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RESEARCH ARTICLE

The Eldari tick *Ixodes eldaricus* (Acari: Ixodidae) in Israel: its occurrence, morphometric and biological characteristics

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ABSTRACT: An isolated population of the Eldari tick *Ixodes eldaricus* Dzhaparidze was studied in the southernmost part of the tick range (western surroundings of Jerusalem, Israel). Unfed adult and nymphal ticks were active from November through April. Ticks could be collected by flagging only from the grass just above the earth. A bimodal activity pattern was observed for adults with a decline in January characterized by the lowest air temperatures. Nymphal ticks had smaller size of their scutum as compared with specimens from the main part of the range. No mating adults were found during survey but when placed in a tube, males and females were immediately observed in the mating position. No tendency to attack humans or attach to them were registered in the field or in laboratory experiments. While having no apparent epidemiological significance, *I. eldaricus* deserves attention because of its possible role in epizootiology of rickettsial infections, which are common in the area of the survey.

Keywords: *Ixodes eldaricus*, *redikorzevi* group, season of tick activity, tick size and weight, mating, human affinity, epizootiology, Israel.

Zoobank: http://zoobank.org/C6F88386-7412-4AD9-B461-28C9D9409A01

INTRODUCTION

In the last decades, the interests of acarologists have been concentrated on about 20-25 tick species of clear medical or veterinary importance (Uspensky, 2006). Hundreds of other species have been favored with researcher's attention only occasionally, if at all. The Eldari tick, *Ixodes eldaricus* Dzhaparidze, 1950, is one of such scarcely studied species. The species was described based on a specimen of an adult female collected near Eldari village located in the Eldari valley (Georgia, then Georgian SSR of the USSR) (Dzhaparidze, 1950). Since its description, only a couple dozen papers have been published, mainly documenting findings of the species in different areas or on various hosts. Only fragmentary information on its biology and ecology can be gleaned from the published literature.

Ixodes eldaricus is the member of the subgenus *Ixodes* (s. str.). The species was considered closely connected with representatives of the *persulcatus* group (Filippova, 1974, 1977, 2008). Later the species was included together with *I. redikorzevi* Olenev, *I. occultus* Pomerantzev and *I. laguri* Olenev in a newly created *redikorzevi* group (Filippova, 2008).

The range of *I. eldaricus* includes the Crimea, the Caucasus (Georgia, Armenia, Azerbaijan, and Dagestan of Russia), Central Asian states (Turkmenistan, Tadzhikistan, Uzbekistan, southern parts of Kazakhstan and Kirgizstan), Iraq and Israel (Filippova, 1974, 1977; Kolonin, 1981). The tick inhabits mountain forests at 300 to 1,800 m above sea level (a.s.l.). Adults parasitize birds, while preadults parasitize birds as well as some small mammals (rodents and insectivores). Nymphs and adult ticks were found on spring migrating birds in Cyprus (Kaiser et al., 1974), Poland (Nowak-Chmura, 2012) and in Turkey (Keskin and Erciyas-Yavuz, 2019). The morphological description of all parasitic stages of *I. eldaricus* as well as the available data on its ecology and biology were summarized by N.A. Filippova (1974, 1977).

In Israel *I. eldaricus* was first collected from the rock partridge, *Alectoris graeca* Meisner (apparently, its eastern equivalent the Chukar partridge, *A. chukar* [J.E. Gray]), about 20 km south of Jerusalem, this finding being first attributed to a new species *Ixodes tatei* Arthur described by Arthur (1959, 1968) on the basis of findings in Iraq. Later *I. tatei* was synonymized with *I. eldaricus* (Filippova, 1974). Yeruham et al. (1995) collected all stages of *I. eldaricus* on the western foothills of Judea (30 km west of Jerusalem) by dragging and flagging. Larvae were also collected from 2 species of rodents, *Acomys cahirinus* (É. Geoffroy) and *Mus musculus* L.

