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Allegheny Woodrat (Neotoma magister) Use of Rock Drainage Channels on Reclaimed Mines in Southern West Virginia

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ABSTRACT.—Allegheny woodrats (*Neotoma magister*) currently receive protected status throughout their range due to population declines. Threats associated with habitat fragmentation (*e.g.,* introduced predators, disease, loss of connectivity among sub-populations and habitat loss) may explain why Allegheny woodrats are no longer found in many areas where they existed just 25 y ago. In southern West Virginia, surface coal mining is a major cause of forest fragmentation. Furthermore, mountaintop mining, the prevalent method in the region, results in a loss of rock outcrops and cliffs within forested areas, typical habitat of the Allegheny woodrat. To determine the extent that Allegheny woodrats make use of reclaimed mine land, particularly rock drainages built during reclamation, we sampled 24 drainage channels on reclaimed surface mines in southern West Virginia, collected habitat data at each site and used logistic regression to identify habitat variables related to Allegheny woodrat presence. During 187 trap nights, 13 adult, 2 subadult and 8 juvenile Allegheny woodrats were captured at 13 of the 24 sites. Percent of rock as a groundcover and density of stems >15 cm diameter-at-breast-height (DBH) were related to Allegheny woodrat presence and were significantly greater at sites where Allegheny woodrats were present than absent. Sites where Allegheny woodrats were present differed substantially from other described habitats in West Virginia, though they may simulate boulder piles that occur naturally. Our findings suggest the need for additional research to examine the dynamics between Allegheny woodrat populations inhabiting rock outcrops in forests adjacent to mines and populations inhabiting constructed drainage channels on reclaimed mines. However, if Allegheny woodrats can use human-created habitat, our results will be useful to surface mine reclamation and to other mitigation efforts where rocky habitats are lost or disturbed.

INTRODUCTION

Allegheny woodrats (*Neotoma magister*) historically ranged along the Appalachian Mountains from southern New York to northern Alabama and west into Kentucky, Ohio and Indiana (Hall, 1985; Balcom and Yahner, 1996). In the past 25 y, the species has experienced precipitous declines, especially along northern and western portions of its range. It is assumed to be extirpated from New York and Connecticut, has experienced drastic declines in New Jersey and eastern Pennsylvania and is found on state lists of threatened, endangered or sensitive species throughout its range (Hall, 1985; Hicks, 1989;

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Kirkland and Krim, 1990; Beans, 1992). Populations appear stable in West Virginia, although statewide survey data are not available (Mengak, 1996; Stihler and Wallace, 1996). Forest fragmentation has been suggested as one cause of declines (Balcom and Yahner, 1996); however, Castleberry *et al.* (2001) suggested the species is tolerant of moderate levels of timber harvesting.

In southern West Virginia, surface coal mining, particularly the mountaintop mine/valley fill (MTMVF) technique, is a major cause of forest fragmentation whose effects on Allegheny woodrat populations have not been studied. In addition to fragmenting the landscape, MTMVF is of concern to Allegheny woodrat conservation because it results in a loss of rock outcrops, the typical habitat of Allegheny woodrats. Mountaintop mining removes upper portions of ridgelines where outcrops are most often found and does not restore them in the reclamation process. Reclamation efforts in the late 1960s and early 1970s involved building drainage channels that contained large rocks and boulders, loosely piled in a deep channel, creating complex interstitial spaces similar to rocky habitat used by Allegheny woodrats. On more recently reclaimed mines, drainage channels are constructed using smaller boulders, resulting in a habitat that contains fewer interstitial spaces. Neither type of channel had surface water flow. Additionally, tree planting as part of the reclamation process has been inconsistent, leaving various levels of woody cover around drainage channels. We sampled drainage channels of different ages and reclamation methods to determine if Allegheny woodrats were present and to identify characteristics of drainage channels related to woodrat presence. Identification of associated characteristics should be useful in Allegheny woodrat conservation, guiding land managers in the creation of woodrat habitat during surface mine reclamation, as well as in other mitigation efforts where rocky habitats are lost or disturbed.

