Rangeland Ecol Manage 63:253–257 | March 2010 | DOI: 10.2111/REM-D-09-00006.1

Research Note

Altered Herbivore Distribution Associated With Focal Disturbance

Ryan F. Limb,[1] *David M. Engle,*[2] *Samuel D. Fuhlendorf,*[3] *Donald P. Althoff,*[4] *and Philip S. Gipson*[5]

Authors are [1]*Senior Research Specialist,* [2]*Regents Professor, and* [3]*Professor, Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK 74078, USA;* [4]*Assistant Professor, School of Sciences, University of Rio Grande, Rio Grande, OH 84674, USA; and* [5]*Professor and Head, Department of Natural Resources Management, Texas Tech University, Lubbock, TX 79409, USA.*

Abstract

Natural disturbances historically created structurally diverse patterns across the landscape, and large herbivores concentrated herbivory in areas where disturbance decreased standing senesced biomass that acted as a grazing deterrent through decreased palatability and overall forage quality. However, following European settlement, many natural large-scale disturbance regimes that influence vegetation and herbivore grazing selection were altered or removed and replaced with fine-scale anthropogenic disturbances. It is unclear how fine-scale focal disturbance and alteration of vegetation structure influences livestock distribution and grazing. Therefore we used a tracked vehicle as a disturbance agent in a mesic mixed-grass prairie to assess the influence of focal anthropogenic disturbance on livestock distribution and grazing. Track vehicle disturbance decreased the height of vegetation ($P < 0.05$) but did not alter plant species composition ($P > 0.05$). Cattle fecal pat density was greater ($P \leq 0.05$) in locations with track vehicle disturbance. Little bluestem tiller height was shorter ($P \leq 0.05$) in tracked locations than nontracked locations in grazed treatments, but was not different in nongrazed locations the first growing season following disturbance. Fecal pat density and tiller height were not different ($P > 0.05$) between tracked and nontracked locations following the second growing season. Therefore, we concluded that fine-scale focal anthropogenic disturbance alters herbivore distribution and defoliation and can maintain structural heterogeneity, but the effect is ephemeral and does not create long-lasting grazing lawns.

Resumen

Los disturbios naturales crearon históricamente patrones de diversidad estructural en el paisaje, y los grandes herbívoros concentraron herbivoría en áreas en las que los disturbios provocaron disminución de la biomasa senescente que actuaba como factor de antiherbivoria a través de la baja palatabilidad y valor nutritivo. No obstante, luego de la colonización Europea, muchos de los regímenes naturales de disturbio de gran escala que ejercen una influencia sobre la vegetación y la selección de pastoreo por parte de los herbívoros fueron alterados o removidos y reemplazados por disturbios antropogénicos de escala fina. No está claro como los disturbios focales de escala fina y la alteración de la estructura de la vegetación alteran la distribución del pastoreo del ganado. De modo que utilizamos un vehículo con orugas como agente de disturbio en una pradera mésica mixta para evaluar la influencia de disturbios focales antropogénicos sobre la distribución y el pastoreo del ganado. El disturbio generado con el vehículo con orugas disminuyó la altura de la vegetación ($P < 0.05$), pero no alteró la composición de especies ($P > 0.05$). La densidad de fecas bovinas fue mayor ($P \leq 0.05$) en lugares disturbados por los vehículos con oruga. La altura de los macollos de *Schizachyrium scoparium* (Michx.) Nash disminuyó ($P \leq 0.05$) en lugares afectados por los disturbios comparado con lugares que no fueron afectados por los vehículos con oruga en tratamientos pastoreados, pero dichas alturas no fueron diferentes en lugares no pastoreados una temporada después del disturbio. No hubo diferencias en la densidad de fecas y la altura de macollos ($P > 0.05$) entre lugares disturbados y no disturbados luego de la segunda temporada de crecimiento después de la aplicación del disturbio. De modo que concluimos que los disturbios focales antropogénicos de escala fina altera la distribución de herbívoros y que la defoliación puede mantener la diversidad estructural, pero el efecto es efímero y no genera céspedes de pastoreo de largo plazo.