The results of our survey of *I. eldaricus* including data on size and weight characteristics and biological patterns of this tick are presented below.

MATERIALS AND METHODS

The site of the survey is located in a hilly area of the Judean Mountains in the western part of Judea (20 km west from Jerusalem). The area is covered with natural Mediterranean forests as well as with planted pine trees. Southwestern (with a creek drying in the summer) and northeastern slopes of a valley along the road Abu-Gosh - Nataf at 550 to 600 m a.s.l. (31°82'N, 35°09'E) were under observation. Ticks were collected by flagging (a white flannel flag by 1x1 m) during October-April 2006/2007. The collections were carried out twice per month on both

slopes, along roads, which are rarely used. Two collectors worked at each site for 45 to 60 min. The tick abundance was estimated as the number of ticks collected by 1 person during 1 hour. During a total of 45 hours of collection, over 200 ticks (adults and nymphs) were collected. The average daily and monthly temperatures in Jerusalem area, multiannual and for the period of the survey, were taken from the archive of the Central Bureau of Statistics (Israel) (http://www.cbs.gov.il). Twice during that period goats from a farm nearby were inspected. An attempt was also undertaken to collect ticks in the area of Yeruham's survey (1995); sporadic attempts of collecting ticks in different areas of Jerusalem and its suburbs were made in February-March 2008 and in summer months (May to September), 2011.

A sample of ticks from our collections (in total 20 males, 25 females, and 20 nymphs) were measured under stereomicroscope with ocular micrometer. Ticks (in total 46 males, 69 females, and 36 nymphs) were also weighed on an electronic scale.

Observations on some features of tick behavior were carried out using ticks collected in the field. Adults of different size ("big" and "small" according visual estimation) in various numbers and combinations were put into glass tubes immediately after collecting; the time before mating and the influence of tick size on mating were noted. A total of 43 males and 76 females collected in February-March were used in these tests. Tick affinity for attacking and biting humans was checked by regular cross-examinations of collectors' clothes and in special tests made in the laboratory. For this purpose, a number of unfed females were placed after collection into specially-equipped glass tubes (Uspensky, 1967) where a gradient of humidity (65-95% RH) was created along the length of each tube (Shashina and Ioffe, 1980). The tests were carried out at the next day after tick collection. The ticks were individually put on the researcher's arm and were observed for up to 1 hour. The temperature in the laboratory was 23-25ºC. A total of 15 females collected in October-November and of 20 females collected in March were used in the tests.

RESULTS

Occurrence

First ticks were collected in November and the tick activity was observed till the end of April. Adult ticks were regularly collected during the entire period of observation. Single nymphs were sporadically collected during the same period with an obvious increase in March. Not a single larval specimen was found. Ticks were collected only from the grass slightly above the ground and were never found on higher vegetation. When on the flag, they did not demonstrate any activity, passively remaining in one spot on the flag. The results of tick collections on the southwestern slope are presented on Fig. 1. The adult tick activity was higher in the beginning of the activity season (November-December) and in its second part (February-March) with a strong decline in January. The numbers of ticks collected on the northeastern slope was much smaller and those data are omitted.

Mean daily air temperatures in November-December, 2006 were lower than the mean daily multiannual temperatures of those months, while in January-April, 2007 mean daily temperatures were higher than the mean multiannual ones (Fig. 2). January was characterized by a strong decline of maximal and minimal daily temperatures.