STUDY AREA AND METHODS

Our study included 2 MTMVF complexes in southern West Virginia (Chamblin, 2002). One mine complex located in the Mud River watershed in Boone County was 2431 ha with average elevation after reclamation of 330 m (241–423 m). The second MTMVF complex (2180 ha) was in the Twenty-mile Creek watershed on the border of Kanawha and Fayette Counties with average elevation of 434 m (332–566 m).

We sampled drainage channels in areas 13–27 y post-reclamation. A variety of small trees and shrubs (Table 1), both introduced and native, growing within the channel or along the edge of it dominated these areas. Red maple (*Acer rubrum*), black locust (*Robinia pseudoacacia*) and princess-tree (*Paulownia tomentosa*) were the most common trees, whereas blackberry and raspberry (*Rubus* sp.), multiflora rose (*Rosa multiflora*) and sourwood (*Oxydendrum arboreum*) were common species of shrub. Grasses, such as tall fescue (*Festuca arundinacea*), and forbs, such as goldenrod (*Solidago* sp.), also were common.

Twenty-four drainage channels (10 in Mud River and 14 in Twenty-mile Creek) characterized by rocks larger than 1 m in diameter and canopy cover levels greater than about 5% were chosen for trapping. Reclaimed land on each mine complex consisted of former MTMVF mines as well as contour mines. Reclamation techniques differed over time and among sites. MTMVF and contour mined sites generally differed in appearance. Contour mined sites were older with more established vegetation and were constructed of larger boulders than MTMVF sites. Moreover, topography on MTMVF drainage sites often was steep-sloping channels built into a terraced valley fill, whereas contour-mined sites had more gently sloping drainages. We chose trapping sites without regard to these factors because our objective was to identify basic characteristics of reclaimed drainage channels used by Allegheny woodrats.

TABLE 1.—Shrub and tree species recorded at 24 reclaimed drainage channels trapped for Allegheny woodrats on mountaintop mine/valley fill sites in southern West Virginia in 2000 and their potential food value to woodrats

Common name	Scientific name	Food value[a]	No. sites	Size class (DBH[b]) <3 cm	≥3–8 cm	>8–15 cm	>15 cm
Fruit and other soft mast							
Tree of heaven	*Ailanthus altissima*		9	35	14	12	11
Flowering dogwood	*Cornus florida*	*	2	1	1	0	0
Autumn olive	*Elaeagnus umbellata*	**	5	12	1	0	0
Princess-tree	*Paulownia tomentosa*		13	7	9	19	29
Pin cherry	*Prunus pennsylvanica*	**	3	4	0	0	0
Black cherry	*Prunus serotina*	**	3	1	0	4	0
Winged sumac	*Rhus copallinum*	*	1	3	0	0	0
Staghorn sumac	*Rhus typhina*	*	7	34	6	7	0
Multiflora rose	*Rosa multiflora*	*	9	271	0	0	0
Blackberry or raspberry	*Rubus* sp.	**	22	735	0	0	0
Blue elderberry	*Sambucus cerulea*	*	1	4	0	0	0
Blueberry	*Vaccinium* sp.	**	1	3	0	0	0
Grape	*Vitis* sp.		7	63	0	0	0
Seeds and other hard mast							
Box elder	*Acer negundo*	**	4	3	1	4	3
Red maple	*Acer rubrum*	**	17	66	16	20	0
Sugar maple	*Acer saccharum*	**	5	0	0	1	3
Yellow birch	*Betula allegheniensis*	*	1	0	0	1	0
Black birch	*Betula lenta*	*	8	33	35	25	13
American beech	*Fagus grandifolia*	*	1	1	1	1	0
White ash	*Fraxinus americana*		4	7	1	0	0
Green ash	*Fraxinus pennsylvanica*		1	1	0	0	0
Bicolor lespedeza	*Lespedeza bicolor*		3	12	0	0	0
Yellow-poplar	*Liriodendron tulipifera*		10	4	4	12	11
Pine	*Pinus* sp.	**	2	0	0	3	2
American sycamore	*Platanus occidentalis*	**	10	5	2	8	4
Black locust	*Robinia pseudoacacia*		22	55	27	85	38
Sassafras	*Sassafras albidum*		1	2	1	1	0
American basswood	*Tilia americana*		1	0	0	1	0
Bark and green vegetation							
Eastern redbud	*Cercis canadensis*		3	4	0	0	0
Sourwood	*Oxydendrum arboreum*		9	26	15	5	0
Willow species	*Salix* sp.		2	13	0	5	3
Bigtooth aspen	*Populus grandidentata*		3	4	2	1	6
Eastern hemlock	*Tsuga canadensis*	**	1	0	0	1	0
Non-food							
Snag			17	88	8	49	13