Key Words: anthropogenic disturbance, heterogeneity, tracked vehicles, vegetation structure

INTRODUCTION

Grassland ecosystems are dependent on disturbances such as fire, grazing, burrowing, and foraging activity by fossorial animals. Historically, bison wallowing created structurally diverse vegetation patterns, at multiple spatial and temporal scales, across the landscape (Coppock et al. 1983; Coppedge et al. 1999; Fuhlendorf and Engle 2001; Limb et al. 2009). Large herbivores concentrated herbivory in areas where disturbance decreased standing senesced biomass, which acted as a grazing deterrent through decreased palatability and overall forage quality. McNaughton (1978) noted that when highly palatable grasses and forbs were in close proximity to less palatable species, consumption of the highly palatable grasses and forbs was lower than when they were distant. Canopy of sagebrush can act as a barrier to herbivores, therefore protecting more palatable understory species (Davis and Bonham 1979). However, following European settlement, many natural dis-

Correspondence: Ryan F. Limb, NREM, 008c Agricultural Hall, Stillwater, OK 74078, USA. Email: ryan.limb@okstate.edu

Manuscript received 13 January 2009; manuscript accepted 3 December 2009.

turbance regimes that influence vegetation structure and herbivore grazing selection were altered or removed from grasslands and replaced with anthropogenic disturbances.

Anthropogenic activities, including military vehicle training exercises and livestock production, are commonplace within the current grassland landscape and partially mimic natural disturbance created by fossorial animals, bison wallowing, and fire. Vehicular disturbance, widespread throughout grasslands, can create soil disturbance during turn maneuvers, and while not a direct replacement, this disturbance can mimic the natural soils disturbances created by fossorial animals (Leis et al. 2005). A second affect of vehicular disturbance is the destruction of aboveground plant parts (Hirst et al. 2003), which effectively alters plant vertical structure and decreases grazing deterrents, similar to historical fire disturbances. However, unlike fire, vehicle disturbance is typically a fine-scale focal disturbance (Dale et al. 2005). It is unclear how a fine-scale focal vehicular disturbance and alteration of vegetation structure influences livestock distribution and preferential selection of grazing locations.

We used a tracked vehicle as a disturbance agent in a mesic mixed-grass prairie to assess the influence of focal anthropogenic disturbance on livestock distribution, grazing, and vegetation structure. We predicted that grazing animals would preferentially graze locations disturbed by tracked vehicles, as a result of decreased senesced plant height acting as a grazing barrier. Secondly, preferential grazing would maintain vegetation structural heterogeneity. We also predicted that the effect would persist for more than one growing season.

METHODS

The study was located at the Smoky Hills Air National Guard Bombing Range (Smoky Hills Range, hereafter) about 10 km southwest of Salina, Kansas. The Smoky Hills Range is 14 000 ha comprised of occasional sandstone formations intermixed with well-formed silty loam soils (Soil Conservation Service 1992). The climate is continental with 51% of the 802 mm annual precipitation occurring between May and August. July is the warmest month with a mean high temperature of 34°C and January is the coldest month with a mean high temperature of 3.9°C. The vegetation is classified as mixed-grass prairie with dominant grass species including little bluestem (*Schizachyrium scoparium* [Michx.] Nash), big bluestem (*Andropogon gerardii* Vitman), indiangrass (*Sorghastrum nutans* [L.] Nash), and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.). Prescribed fire is not intentionally used at the bombing range; however, due to frequent military training activity, fires frequently burn throughout the landscape. Portions of the Smoky Hills Range are continuously grazed 1 May through 31 October each year with cow/calf pairs, at a density of 1 animal unit $\cdot$ 2.8 ha^{-1} for the previous 25 yr.

In each of six 259-ha pastures we established two 100 × 100 m plots ≤ 75 m of each other but with similar soil and vegetation characteristics (Natural Resources Conservation Service [NRCS] 2004). In March 2006, before active spring growth, both plots were disturbed by a 39 000-kg tracked vehicle driven in a 2.8-km pattern, at constant speed, simulating military tracked vehicle maneuvers (Fig. 1). The track pattern planned for nearly equal amounts of both straight and turn maneuvers; however, the application resulted in mostly straight patterns with few abrupt turns. After the tracked-vehicle disturbance, we randomly selected one plot within each pasture and excluded it from grazing during the 2006 and 2007 growing seasons. Within each grazed and nongrazed plot, a 2 × 25 m belt transect was established at a disturbed location (tracked). A second 2 × 25 m belt transect was established at a random location (nontracked) between 25 m and 50 m distant of the 100 × 100 m disturbance plot. This resulted in a pair of transects (tracked and nontracked) for each plot. The disturbance severity by tracked vehicles depends on the pattern of vehicle movement, in which straight movement minimally disturbs soil but removes vegetation, and turn movement often results in greater soil disturbance. For this study, we focused on areas with straight vehicle movement.