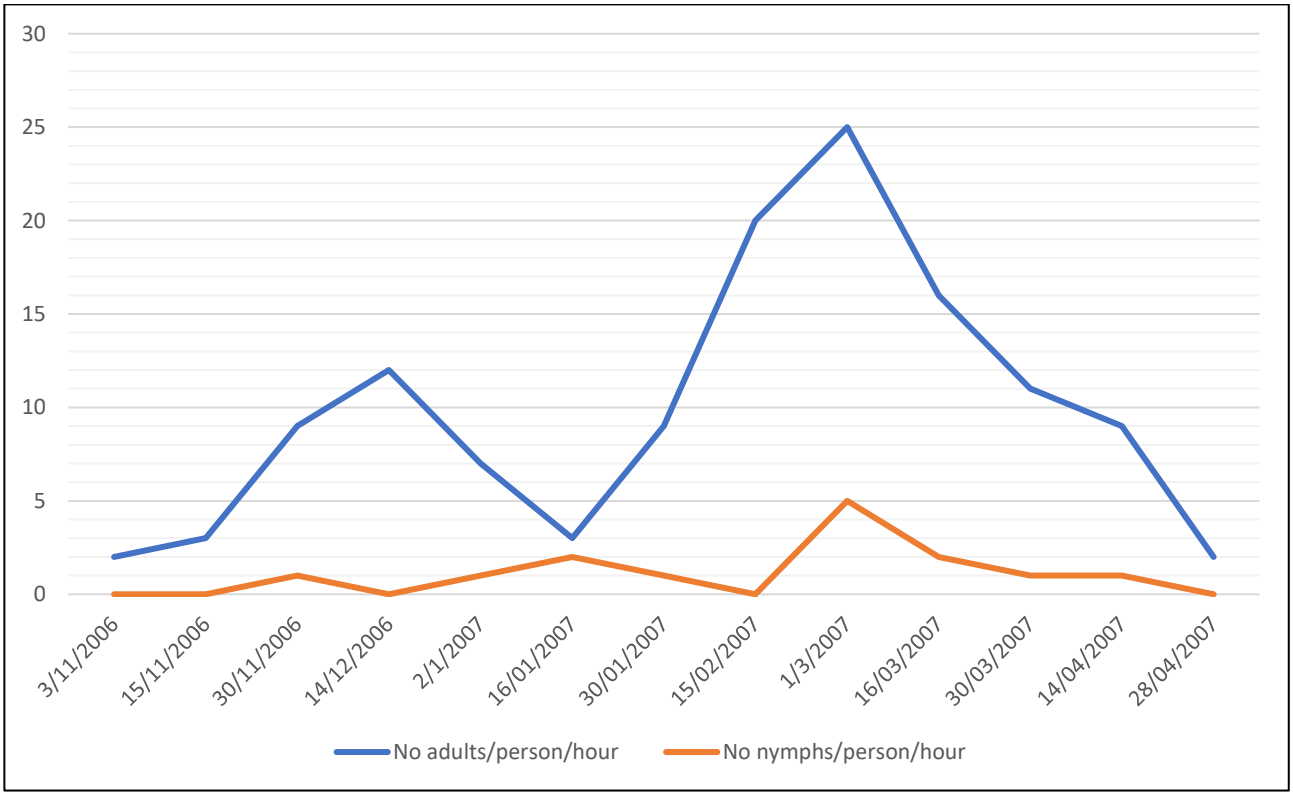

Figure 1. No of ticks collected in the survey area (vertical axis – No of ticks).