[a] Species followed by a single asterisk (*) have been identified as food sources for *Neotoma* sp. in other studies; two asterisks indicate that the species has been identified as a relatively important food source (Martin *et al.*, 1951; Castleberry, 2000a; Castleberry *et al.*, 2002b)

[b] Diameter at breast height

Allegheny woodrat trapping.—We baited Tomahawk®[4] live traps (Tomahawk Live Trap, Tomahawk, Wisconsin) with apples and placed them beneath overhanging rocks in the channel to protect captured animals from rainfall or extreme temperatures. Trapping was conducted for 2 consecutive nights from 3 to 28 July and 15 to 20 September 2000, with 2–10 traps placed at each drainage channel site. Number of traps used depended on the amount of rock habitat available at each site.

Captured Allegheny woodrats were ear-tagged, weighed, sexed, examined to determine reproductive condition and aged based on mass. Animals were classified as juvenile if they weighed less than 175 g, as subadults between 175–225 g and as adults if mass was >225 g (Castleberry, 2000b).

Habitat data collection.—We quantified vegetation and habitat variables (Table 2) on 1–2 plots in each channel using sampling methods modified from James and Shugart (1970) and Martin *et al.* (1997). We placed 0.04 circular plots at 50-m intervals along the approximate center of drainage channels. Within each plot, we identified individual trees to species and placed them into 2 DBH categories: >8–15 cm and >15 cm. Shrub, sapling and pole stems were counted within 4 transects (1-m wide by 11.3-m long) that radiated from the plot center to the plot edge (James and Shugart, 1970). Shrub was defined as any woody stem <3 cm DBH and <2 m in height; sapling included woody stems <3 cm DBH and >2 m in height; and pole stems were 3–8 cm DBH and >2 m in height. Percent ground cover (<0.5 m in height) and canopy cover ≥0.5-m high were estimated by sighting at the ground and upward at the canopy using an ocular sighting tube (James and Shugart, 1970) at 2.3-m intervals along each transect. Ground cover was recorded as green (all ferns, forbs and moss), only *Sericea lespedeza,* leaf litter, shrub, brier (*Rubus* sp. and *Smilax* sp.), downed woody debris, rock, bare ground or water.

To characterize rock structure in each channel, we made visual estimates of the depth to channel floor and the 3-dimensional size of rocks whenever rock groundcover was present. Approximate volume for each rock tallied was calculated as the product of width, length and height and used as an indicator of the relative amount of interstitial habitat between rocks. Aspect, slope, canopy height and drainage width were recorded at each plot (Table 2). A Global Positioning System unit was used to record location of each trapping station and ArcView 3.2 was used to measure distance to the nearest forest edge and elevation on digital aerial photos. Each site also was given a qualitative classification based on a system developed by the Pennsylvania Game Commission (1996) for evaluation of Allegheny woodrat habitat that incorporates habitat type, relative depth of interstitial spaces and size class of rocks (Table 3).

Statistical analyses.—We used habitat variables to assess differences between occupied and unoccupied sites; drainage channels in which 1 or more Allegheny woodrats were captured were considered occupied. Summary statistics (n, mean, standard error) were calculated for sites where Allegheny woodrats were present and absent, and means were compared with a two-sample *t*-test (Zar, 1999). Results of *t*-tests were considered significant at $P < 0.05$.

We used stepwise logistic regression to identify correlative habitat variables for Allegheny woodrat presence or absence. Aspect, elevation, distance to nearest forest edge, canopy height, percent canopy cover, channel width, channel depth, rock volume, percent groundcover categories, number of shrub and sapling stems (combined), number of pole stems, number of tree stems >8–15 cm DBH and number of tree stems >15 cm DBH were tested in the model. Variables entered the models at $P < 0.03$ and stayed in the models at

[4] Use of tradenames does not constitute endorsement by the federal government

TABLE 2.—Habitat variables at rock drainage channel sites where Allegheny woodrats were present and absent on mountaintop mine/valley fill sites in southern West Virginia in 2000