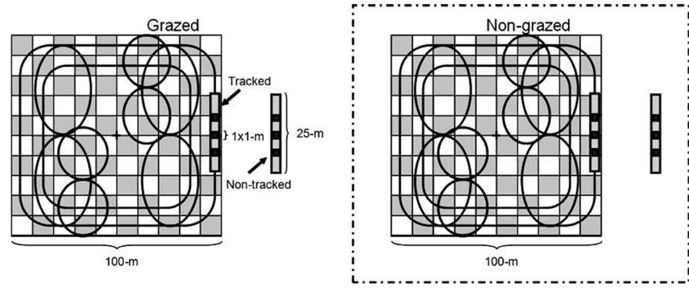

Figure 1. Focal disturbance pattern applied with a tracked vehicle to 100 × 100 mixed-grass prairie plots at the Smoky Hill Range near Salina, Kansas. Rectangles are belt transects located in straight-tracked locations and at random nontracked locations. Squares are plant species composition sampling locations within each belt transect. Dashed lines represent the grazing exclosure. Comparisons were between straight-tracked and nontracked locations within grazed or nongrazed treatment plots.

Along the center line of each 2 × 25 m belt transect, we measured the vegetation height nearest a point at 1-m intervals ($n = 25$) before and immediately after the focal disturbance, as an index to removal of barriers to grazing. Canopy cover of plant species, litter cover, and bare ground were estimated using modified Daubenmire cover classes (Daubenmire 1959) in June 2006 and 2007 within 1 × 1 m frames placed at three random locations within the tracked and nontracked transects.

To estimate cattle preference for tracked and nontracked areas, we counted fecal pats within tracked and nontracked transects in early October, which is at the end of the grazing season. Fecal pat counts are often used to monitor wildlife populations (Neff 1968), and although coarse and inexact, they can be used to estimate cattle abundance and distribution (Bailey and Welling 1999; Tate et al. 2003). Sample transects were randomly located within each pasture; therefore, fecal pats were not removed before the first year of treatment. Additionally, the tracked vehicle was likely to crush any existing fecal pats, so bias would favor the nontracked locations. All fecal pats were removed from both tracked and nontracked locations before the second year to reduce bias from the previous year. Fecal pat size can be an indication of animal movement or resting, and although not measured, fecal pat size visually appeared to be similar between tracked and

Table 1. Vegetation height, bare ground, and litter abundance (mean ± SE) in tracked and nontracked plots before and after tracked vehicle disturbance at the Smoky Hills Range near Salina, Kansas. Letters a and b represent differences ($P \leq 0.05$) between tracked and nontracked treatments within predisturbance or postdisturbance, and letters x and y represent differences ($P \leq 0.05$) between predisturbance and postdisturbance within respective tracked and nontracked treatments.

	Vegetation height (cm)		Bare ground (%)		Litter (%)	
	Tracked	Nontracked	Tracked	Nontracked	Tracked	Nontracked
Predisturbance	23.1 ± 8.5 a,y	27.2 ± 8.8 a,x	2.4 ± 0.8 a,x	2.2 ± 1.3 a,x	19.0 ± 2.3 a,x	21.1 ± 3.6 a,x
Postdisturbance	6.3 ± 1.2 a,x	26.8 ± 8.7 b,x	6.6 ± 1.3 a,x	5.5 ± 1.5 a,x	18.7 ± 4.4 a,x	20.3 ± 3.6 a,x

nontracked locations. To estimate defoliation intensity, the height of the nearest actively growing little bluestem tiller was recorded at 1-m intervals in early October, along the centerline of each tracked and nontracked transect. The height of little bluestem tillers was also measured in nongrazed plots to assess the effect of the tracked vehicle on aboveground plant growth. Little bluestem was selected because it is the dominant grass with near uniform spatial distribution in the study area (Limb 2008).

