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Technical note

Carrying capacity of white-tailed deer (*Odocoileus virginianus texanus*) in northeast Mexico

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Abstract:

White-tailed deer (*Odocoileus virginianus texanus*) is widely distributed in the desert scrublands of Mexico and is both ecologically and economically important. Knowledge about forage production in deer habitat is essential to designing effective management plans. It was used aboveground biomass production in microphyllous desert scrub to calculate carrying capacity (K) for white-tailed deer as a reference in extensive management of this species in the municipality of Monclova, Coahuila, in northern Mexico. Data were collected at the

Rancho San Juan Wildlife Conservation Management Unit during a full seasonal round: October 2018 to August 2019. The Adelaide method was used to estimate production in high, middle and low vegetation strata. Estimation of K was based on the Holechek model. Average seasonal biomass production was 621.19 kg DM ha^{-1}. Production was highest in the middle stratum (377.77 ± 73.92 kg DM ha^{-1}), and lowest in the high stratum (37.59 ± 23.59 kg DM ha-1). Production was highest in summer (744.35 kg DM ha^{-1}) and fall (607.93 kg DM ha^{-1}). Estimated K was 4.94 ha per deer annually, equivalent to 209 deer in a 1,030 ha area. Aerial census of the deer population in October 2020 recorded a density of 1.77 ha per deer, or 582 deer in the same area. Although this is more than double the calculated K for the study area, it highlights the role of supplementary feed and water in maintaining deer population growth.

Key words: Aerial biomass, Density, Microphyllous desert scrub, Adelaide method, Holechek model.

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Sustainable management of white-tailed deer (*Odocoileus virginianus texanus*) habitat involves assessing its carrying capacity (K). This parameter, linked to habitat conditions, is defined as the number of animals that rangeland can support per unit of surface area without causing deterioration in the plant community or other resources(1). It is useful for identifying fluctuations in natural forage production and quality(2). Carrying capacity varies constantly in time and space. It is influenced by density-independent factors such as the availability of food, water, cover and usable space, as well as by density-dependent factors related to animal density per unit area(3).

Of the models used to estimate K, those that incorporate forage production generate values useful to rangeland managers in northern Mexico(1,3). Trends in plant biomass production and forage utilization, the latter defined as the amount of organic matter per unit of surface area used as an energy source by herbivores(1), are significant elements in the concept of K because, for deer, a decline in forage production indicates that animal density is exceeding K(4). Unlike climate, the habitat elements of forage availability and production can be influenced by habitat improvement techniques. Of course, model results are estimates(3). It is also best to produce region-specific estimates to calculate K in managed white-tailed deer populations and, because forage production conditions vary by region, to avoid utilizing K results from one region in other regions and ecosystem types(4).

White-tailed deer population density varies geographically. For example, in the United States, the Edwards Plateau in the state of Texas boasts the highest density of white-tailed deer in the world: more than 0.45 deer ha^{-1}(3). In contrast, parts of the High Plains and Rolling Plains regions support less than 0.15 deer ha^{-1}. Deer densities in the Cross Timbers and South Texas Plains regions range from 0.15 to 0.30 deer ha^{-1}(3). Although poaching and habitat degradation in northern Mexico drove white-tailed deer near extinction in the 1970s, current population densities are estimated to range between 0.10 and 0.20 deer ha^{-1}(5). In Tlachichila in the Sierra El Laurel mountains, in the state of Zacatecas, Mexico, deer density is 0.03 deer ha^{-1}(6).

Carrying capacity also varies within Mexico. In the La Michilía Biosphere Reserve, in the state of Durango, estimated K is 0.22 deer ha^{-1}(7). In dry tropical forest in the state of Jalisco, estimated K is 0.16 to 0.18 deer ha^{-1}(8), and in the Mixteca region, it is 0.10 deer ha^{-1}(9). White-tailed deer may be one of the most studied herbivore species in North America, but it is still essential to individually assess each area where it is managed extensively. This is particularly relevant in fragmented habitats because K is influenced by the size and connectivity of preserved habitat fragments(8).

Available forage directly influences herbivore population trends, so K based on forage production provides the most practical conceptual foundation for extensive deer management(6,9). The present study objective was to estimate seasonal forage production in microphyllous desert scrub vegetation in eastern Coahuila, Mexico, and calculate K for white-tailed deer to produce data for use in management plans and habitat conservation strategies for this species in northeastern Mexico.

