.4	3.3
Bushy-tailed Woodrat <i>Neotoma cinerea</i>	—	1.3	1.1	4.0	0.4	2.5
Ground Squirrel <i>Spermophilus</i> spp. ⁷	28.4	—	20.0	0.2	28.0	0.1
Weasel <i>Mustela</i> spp.	1.1	0.7	1.1	1.0	0.8	0.8
Total squirrel-sized prey	43.2	18.6	41.1	39.7	47.2	28.2
Undetermined rodent	15.9	—	14.7	—	18.8	—
Virginia Opossum <i>Didelphis virginiana</i>	1.1	—	—	—	0.4	—
American Badger <i>Taxidea taxus</i>	—	—	1.1	—	0.4	—
Mountain Cottontail <i>Sylvilagus nuttallii</i>	—	—	—	1.8	—	0.9
Undetermined <i>Lepus</i> spp. ⁸	—	2.2	2.1	1.2	0.8	1.4
Undetermined lagomorph	2.3	—	1.1	—	1.2	0.1
Total hares and rabbits	2.3	2.2	3.2	3.0	2.0	2.4
Undetermined cervid ⁹	5.7	—	5.3	2.6	4.4	2.0
Porcupine <i>Erethizon dorsatum</i>	—	0.3	—	—	—	0.2
Domestic cattle	1.1	—	—	—	0.4	—
BIRDS	18.2	15.3	16.8	19.8	23.2	19.5
REPTILES						
Garter Snake <i>Thamnophis</i> spp.	1.1	—	1.1	—	0.2	—
FISH	—	—	—	0.4	—	0.2
ARTHROPODS/INSECTS						
Wasps <i>Vespidae</i>	12.5	24.9	9.5	7.6	9.2	15.6
Ants <i>Formicidae</i>	—	4.2	—	3.8	0.4	3.9
Other arthropods/insects ¹⁰	31.8	11.1	22.1	0.6	32.4	7.8
Total arthropods/insects	33.0	31.3	29.5	15.6	36.0	22.4
PLANT MATERIAL	8.0	27.5	13.7	5.2	9.2	13.3
TOTAL SAMPLES	88	307	95	501	250	1014

¹ Includes samples with collection dates not known.

² In SC, species = *palustris* in summer and winter, and *monticolus* in all year.

³ Coast Mole (*Scapanus orarius*).

⁴ In SC, most if not all were *N. amoenus* (J. A. Allen, 1890), Yellow-pine species (see Patterson and Norris 2016).

⁵ Species *californicus* in SC and *gapperi* in NE.

⁶ Species *hudsonicus* (Red) in NE and *douglasii* (Douglas') in SC.

⁷ In SC, includes Golden-mantled species *lateralis*, and Belding's, species *beldingi*.

⁸ In both locations, species = *americanus* (Snowshoe Hare), and in SC = *townsendii* (White-tailed Jackrabbit).

⁹ In SC Elk, *Cervus elaphus*; and Mule or Black-tailed Deer, *Odocoileus hemionus*, identified.

¹⁰ All other arthropods not in the above 2 categories include order Coleoptera 12.0%; Orthoptera 4.8%; Diptera 2.0%; and Ixodida 0.4%.

were mostly undetermined (Table 1). We identified 9 mammalian species in our study scats in addition to those identified in the NE Oregon study, and 2 species found in the NE Oregon study were not found in our scat samples (Table 1).

The FO of *Microtus* spp. (13–22%) and *Myodes* spp. (4–10%) voles in our study were less than in the NE Oregon study, where they were the 2 dominant small-bodied mammals (*Microtus* spp., 25–30%; *Myodes* spp., 22–27%) (both $P < 0.001$) (Table 1). In summer in our study, *Microtus* spp. FO (16–34%) was as high as *Neotamias* spp. FO (15–33%), but on an annual basis was lower than *Neotamias* spp. (22–33%) ($P \approx 0.01$) (Table 1).

We did not observe a seasonal shift from small- to larger-bodied small mammals in winter as reported in the NE Oregon study. Such shifts have been hypothesized to synchronize with abundance and availability of prey, to optimize metabolic energy, and to minimize predation risk (Zielinski and others 1983; Zielinski 1988; Drew and Bissonette 1997). Hibernation and snow cover concealing prey, and energy constraints on marten were posited as reasons for the winter shift to larger prey in the NE Oregon study (Bull 2000). The evenness of seasonal occurrence between the small and larger body-size groups in our study may confirm a good year-round availability in the mammalian prey base. Anecdotal reporting from preliminary small mammal live-trapping in our study area noted an "...unusually high abundance of ground squirrels and chipmunks, which may explain the abundance of marten in this atypical habitat" (Katnik and others 1996: 3). The climate is less harsh in winter in our study area than in the NE Oregon study area, likely contributing to an increased availability and vulnerability of hibernating ground squirrels and chipmunks to predation during this season. Chipmunks and ground squirrels hibernating in winter burrows may be vulnerable to marten in a way similar to the hypothesized vulnerability of *Tamiasciurus* spp. in subnivean middens when resting at night (Zielinski and others 1983; Drew and Bissonette 1997).