We used a two-tailed paired t-test to compare the mean tallest plant within each plot ($n = 12$; Steel et al. 1997). We pooled the grazed and nongrazed data to increase sample size because the mean height of the tallest plant, immediately following tracked vehicle disturbance, was not different ($P < 0.05$) between grazed and nongrazed plots. The fecal pat count ($n = 6$), height of little bluestem tillers ($n = 6$), litter abundance, and percent bare ground were compared between tracked and nontracked locations for both 2006 and 2007 and within location between years with a two-tailed paired *t*-test. Litter abundance and bare ground data were not distributed normally, and the Wilcoxon signed rank test, which is a nonparametric equivalent of the paired *t*-test, was used to evaluate these variables (Steel et al. 1997). We used permutation-based nonparametric multivariate analysis of variance (PERMANOVA) with a Sorensen distance measure (Anderson 2001) to compare the plant species composition between the tracked and nontracked locations. The mean from three frames within tracked and nontracked locations for plant species cover was used in the PERMANOVA.

RESULTS

Tracked vehicles did not alter bare ground ($P = 0.53$) or litter abundance ($P = 0.68$), but the disturbance decreased the height of vegetation ($P \leq 0.05$) located in tracked locations by nearly 20 cm (Table 1). Despite large variation in plant height in nontracked locations (SD = 21.3), tracked vehicle disturbance resulted in more uniform vegetation height (SD = 2.9; Table 1). However, plant composition did not differ between tracked and nontracked locations in 2006 or in 2007 ($P = 0.95$; data not shown).

Fecal pats were more abundant in tracked locations than nontracked locations the first year (2006) following treatment ($P \leq 0.05$), but fecal pat density did not differ between tracked locations and nontracked locations the second year (2007) following treatment ($P > 0.05$; Table 2). Cattle defoliated little bluestem more intensively (i.e., tiller heights were shorter) in tracked locations the first year (2006) following focal disturbance ($P \leq 0.05$); however, greater defoliation levels on tracked locations did not continue the second year (2007) following treatment (Table 2). Tracked vehicle disturbance in nongrazed plots did not affect little bluestem tiller height ($P > 0.05$) in either 2006 or 2007 (Table 2).

DISCUSSION

Consistent with our prediction, focal disturbance with a tracked vehicle decreased vertical vegetation structure and created structurally heterogeneous patches. Structural heterogeneity did not persist throughout the first growing season in nongrazed treatments. Shorter tillers of little bluestem and greater fecal pat density in tracked areas support our conclusion that cattle foraged preferentially within the vehicle tracks, which maintained structural heterogeneity throughout the growing season following the tracked vehicle disturbance. We were unable to detect persistence of the response into the second growing season. Fire, herbivory, and fossorial animal

Table 2. Little bluestem tiller height and cattle fecal pat density (pats · 50 m^{-2}; mean ± SE) within tracked and nontracked transects at the Smoky Hills Range near Salina, Kansas. Letters a and b represent differences ($P \leq 0.05$) between tracked and nontracked transects within respective grazing treatments for 2006 or 2007.

	Tiller height (cm)		Fecal pat density	
Treatment	2006	2007	2006	2007
Grazed				
Tracked	3.9 ± 1.7 a	10.7 ± 3.2 a	16 ± 2 b	11 ± 4 a
Nontracked	9.1 ± 2.9 b	10.8 ± 3.3 a	4 ± 1 a	11 ± 3 a
Nongrazed				
Tracked	9.0 ± 1.7 a	10.6 ± 3.1 a	—	—
Nontracked	9.1 ± 2.9 a	10.4 ± 3.3 a	—	—

disturbances historically reduced standing plant structure exposing plant parts with relatively high quality forage, which consequently attracted herbivores (Coppock et al. 1983; Fuhlendorf and Engle 2001). The coupled fire–grazing disturbance maintains structural heterogeneity throughout the growing season (Fuhlendorf and Engle 2004), but heterogeneity created by fire without grazing does not persist throughout the growing season (Bidwell et al. 1990). Grazing animals select foraging locations based on many factors, including forage quality, biomass, and intake optimization of both quality and quantity (Pyke 1984; Pinchak et al. 1991). Plant regrowth in heavily utilized areas is more palatable than adjacent non-utilized areas (McNaughton 1984; Illius and Gordon 1987), and therefore promotes recurring utilization and heterogeneity over multiple growing seasons.