The study was done in the Rancho San Juan Wildlife Conservation Management Unit (UMA) (26° 49’ 31.11’’ N, 101° 01’ 57.77’’ W), in the municipality of Monclova, in the state of Coahuila, Mexico. This UMA is located 38 km east of the municipal seat and 43 km west of the municipality of Candela. The predominant vegetation types in this area are microphyllous desert scrub and rosetophyllous desert scrub, with some open medium grassland associations(10). The climate is dry (BSohw), with an average temperature of 21°C. Annual precipitation varies from 200 mm to 900 mm, and elevation ranges from 600 to 1,000 m asl(11). Extensive management of a population of Texas white-tailed deer is done in a 1,030 ha area at this UMA.

To estimate K values, forage production was evaluated over a full seasonal round: fall (October 2018), winter (February 2019), spring (May 2019) and summer (August 2019). Using the Adelaide method, forage production was expressed as the amount of aerial biomass per plant stratum(12). Forage production in the high stratum (>1.5 m) was quantified in 18 parcels covering 50 m^2, and for the middle stratum (<1.5 m) 18 plots of 25 m^2 were used. To estimate the number of units of each specimen and the sampled species in each plot, a representative unit of each plant per species was selected considering its leaf shape and density. In the lower stratum, grasses and herbaceous plants, production was quantified by completely harvesting 18 plots of 1 m^2, according to the methodology proposed by Chávez[13]. All biomass samples (grasses and herbaceous plants, plus the reference units) were placed in paper bags, labeled and dried in an oven (120VAC 60HZ INOX) at 75 °C to constant weight. After drying, sample dry weight was measured using a scale (ENTRIS 8201-1S). These data were used to calculate biomass production with the equation[12]:

$$Bt = Wd * ni$$

Where: Bt = total aerial biomass (kg DM ha^{-1}); Wd = dry weight of each manual sample; ni = number of replicates of species i inside each parcel.

Seasonal differences in biomass production were calculated using a non-parametric Kruskal-Wallis test ($\alpha \leq 0.05$) run with RStudio[14].

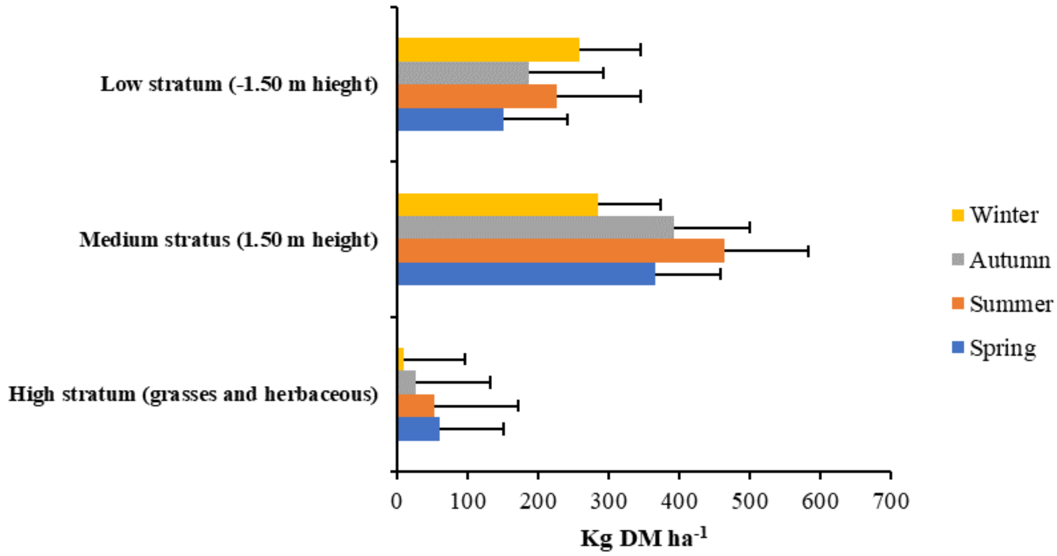
Carrying capacity was calculated with the forage production results, and expressed as the number of animals per hectare (deer ha^{-1}) per year. Only 25 % of the area's total biomass production was used in the calculation because this conservative value allows for a sustainable estimation of animal load with the goal of maintaining long-term, stable forage production[1]. Calculation of K was done using study area surface area, available biomass, live deer weight and daily dry matter intake (%), with the equation[1]:

$$K = \frac{LW \times DIDM \times GC}{DMP \times 0.25}$$

Where: K= carrying capacity (deer ha^{-1}); LW= animal live weight (kg); DIDM= daily intake dry matter (3 % LW); GC= grazing cycle (365 d); DMP= dry matter production (kg ha^{-1}); 0.25= forage utilization percentage (25 %).

Average annual forage production in the studied microphyllous desert scrub was 2,484.77 kg DM ha^{-1}. Estimated average biomass production per season was 621.20 ± 85.08 kg DM ha^{-1}. Biomass production was highest in the summer (744.36 ± 44.20 kg) and fall (607.93 ± 57.77 kg), and lowest in the winter (553.36 ± 50.12 kg) (Figure 1). All these seasonal production levels are relatively low compared to the 1,501 ± 492.35 kg DM ha^{-1} per season reported in a study in the state of Tamaulipas[15], and the 929.2 ± 401.64 kg reported in Zacatecas[6].

Figure 1: Aerial biomass production by vegetation stratum and season at the Rancho San Juan UMA, Monclova, Coahuila, Mexico.



Lines extending to right of colored bars indicate standard error.

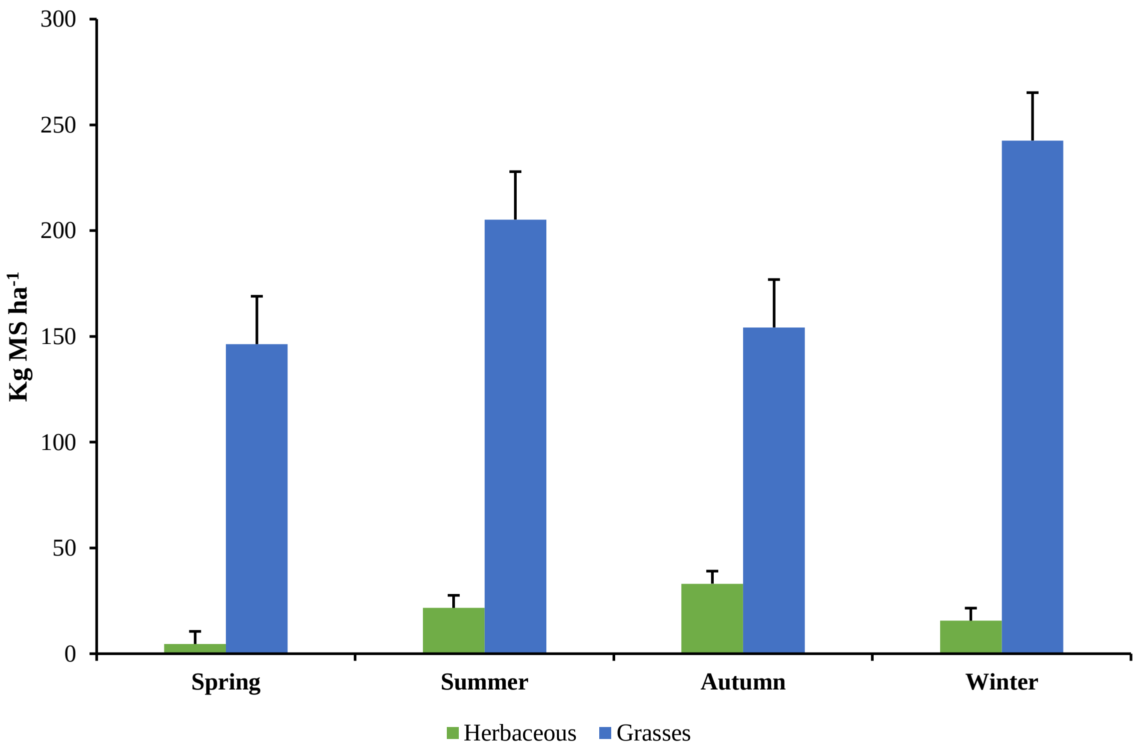
Habitat biomass production directly affects deer development and, therefore, the low production observed here had a direct impact on vegetation K. An adult deer requires a daily biomass intake of 2 to 4 % of its body weight (60 kg average for adult animal and 0.13 animal unit)[3,4,16]. However, this intake varies in response factors such as physiological state, animal age, nutritional value of available plants, forage species composition and forage spatial distribution[17].