	Present (n = 13)				Absent (n = 11)					
	Mean	SE	Min	Max	Mean	SE	Min	Max	t	P
Aspect (°)[a]	189.3	28.9	40.0	331.0	185.5	29.4	5.0	312.0	0.78	0.44
Distance to forest edge (m)	215.9	35.0	39.0	399.0	229.1	43.9	45.0	595.0	−0.24	0.81
Elevation (m)	398.8	15.5	318.0	469.0	402.4	13.0	341.0	469.0	−0.17	0.86
Canopy height (m)	7.3	0.4	3.7	9.4	6.9	0.7	3.0	10.1	0.51	0.62
Canopy cover (%)[b]	47.9	7.6	10.0	100.0	40.4	8.1	5.0	90.0	0.80	0.43
Channel width (m)	10.4	1.0	6.0	17.0	9.9	1.6	4.0	24.0	0.29	0.78
Channel depth (m)	2.0	0.3	0.4	4.1	1.6	0.2	0.7	3.4	0.89	0.38
Rock volume (m^3)[c]	4.5	1.3	0.3	15.8	4.1	0.8	0.6	8.5	0.24	0.81
Ground cover (%)										
Green	26.5	4.3	5.0	55.0	39.3	5.5	15.0	67.5	−1.86	0.08
Leaf Litter	11.2	3.4	0.0	35.0	8.4	3.8	0.0	40.0	0.59	0.56
Shrub	3.8	1.9	0.0	20.0	6.1	3.1	0.0	35.0	−0.52	0.61
Brier	3.5	1.4	0.0	15.0	3.2	2.1	0.0	25.0	0.42	0.68
Woody debris	0.2	0.2	0.0	2.5	0.4	0.4	0.0	5.0	−0.36	0.72
Rock	49.6	5.3	5.0	70.0	30.2	4.1	10.0	55.0	2.62	0.02
Bare ground	1.1	0.6	0.0	5.0	1.8	1.0	0.0	10.0	−0.40	0.69
Water	1.1	1.2	0.0	15.0	0.0	0.0	0.0	0.0	1.00	0.33
Sericea	2.5	1.1	0.0	10.0	9.8	4.2	0.0	50.0	−1.83	0.08
Stem densities (no./plot)										
<3 cm (shrub and sapling)	41.8	6.6	5.0	86.0	66.2	11.7	13.5	131.0	−1.85	0.08
≥3–8 cm (pole)	5.0	0.9	0.0	11.0	4.9	1.4	0.0	14.0	0.06	0.95
>8–15 cm	8.0	1.3	1.0	17.0	9.4	2.2	0.0	28.0	−0.56	0.58
>15 cm	6.3	1.4	0.0	16.0	2.2	0.5	0.0	5.0	2.78	0.01
Species richness										
<8 cm DBH[d]	6.6	0.7	3.0	11.0	6.0	0.4	4.0	8.0	0.7	0.47
≥8 cm DBH	4.2	0.6	2.0	9.0	3.6	0.6	1.0	8.0	0.7	0.51

[a] Beers transformation performed on aspect prior to analysis (cos[45 − x] + 1) (Beers *et al.*, 1966); actual data presented in table

[b] Percentage variables were arcsine square root transformed before running *t*-test; actual data presented in table

[c] Calculated as the average of the product of the estimated length, width and height for rocks recorded as ground cover

[d] Diameter at breast height

P < 0.10. All statistical analyses were completed with the Statistical Analysis System (SAS Version 8, SAS Institute, Inc., 1998, Cary, North Carolina).

RESULTS

Allegheny woodrats were captured at 13 of 24 sites (54%). Of 23 individuals captured during 187 trap nights, 13 were adults in reproductive condition (6 males, 7 females), 2 were subadults (both males) and 8 were juveniles (3 males, 5 females). No subadults or juveniles were in reproductive condition. Juvenile Allegheny woodrats were captured at 4 of 7 sites where adult females also were captured.