Both our study area and the NE Oregon study area sites had relatively low FO of arboreal squirrels in samples (*Tamiasciurus* spp. and *Glaucomys* spp., 4–7%) (Table 1). Salvage logging in our study area and partial overstory removals

of >80% in NE Oregon likely diminished habitat quality for arboreal squirrels. However, the species-specific relative importance of arboreal squirrels in both studies was also likely confounded by the relatively high proportions of undetermined squirrel species in the samples (Table 1).

Other mammals with high FO that were more frequent in our study than in NE Oregon include *Thomomys* spp. (7–14% > 2–4%; $P < 0.001$), owing to the high FO in summer (9–24% > 2–7%; $P < 0.01$); *Peromyscus* spp. (11–19% > 6–10%; $P < 0.01$); and *Phenacomys* spp. (12–22%), which was not reported from NE Oregon (Table 1).

Birds could not be determined to species from scat remains, but cameras used at marten dens documented 2 sequences of predation on Dark-eyed Juncos (*Junco hyemalis*) (Jones and others 1997). In summer, the FO of birds in male scats (33.3%, 20–50%) was greater than in female scats (10.9%, 5–23%) ($P < 0.05$), but in winter, this was reversed (F [30.3%, 17–47%] > M [7.3%, 2.5–19%] ($P \approx 0.01$) (Fig. 1). Also, the FO of birds in female scats in winter was greater than in summer ($P \approx 0.05$), and the FO of birds in male scats in winter was less than in summer ($P \approx 0.01$). This seasonal shift may be related to the different activities of female and male marten. In general, marten are focused on birds during the nesting season (Walankiewicz 2002; Weidinger 2009), but marked females in our study were observed rearing young in mostly ground-level dens (Raphael and Jones 1997). In winter, which included pre-denning with more movement by females (including tree searches for den cavities), there may have been increased opportunities for bird encounters.

The arthropod group with the highest FO was coleopterans (beetles; 12%), of which 3.2% were identified as the Mountain Pine Beetle (*Dendroctonus ponderosae*). We found that 9.2% of samples contained the hymenopteran vespid wasps, yellowjackets (*Vespula* spp.), and Bald-faced Hornets (*Dolichovespula maculata*) (Table 1). We also identified Orthoptera (grasshoppers, crickets, etc.; 4.8%), Diptera (flies; 2.0%), Ixodida (ticks; 0.4%), and Formicidae (ants; 0.4%).

The FO of arthropods in our study (30–42%) was greater than in the NE Oregon study (Bull 2000) (20–25%) ($P < 0.001$), whereas birds, plant material, and lagomorphs were similar between locations (Table 1). However, the FO of plant

material varied seasonally between the 2 studies: in summer, NE Oregon (FO = 23–33%) was greater than in our study (4–16%) ($P < 0.001$); it reversed in winter (our study = 8–22%, NE Oregon = 4–8%; $P < 0.01$) (Table 1). Note that arthropods in the table are grouped for direct comparison with the table formatted by Bull (2000).

In our study, we reported the 2nd highest FO for insects (arthropods) in the marten diet, comprised primarily of carpenter ants (*Camponotus* spp.), Bald-faced Hornets, and yellow-jackets. Only Newby (1951) reported a higher FO (42.8%) for insects in the diet, and Bull (2000) reported the 3rd highest FO in the NE Oregon study (Table 1). Newby (1951) also reported a FO of 54.7% for arthropods in the summer diet of martens at the eastern Cascades site in Washington (compare to Table 1). Yellowjackets are consumed by marten primarily in the west, where yellowjacket (aerial/ground) and hornet (aerial) nests occur at high frequency, which marten appear to skillfully pilfer (Newby 1951; Bull 2000). Vespid FO was relatively large in our study, and with coleopterans and orthopterans, comprised 24.8% of the identified arthropods. The FO for Mountain Pine Beetles (as well as carpenter ants) was likely greater than we determined, considering the beetle-damaged forest of our study area, but amounts were likely hidden in the 20.0% of samples containing specimens that we could not classify to a lower taxonomic level for more specific identification.

Plant material had relatively low FO as undetermined seeds (7.6%), undetermined plants (1.6%), and lichen (0.4%). Fungi occurred in 53% of the random subsamples. *Rhizopogon* spp. spores occurred in 47% of those samples, and *Gautieria* spp. and *Hysterangium* spp. were present in 2 samples each. *Melanogaster* spp., *Sclerogaster* spp., *Cortinariaceae* (order Agaricales, gilled mushrooms), and order Mucorales (pin molds) each were identified in 1 sample.