An example of this is that adult male body weight increases rapidly during spring, which increases their forage intake[16]. But this coincides with the season of lowest natural forage availability (Figure 1). To stabilize the deer population during this time of year, food supplementation strategies are implemented at the Rancho San Juan UMA. A total of 39 feeders are installed to supplement nutrients from natural sources at critical times of the year, normally from the first half of March to the end of October. During this period, the forage species preferred by deer are scarce. At the feeders, deer have free access to feed consisting of pellets containing 18 % crude protein (CP) and cotton seed. This feed helps to promote muscle gain, antler development, and milk production[4].

The seasonal variations in above-ground biomass production observed here (Figure 1) coincide with seasonal fluctuations in forage intake by deer reported for South Texas. In this region, a drop in forage intake occurs in the summer, followed by an increase in the fall, and another decline in the winter[18].

Among the three vegetation strata, the middle stratum contributed the most to aboveground biomass in all four seasons. This stratum's contribution was highest in the summer (Figure 1; 1,858.52 kg DM ha^{-1}), largely due to relatively high rainfall (80 mm) in July 2019. The low stratum (grasses and herbaceous plants) produced the largest amount of aboveground biomass during the winter (Figure 2; 1,032.70 kg DM ha^{-1}). The high stratum produced the lowest contribution overall: ≤ 250 kg (Figure 1).

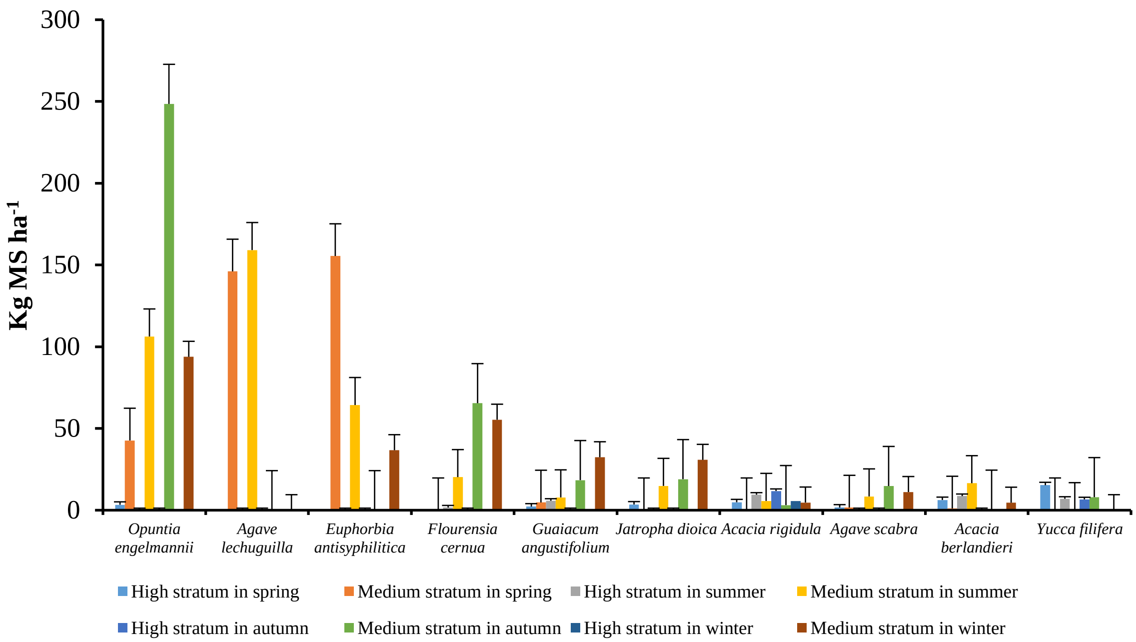
Figure 2: Seasonal dry matter production of grasses and herbaceous plants at the Rancho San Juan UMA, Monclova, Coahuila, Mexico



Lines extending to right of colored bars indicate standard error.