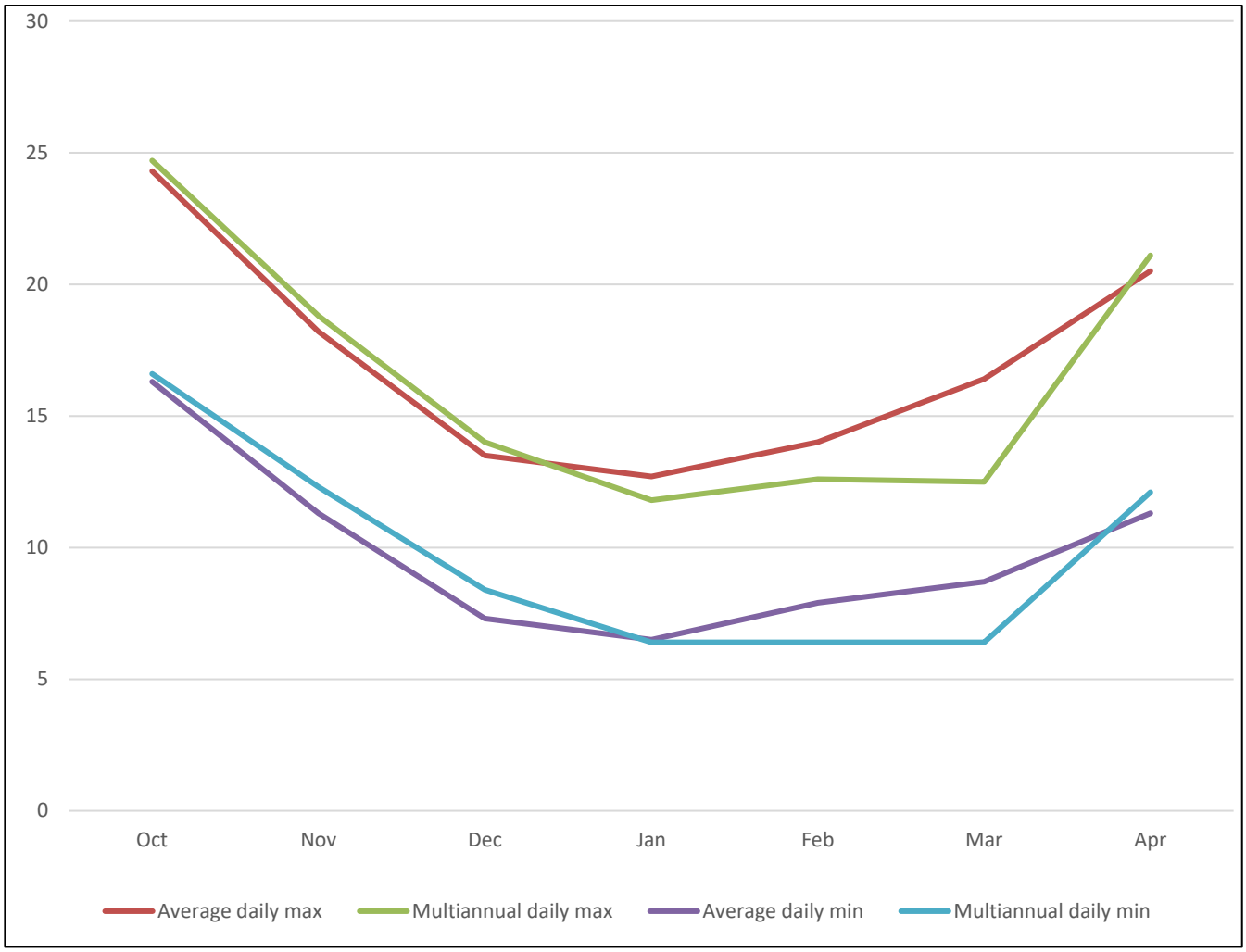

Figure 2. Maximal and minimal average daily temperatures: in the season 2006/2007 and multiannual (vertical axis – temperature in ºC).

Table 1. Size and weight characteristics of unfed nymphal and adult *I. eldaricus* [Mean ± SD, (range)].

Characteristics	Nymphs	Adults	
		Males	Females
Scutum (conscutum for males), mm	0.527 ± 0.051 (0.439 – 0.610)	1.84 ± 0.10 (1.66 – 2.00)	1.2 ± 0.12 (0.93 – 1.37)
width	0.451 ± 0.058 (0.366 – 0.561)	0.98 ± 0.07 (0.87 – 1.10)	0.91 ± 0.07 (0.78 – 1.03)
Alloscutum, mm length	0.992 ± 0.065 (0.875 – 1.078)		2.17 ± 0.11 (2.00 – 2.39)
Width	0.585 ± 0.058 (0.488 – 0.648)		1.35 ± 0.09 (1.19 – 1.51)
Weight, mg	0.12 ± 0.01 (0.085 – 0.15)	0.79 ± 0.11 (0.45 - 1.0)	1.18 ± 0.27 (0.6 - 1.9)

When goats from the farm located near-by that had been pastured over the sites of survey were examined, we found no *Ixodes* ticks but only a small number of ticks of the genus *Haemaphysalis*.