Percentage of rock as groundcover (Wald $X^2 = 4.29$, $P = 0.04$) and tree stems >15 cm DBH (Wald $X^2 = 2.99$, $P = 0.08$) were the only variables identified by logistic regression as

TABLE 3.—Classification and percent occupancy by Allegheny woodrats of reclaimed drainage channels on mountaintop mine/valley fill sites in southern West Virginia in 2000

Rock habitat type[a]	Quality of habitat[a]	Rock size[a]	Mean no. stems >15 cm	No. sites trapped	Percent occupied
Talus	Bare rock, deep interstices	>3–5 m	1.0	2	0
Talus	Bare rock, shallow interstices	>1–3 m	4.6	7	71.4
Talus	Bare rock, shallow interstices	>3–5 m	2.6	6	33.3
Rock city, large float block	Bare rock, deep interstices	>5–10 m	6.8	8	75.0
Rock city, large float block	Bare rock, shallow interstices	>5–10 m	3.0	1	0

[a] Pennsylvania Game Commission (1996) protocol for assessment of Allegheny woodrat habitat

related to Allegheny woodrat presence. Allegheny woodrats were more likely to be present where both rock groundcover and density of trees >15 cm DBH were greater. Model fit was high (Somer's D = 0.776) with good predictive power (88.8% concordance). Additionally, *t*-tests identified rock groundcover and tree stems >15 cm DBH as habitat characteristics that were significantly greater where Allegheny woodrats were present (Table 2).

Reclaimed drainage channels fit into 5 categories (Table 3) using the Pennsylvania Game Commission's classification system for rocky habitat. Most sites (62.5%) were the talus habitat type, with 7 of 15 sites (46.7%) occupied by Allegheny woodrats. The remaining 9 sites were classed as the rock city, large float block habitat type; 6 (66.7%) were occupied by Allegheny woodrats. There did not appear to be use of any particular rock size or depth of interstices suggesting no association between these characteristics and Allegheny woodrat presence. Mean density of tree stems >15 cm varied from 1 to 6.8 trees within the 5 rock types. Rock types with higher stem densities were more likely to be occupied by Allegheny woodrats.

DISCUSSION

Typical Allegheny woodrat habitat consists of rock structure, such as outcrops, cliffs and limestone caves, surrounded by forest (Poole, 1940). The presence of Allegheny woodrats in constructed drainage channels on a MTMVF landscape was unexpected because channels were generally surrounded by large expanses of early-successional habitats such as grasslands or scrub-shrub. Canopy cover at our occupied sites averaged 50.2%, much lower than values of 71.5% and 80.4% reported in other parts of West Virginia (Myers, 1997; Wood, 2001). Castleberry *et al.* (2001) found that Allegheny woodrats in central West Virginia occupied rock outcrops adjacent to clearcuts when intact forest was maintained on one side of the outcrop; outcrops completely surrounded by clearcuts were not occupied. Although canopy cover at the rock outcrop itself was not reported, Allegheny woodrats foraged in clearcuts where canopy cover averaged 17.1%, as well as in the adjacent forest where canopy cover averaged 81.7%. Our results and those of Castleberry *et al.* (2001) suggest that Allegheny woodrats tolerate a wide range of canopy cover.

Allegheny woodrat occupation of drainage channels was associated with abundance of trees >15 cm DBH, although stem density was lower than typical Allegheny woodrat sites in other parts of West Virginia. Our drainage channels averaged 6.3 stems/plot >15 cm DBH, whereas other studies reported an average of 16.3 (Myer, 1997) and 10.9 (Wood, 2001). This reflects the early-successional state of reclaimed MTMVF sites. However, presence of at least some larger trees likely improved habitat quality of the drainage channels for Allegheny woodrats by providing shade and food. Many of the tree species present in channels potentially provide seeds, fruit or green vegetation eaten by Allegheny woodrats (Table 1; Martin *et al.*, 1951; Castleberry, 2000a).

The percentage of rock ground cover was strongly predictive of Allegheny woodrat presence in reclaimed areas. The amount of rock groundcover at MTMVF sites reflects the size of the area covered by drainage channels and may be an indicator of the complexity of interstitial networks and the ability of a site to provide predator protection and den sites. Other characteristics of rock channels such as channel depth, channel width and mean rock volume, appeared to be less important. Loosely piled boulders in drainage channels provided an uncountable number of crevices for protective cover and den sites. These channels may simulate natural boulder piles that form as rock crumbles from outcrops and that are known to provide Allegheny woodrat habitat. We found no quantitative description of natural boulder piles for comparison with rock channel width, depth and rock size that we measured at mine sites, but reclaimed drainage channels probably resemble this type of habitat more closely than they do natural rock outcroppings.