Shorter plants within vehicle tracks in 2006 indicate that cattle preferentially grazed within the vehicle tracks, which created a grazing lawn. Grazing lawns, locations with repeated heavy grazing and short vegetation, often persist for multiple seasons (McNaughton 1984; Collins 1987; Coppedge and Shaw 1998), and they are prevalent in landscapes absent periodic large-scale disturbances (such as fire) that redistribute herbivore spatial preferences (McNaughton 1985; Karki et al. 2000). We expected the grazing lawn to persist within the vehicle tracks in the second year of the study, reasoning that cattle would continue to prefer grazing in the tracked locations in the second year because we did not impose a new set of track disturbances to attract grazing. However, the grazing lawns did not persist into the second year, and therefore, neither did the enhanced structural heterogeneity.

We believe that grazing pressure was insufficient to maintain the grazing lawn in the second year because of unusually favorable plant growth conditions, which is known to reduce heterogeneity of moderately stocked rangeland in this region (Pfeiffer and Hartnett 1995). The stocking rate at the Smoky Hills Range was set at moderate NRCS-recommended rates (NRCS 2004) and designed to favor persistence of taller grasses. By design, stocking rate was insufficient to maintain short-statured vegetation, particularly with abundant precipitation in 2007.

We observed no evidence of persistent effects of tracked vehicle disturbance, even though tracked vehicle disturbance often compacts the soil and can reduce aboveground herbaceous growth (Althoff and Thein 2005). Little bluestem height and plant species composition were unaffected by tracked vehicle disturbance in the absence of grazing in our study. Tracked vehicle disturbance on wet soil in tallgrass prairie, about 90 km northeast of our study area, decreased vegetation biomass nearly three times more than disturbance in areas with less soil moisture (Althoff and Thein 2005). Dry soil in 2006 in our study precluded soil compaction and change in plant growth and vegetation composition.

MANAGEMENT IMPLICATIONS

Given the benefits of heterogeneity to livestock, wildlife, and biodiversity (Fuhlendorf and Engle 2001; Limb et al. 2009), tracked vehicle disturbance coupled with grazing is a potential management tool to create and maintain structural heterogeneity throughout a growing season. If the soil is dry at the time of track vehicle disturbance or favorable growing conditions occur following track vehicle disturbance, grazing lawns within the vehicle tracks, which enhance structural heterogeneity, might not persist beyond the first growing season. If so, multiple tracked vehicle disturbance events might be necessary to maintain grazing lawns and enhance structural heterogeneity, and relocating the tracked vehicle disturbance over the landscape in subsequent years could create a fine-scale shifting mosaic pattern of disturbance.

ACKNOWLEDGMENTS

This research was funded by the Oklahoma Agricultural Experiment Station, and the US Army Construction Engineering Laboratory grant number W9132T-07-P-0095. Thanks go to Alan Anderson, Heidi Howard, and Galen Wiens for collaboration efforts.

LITERATURE CITED

Althoff, P. S., and S. J. Thien. 2005. Impact of M1A1 main battle tank disturbance on soil quality, invertebrates, and vegetation characteristics. *Journal of Terramechanics* 42:159–176.

Anderson, M. J. 2001. A new method for nonparametric multivariate analysis of variance. *Austral Ecology* 26:32–46.

Bailey, D. W., and G. R. Welling. 1999. Modification of cattle grazing distribution with dehydrated molasses supplement. *Journal of Range Management* 52:575–582.

Bidwell, T. G., D. M. Engle, and P. L. Claypool. 1990. Effects of spring headfires and backfires on tallgrass prairie. *Journal of Range Management* 43:209–212.

Collins, S. L. 1987. Interaction of disturbances in tallgrass prairie: a field experiment. *Ecology* 68:1243–1250.

Coppedge, B. R., S. D. Fuhlendorf, D. M. Engle, and B. J. Carter. 1999. Grassland soil depressions: relict bison wallows or inherent landscape heterogeneity. *American Midland Naturalist* 142:382–392.