An attempt to collect ticks at the site of previous collections (Yeruham et al., 1995) was unsuccessful: not a single specimen was found. Additionally, one male of *I. eldaricus* was collected by flagging grass vegetation in the southern part of Jerusalem, in a woody ravine dividing two residential areas in March, 2008. No ticks were found in summer months.

Size and weight characteristics

The measurements of the scutal/conscutal length and width for males, females and nymphs and of the alloscutal length and width for females and nymphs as well as the weights of ticks from these groups are presented in Table 1.

Biological patterns

No adults in the mating position were found during tick collection. However, when collected ticks of different sex were put together in the same tubes, it took 1 to 3 min for ticks to be in the mating position. Large females were preferable for males and large males had advantage over small males. In any case, mating took place regardless of the male size. Interestingly, these patterns of behavior were consistently observed in all of our tests.

Not a single tick was found on the collector's clothes during tick collection. When unfed females were put on a human arm, no cases of tick attachment were observed (Table 2). More than 80% of ticks left the arm after 30 min of observation and more than 90% after 45 min.

Table 2. Affinity for attacking humans in unfed *I. eldaricus* females.

Ticks		**No. ticks left on the arm, min**				**No. ticks kept on the arm after 1 h**	**No. ticks attached to the arm**
Collected in	No.	<15	16-30	31-45	46-60		
October-November	15	4	8	2	0	1	0
March	20	8	10	1	1	0	0

DISCUSSION

Although *I. eldaricus* inhabits xerophilous mountain forests and bush, the tick avoids both very high and very low temperatures and prefers habitats, characterized by adequate humidity. This is indicated by the differences in the seasons of activity of the tick (spring and autumn months in the northern part of the range (Filippova, 1977) and winter months in our observations and in those by Yeruham et al. (1995), and by its preferential occurrence in the areas characterized by higher humidity and lower sun irradiation in our and Yeruham's observations. A bimodal activity pattern with a strong decline of activity in January observed in our survey is also common to *I. ricinus* near the southern border of its range (Daniel et al., 2015; Aydin et al., 2020). Our data allow to estimate the average daily maximal air temperatures in the range of 13-20°C as optimal for activity of adult *I. eldaricus*. The minimal daily temperatures appear less essential since their values in December and February were close to those in January (Fig. 2) and did not suppress high tick activity. It is unclear whether the differences in temperatures of the 2006/2007 season from multiannual ones (lower in October-December and higher in February-March) influenced the tick activity pattern. Our observation on tick abundance dynamics during the season of their activity is a first attempt of such kind. We have no ready explanation for the absence of larval ticks in our collections as compared with data by Yeruham et al. (1995).

The habitats of *I. eldaricus* usually look as "spots" among xerophilic vegetation typical for the entire range of this species. Tick location in the lowest level of the vegetation and their low activity determine various degrees of isolation of *I. eldaricus* populations from each other with possible connection provided only by the bird hosts. Our lack of success in finding ticks at the site of Yeruham's collections may be explained by a drastic decrease in soil humidity following the planting of eucalyptus trees in the area. In the Crimea, this species has been classified as "disappearing" (Nebogatkin, 1998) because of anthropogenic destruction of its habitats and reduction of host populations in the 1990s. Gradual warming of the Earth's temperature in the past decades may also be an unfavorable factor for *I. eldaricus* populations.