During the spring, the plants *Euphorbia antisyphilitica* and *Agave lechuguilla* provided the highest vegetal biomass contribution (Figure 3), but in conjunction only represented 3.86 % of the white-tailed deer diet in this season(19). However, the cactus *Opuntia engelmannii*, an important forage species for white-tailed deer in northeastern Mexico(4,19), was among the ten species with the highest biomass production in spring. In contrast, the perennial shrub *Eysenhardtia texana*, another important deer forage plant, made the lowest biomass contribution (0.06 kg DM ha^{-1}) in spring.

Figure 3: The ten high- and middle-stratum plant species with the highest seasonal biomass contribution at Rancho San Juan UMA, Monclova, Coahuila, Mexico



Lines extending above the colored bars indicate standard error.

In summer, *A. lechuguilla* and *O. engelmannii* made the greatest contribution to biomass (Figure 3; 265.35 kg DM ha^{-1}), although *O. engelmannii* accounted for a relatively low proportion (4.29 %) of the deer diet[19]. *Acacia rigidula*, another important forage species in the summer (12.57 %)[19], did not have a particularly high biomass production.

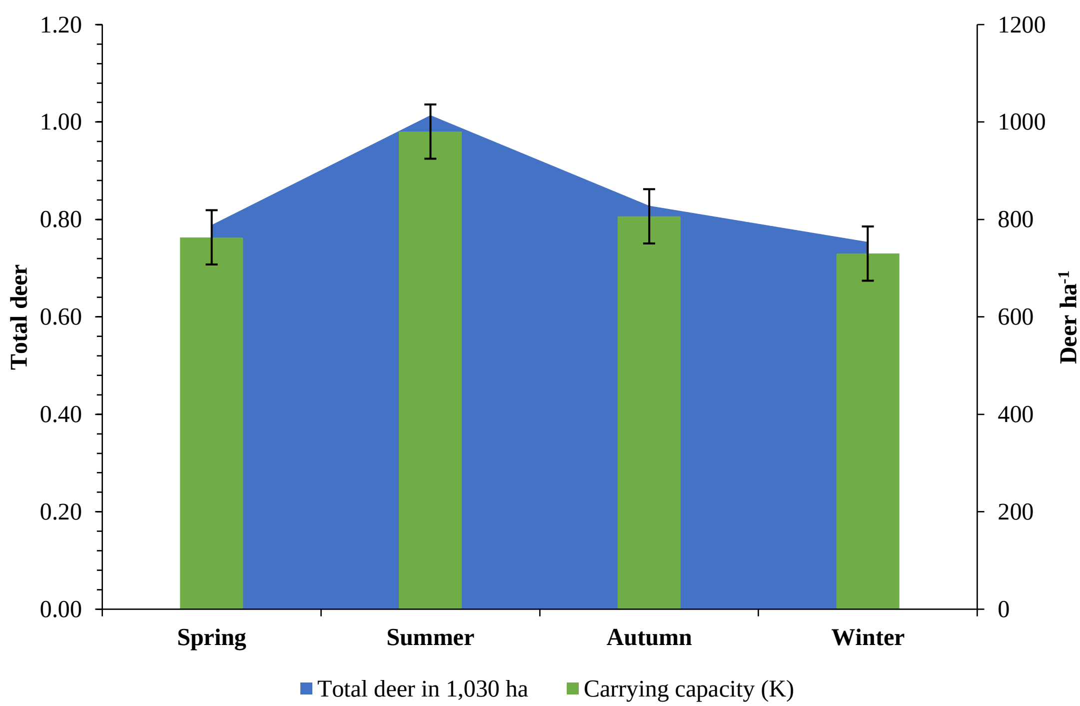
In autumn, *O. engelmannii* contributed most to total biomass production (40.87 %) (248.49 kg DM ha^{-1}) and accounted for 15.40% of the deer diet (Figure 3)[19]. In winter, *O. engelmannii* contributed 16.95 % (93.80 kg) of the biomass production, and 14.90 % of the deer diet[19]. Although important as a deer forage in autumn[4], *A. rigidula* contributed only 2.44 % (14.85 kg DM ha^{-1}) of the biomass production in this season. Similarly, *Leucophyllum frutescens* provided only 0.01 % (3.07 kg DM ha^{-1}) of biomass production in autumn but was 10.61% of the deer diet[19,20].