Classification of rock channels with the system developed by the Pennsylvania Game Commission (1996) did not suggest an association between rock habitat structure and Allegheny woodrat presence (Table 3). Myers (1997) used a modified version of this system and found that, despite talus rock structure being relatively scarce on his study areas (2.1% of sampling units), the percentage of talus sites occupied (2 of 7 sites, 28.7%) was comparable to the percentage classified as "rock outcroppings with numerous overhangs, crevices, and caves" (26 of 82 sites, 31.7%). He speculated that talus sites, with rocks <5 m in diameter, provide adequate interstitial space for Allegheny woodrat occupation. His sites classified as "rock city, large float block" in contrast, were rarely occupied (1 of 66 sites, 1.5%), possibly because large float blocks did not create the small interstices necessary to provide predator protection. Rock channels on the MTMVF sites were structurally similar to either the "talus" or the "rock city, large float block" categories. Unlike Myers (1997), however, a high proportion (66.7%) of our "rock city, large float block" sites were occupied by Allegheny woodrats. MTMVF drainage channels in this category generally contained numerous smaller rocks in the 1–3-m size range that possibly provided interstitial complexity comparable to Myers' talus sites, as well as containing a large boulder "overstory."

Conservation implications.—Habitat fragmentation has been suggested as one of the causes of Allegheny woodrat declines through the spread of disease, the increase in predator populations and the greater predator access to rock outcrops (Balcom and Yahner, 1996). Though our trapping effort did not assess the abundance of Allegheny woodrats, the presence of adults in reproductive condition and juveniles at the same sites suggests that rock channels provide at least minimally adequate breeding habitat within a highly disturbed landscape and that juveniles were not simply dispersers from other areas but were produced at those sites. Other studies in West Virginia support the idea that Allegheny woodrats can tolerate some disturbance. For example, Wood (2001) found Allegheny woodrats in close proximity to human disturbance and Castleberry *et al.* (2002b) determined that Allegheny woodrats were tolerant of a wide range of macrohabitat conditions in a commercial forest as long as microhabitat conditions were favorable.

The use of reclaimed drainage channels by Allegheny woodrats does not, however, imply that MTMVF is beneficial to the species. Allegheny woodrats typically inhabit natural rock outcrops that are found along ridgelines where erosion due to rain and other elements has worn away topsoil to expose rocks. MTMVF removes ridgelines where rock outcrops occur; consequently, Allegheny woodrat populations are likely to be lost due to MTMVF activities. This study was not designed to determine whether the habitat created adequately replaces—in quantity or quality—the habitat that is lost by MTMVF, though it may mitigate the loss of natural rock outcrops. Loose boulder piles apparently provide an acceptable alternative for Allegheny woodrats and also may substitute as habitat for other species that are associated with natural rock outcrops. Creating rocky habitat during reclamation using boulders of different sizes at low mid and upper slopes may maximize the number of species that benefit. In addition, it may be possible to expedite successional changes that make drainage channels more suitable for Allegheny woodrats. The positive relation between the density of tree stems >15 cm DBH and Allegheny woodrat presence at drainage channels suggests that planting trees during reclamation may improve Allegheny woodrat habitat. Tree species that can survive the harsh soil conditions should be planted, in particular fast-growing native species such as maples, poplars and ashes, as well as fruiting species such as cherries. Once these species become established, they will provide shade as well as perches for birds, which, in turn, will help disperse seeds and continue to advance the successional state. Tree species that provide hard mast, such as oaks, are important to Allegheny woodrats and have not become established at drainage channels. It is unknown whether they would survive in these areas, but their presence would be beneficial to Allegheny woodrats and other small mammals.

Our study suggests the need for further research to examine Allegheny woodrat populations on MTMVF sites and their linkage with populations in nearby natural rock structure. It is not known whether drainage channels act as viable subpopulations in a metapopulation or as sinks colonized by an overflow of individuals from adjacent forested lands (Hanski, 1996; Pulliam, 1988). A more intensive, long-term study is warranted, especially given the tenuous status of the Allegheny woodrat.

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