Because volumes of plants and insects (arthropods) are small, their occurrence in scats may not necessarily indicate their relative importance, and although mustelids like marten are known to eat plants and fungi (Fogel and Trappe 1978; North and others 1997), their occurrence in scats may also reflect stomach contents of herbivorous prey such as voles, mice, chipmunks, and flying squirrels (Martin 1994; Klare and others 2011). In our study, each

type of item was counted only once per sample, which could have underestimated the occurrence and importance of these small items. For example, in Washington, Newby (1951) found that 34.7% of marten scats contained only arthropods, which demonstrated that large volumes were eaten and that they were a main food item.

Compared to 24 marten food studies across North America that we reviewed (Buskirk and Ruggiero 1994; Martin 1994), and the NE Oregon study (Bull 2000), our study reports the highest FO for chipmunks and ground squirrels in marten scats, which we speculate is habitat related. The warm and dry south-central Oregon plateau has an open pine canopy with meadows, scattered brush, and many slash piles that have replaced stumps and fallen tree trunks, which is typical of Yellow-pine Chipmunk (*Neotamias amoenus*) and ground squirrel habitat. *Spermophilus* spp. are known to rapidly colonize new clearcuts (or recent burns) often connected by roads, and they burrow under or near a wide variety of natural and human-made structures (Gashwiler 1970; Sutton 1992; Bartels and Thompson 1993). In moist to mesic conifer-dominated closed-canopy forests that are more typical of marten habitat, red-backed voles, as well as *Microtus* spp. voles are the main marten prey species (Buskirk and Ruggiero 1994; Buskirk and Zielinski 2003; Verts and Carraway 1998). In the western states, *Myodes* spp. in scats in these forests ranged from 28–42% (Martin 1994), greater than in our samples (Table 1). Arboreal squirrel FOs in these studies were larger than the findings for both Oregon sites. For example, research from Washington, California, and Montana reported the FO of *Tamiasciurus* between 10 and 38%, and 21% for *Glaucomys* (Montana) (Marshall 1946 [winter]; Newby 1951 [1 y]; Hargis and McCullough 1984 [winter]). Note that results from referenced studies, unless specified, are relative because occurrence may vary with season and year within a study's duration in relation to cycles of small-mammal populations.

In our study area, slash piles likely lessened logging impacts on ground-level habitat structure and created exceptional hunting opportunities for marten (Lisgo and others 2002; Andruskiw and others 2008). For example, slash piles and windrows on clearcuts enhanced

species-specific abundance and persistence, species richness, and increased winter activity of forest-floor small mammals (particularly red-backed voles, *Myodes* spp.) in British Columbia (Sullivan and others 2012). In our study area, slash piles were the most frequently used structures for marten denning (44% of telemetry locations) and resting (40%), often with females using multiple den sites (Raphael and others 1998). Presumably, slash piles were the main ground structures because removal of snags and large downed woody debris was part of the experimental treatment (Katnik and others 1996). Woody debris (in this case, slash piles) provides visual cues to marten, which enhances predation efficiency (see Andruskiw and others 2008).

Our findings support describing marten as generalist predators (Buskirk and Ruggiero 1994; Martin 1994). The high occurrence of chipmunks and ground squirrels and their relative evenness in seasonal occurrence, as well as the prevalence of vole- and squirrel-sized species groups in general in the diet of marten is novel. Slash piles in quantities greater than those created during operational-scale salvage logging may be a practical and important habitat-management approach for maintaining prey and marten in the south-central Oregon pine forests. For example, before salvage logging, there were about 4.8 larger slash piles/km² and 10.7 smaller piles/km² in the core study area (Jones and Raphael 1990); by the end of the study, there were >1500 slash piles in the study area (Raphael and others 1998), an implied density of >17.6/km². Slash pile configurations were highly variable and were artificially constructed multi-layered stacks of branches and foliage, logs, ordered log decks for firewood cutting, stumps, and other debris that were ≥4 m² in ground-level surface area (Jones and others 1996; Raphael and Jones 1997). These quantities may be particularly important to chipmunks and ground squirrels, which were staples in the year-round diet of marten. Slash piles may also have allowed for the persistence of *Myodes*, a genus that requires downed logs, but is often absent in more xeric habitats (Verts and Carraway 1998) such as our study area. As an endnote, we point forest managers to the specific guidelines for woody debris structures (slash piles and windrows) from the landmark experiment in beetle-damaged salvage-logged Lodge-

pole Pine forests in British Columbia (Sullivan and others 2012).

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