White-tailed deer show a marked preference for consumption of shrub leaves and stems since these plant elements have a higher protein content and relatively lower fiber and lignin levels[4]. Scrubland is a major source of shrub biomass year round (Figure 1), but primarily in the summer, when does require more forage to produce milk for fawns[3]. Grass and herbaceous plant production is also essential since deer resort to them when facing competition for food[4]. Grasses with high lignin content and a low digestibility percentage (1.4) show a higher average aboveground biomass production (187.11 ± 45.28 kg DM ha^{-1})

per season, and represent up to 43.84 % of total winter biomass production (Figure 2). Of note is that *Acacia berlandieri* and *A. rigidula*, both scrubland plants preferred by deer(4,19,20), have average seasonal biomass production (18.79 ± 15.13 kg DM ha^{-1}) that is <5.5 % of their average seasonal aerial aboveground biomass production (621 ± 85.08 kg DM ha^{-1}).

Aboveground biomass production was used in estimating K for white-tailed deer. In the present results, overall K was calculated as 0.2 (± 0.15) deer ha^{-1}, equivalent to 209 deer in 1,030 ha (Figure 4). It was higher in spring (0.76 deer ha^{-1}) and winter (0.73 deer ha^{-1}). An aerial deer population survey done in October 2020 (parallel N/S transects of variable length at 200 m spacing) estimated a density 0.57 deer ha^{-1} (i.e., 582 deer) in 1,030 ha. This deer density is over twice the calculated K for this UMA. The studied population has apparently grown beyond habitat K in response to the supplementary feed and water supplied by unit managers, however, deer in this UMA have been documented eating native grasses, suggesting forage overuse(3). In addition, plant species known to be key in the deer diet, such as *A. rigidula* and *A. berlandieri*, contributed significantly less to biomass production than the grasses.

Figure 4: Carrying capacity (K) for white-tailed deer at the Rancho San Juan UMA, Monclova, Coahuila, Mexico



Lines extending above the bars indicate standard error.

The K calculated in the present study (0.2 deer ha^{-1}) is lower than the 0.03 deer ha^{-1} reported for the Sierra El Laurel, in Tlachichila, Zacatecas(6), but similar to the 0.22 deer ha^{-1} reported for the La Michilía Biosphere Reserve, Durango(7). Lower K values have been reported for dry tropical forest in Jalisco (0.16 and 0.18 deer ha^{-1})(8) and the Mixteca region (0.16 and 0.18 deer ha^{-1})(9); in both these regions deer population density is below K.

Sampling methods can introduce error into estimates of K based on forage biomass. For example, sampling strategies often do not consider herbivore grazing patterns(21). In addition, the 25 % standard forage use value (considered a conservative value because it prevents overestimation of the number of animals per unit area that a habitat can sustainably support)(22,23) included in calculation of K does not contemplate losses due to trampling, and forage contamination by feces, rodents and insects. In a study done in the state of Utah, United States of America, 23 % trampling losses of available forage were reported(5), and in a study in desert grasslands, small mammals were found to consume up to 20 % of the forage available to large herbivores(4).

Estimates of K should be considered as approximations, but are useful as indicators to guide management decisions for white-tailed deer habitat(3). Management decisions should be based on temporal trends in K capacity; a decrease in K means animal load could need to be reduced(24). In addition, calculations of the relationship between forage production in forage species and forage nutritional value are useful in refining estimates of K, and should be done annually.

Estimates of animal carrying capacity and aboveground biomass production are valuable in extensive management of white-tailed deer populations in northeastern Mexico. Forage production varies by vegetation stratum and season of the year, with the highest values observed in the middle stratum in summer and fall. The carrying capacity calculated for the Rancho San Juan UMA during the study period was higher than some previous reports in Mexico. Although the population density exceeded the ecosystem's carrying capacity, feed supplementation strategies may have been acting as buffers, preventing forage overuse and consequent population decline. Future research can focus on evaluating how the use of supplemental feed and water might affect ecosystem carrying capacity.

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Conflict of interests

The authors declare no conflict of interests.

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