Coppedge, B. R., and J. H. Shaw. 1998. Bison grazing patterns on seasonally burned tallgrass prairie. *Journal of Range Management* 51:258–264.

Coppock, D. L., J. E. Ellis, J. K. Detling, and M. I. Dyer. 1983. Plant-herbivore interactions in a North American mixed-grass prairie II. Responses of bison to modification of vegetation by prairie dogs. *Oecologia* 56:10–15.

Dale, V., D. L. Druckenbrod, L. Baskaran, M. Aldridge, M. Berry, C. Garten, L. Olsen, R. Efroymson, and R. Washington-Allen. 2005. Vehicle impacts on the environment at different spatial scales: observations in west central Georgia, USA. *Journal of Terramechanics* 42:383–402.

Davis, J. H., and C. D. Bonham. 1979. Interference of sand sagebrush canopy with needle-and-thread. *Journal of Range Management* 32:384–386.

Daubenmire, R. F. 1959. A canopy coverage method of vegetation analysis. *Northwest Science* 33:43–64.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. *Bioscience* 51:625–632.

Fuhlendorf, S. D., and D. M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology* 41:604–614.

Hirst, R. A., R. F. Pywell, R. B. Marrs, and P. D. Putwain. 2003. The resistance of a chalk grassland to disturbance. *Journal of Applied Ecology* 40:368–379.

Illius, A. W., and I. J. Gordon. 1987. The allometry of food intake in grazing ruminants. *Journal of Animal Ecology* 56:989–999.

Karki, J. B., Y. V. Jhala, and P. P. Khanna. 2000. Grazing lawns in terai grasslands, Royal Bardia National Park, Nepal. *Biotropica* 32:423–429.

Leis, S. A., D. M. Engle, D. M. Leslie, Jr., and J. S. Fehmi. 2005. Effects of short- and long-term disturbance resulting from military maneuvers on vegetation and soils in a mixed prairie area. *Environmental Management* 36:849–861.

Limb, R. F. 2008. The effect of disturbance on grassland communities [dissertation]. Stillwater, OK, USA: Oklahoma State University. 109 p.

Limb, R. F., S. D. Fuhlendorf, and D. E. Townsend. 2009. Heterogeneity of thermal extremes: driven by disturbance or inherent in the landscape? *Environmental Management* 43:100–106.

McNaughton, S. J. 1978. Serengeti ungulates: feeding selectivity influences the effectiveness of plant defense guilds. *Science* 199:806–807.

McNaughton, S. J. 1984. Grazing lawns: animals in herds, plant form, and coevolution. *American Naturalist* 124:863–886.

McNaughton, S. J. 1985. Ecology of a grazing ecosystem: the Serengeti. *Ecological Monographs* 55:259–294.

Neff, D. J. 1968. Pellet-group count technique for big game trend census and distribution—a review. *Journal of Wildlife Management* 32:597–614.

[NRCS] Natural Resources Conservation Service. 2004. The electronic field office technical guide. Available at: http://www.nrcs.usda.gov/technical/eFOTG/. Accessed 9 February 2006.

Pfeiffer, K. E., and D. C. Hartnett. 1995. Bison selectivity and grazing response of little bluestem in tallgrass prairie. *Journal of Range Management* 48:26–31.

Pinchak, W. E., M. A. Smith, R. H. Hart, and J. W. Waggoner, Jr. 1991. Beef cattle distribution patterns on foothill range. *Journal of Range Management* 44:267–275.

Pyke, G. H. 1984. Optimal foraging theory: a critical review. *Annual Review of Ecology and Systematics* 15:523–575.

Soil Conservation Service. 1992. Soil survey of Saline County, Kansas. Washington, DC, USA: National Cooperative Soil Survey—United States Department of Agriculture. 122 pp.

Steel, R. D., J. H. Torrie, and D. A. Dickey. 1997. Principles and procedures of statistics a biometrical approach. 3rd ed. Boston, MA, USA: McGraw-Hill. 666 p.

Tate, K. W., E. R. Atwill, N. K. McDougald, and M. R. George. 2003. Spatial and temporal patterns of cattle feces deposition on rangeland. *Journal of Range Management* 56:432–438.