Since *I. eldaricus* is characterized by low abundance, low activity and specificity in locations and hosts (and is not of the primary interest of researchers), its geographic range is insufficiently described. Main hosts of *I. eldaricus* in all parasitic stages are ground-foraging passerine birds, many of them with a limited distance of seasonal migrations. Findings of specimens of this tick on migrating birds in Cyprus (Kaiser et al., 1974) and Turkey (Keskin and Erciyas-Yavuz, 2019) were thought to be the result of bird infestation in the same or adjacent countries. It was also suggested that this species should be present in Iran (Filippova et al., 1976). Most probably, isolated populations of *I. eldaricus* can be found in Lebanon and western part of Syria. Long-distance introduction of specimens of this species is extremely rare; only one case of such kind has been documented to date (Nowak-Chmura, 2012).

Ixodes eldaricus was first considered closely connected with the species from the *persulcatus* group (Filippova, 1974, 1977) but later it was included in a newly created *redikorzevi* group (Filippova, 2008). It may be informative to compare our data with the corresponding published data on both of these groups.

The scutum of *I. eldaricus* nymphs from our collections is a little shorter (but statistically significantly, according to the Student's *t*-criterion = 4.58) than that of nymphal *I. eldaricus* from other parts of the range (Filippova, 1974, 1977). It might be explained by the fact that the area of our survey is located in the southernmost part of the tick range where the conditions are less favorable than in the main part of its range. At the same time, it is comparable with the data for *I. redikorzevi* and *I. occultus* but less than that of the ticks from the *persulcatus* group (Filippova, 1977). The weight of *I. eldaricus* nymphs is a little less than that of nymphal *I. persulcatus* and *I. ricinus*, while the weight *I. eldaricus* females is about half that of the two species mentioned above (Uspensky et al., 1999). It means that nymphs of *I. eldaricus* engorge less blood than the ticks of the *persulcatus* group. Using the data on feeding of adult *I. redikorzevi* obtained by Tiflova (1974), we

can assume that the mean weight of engorged *I. eldaricus* females could not exceed 100 mg.

No copulating pairs of *I. eldaricus* adults were found during tick collection which strongly differs from *I. persulcatus* or *I. ricinus* whose adults were regularly found in the mating position (Ioffe-Uspensky and Uspensky, 2017). However, field-collected males and females of *I. eldaricus* mated immediately after being placed together in the same tube, similarly to *I. persulcatus* specimens. Interestingly, in our previous experiments with a laboratory colony of *I. persulcatus* (Uspensky and Repkina, 1978), virgin adults could be together in the tube for up to 31 days making no attempt to mate. It is possible that pheromone regulation is fully manifested only in the field populations of adult *Ixodes* ticks and is suppressed in the laboratory conditions. The absence of copulating *I. eldaricus* adults in the field puts question on pheromone regulation in this species as compared with *I. persulcatus* and *I. ricinus* ticks where such regulation does exist (Uspensky and Yemel'yanova, 1980; Háiková and Leahy, 1982).

Adult *I. eldaricus* did not show any aggressiveness toward humans while *I. persulcatus* is a very aggressive species (Uspensky, 1993, 2016). This is in agreement with Filippova's observations (1974, 1977) that *I. eldaricus* was not found attacking humans in nature. A tick species which have no epidemiological significance might, however, have certain significance in epizootiology of known and unknown infections. For example, such species as *I. arboricola*, another poorly-studies species, only recently was found to participate in circulating several rickettsia species among bird hosts (Špitalská et al., 2011). Considering that *I. eldaricus* can be found in areas where *Rickettsia conorii israelensis* and other rickettsial agents are spread (Guberman et al., 1996; Mumcuoglu et al., 2002; Rose et al., 2017), the necessity of studying the role of this species in epizootiology of these pathogens is important.

It would be informative to test Israeli *I. eldaricus* for *Borrelia burgdorferi* s.l., especially in view of the following considerations:

(i) The range of *I. ricinus*, one of the main vectors of that pathogen, covers the territory of the Levant from Turkey (Bursali et al., 2012) to the northern part of Israel (Erster et al., 2013) (although there is no data from Lebanon and the western part of Syria, it would be reasonable to assume that this tick populates the forested areas of these countries, especially the mountain forests). *Borrelia burgdorferi* s.l. was isolated from *I. ricinus* in Turkey (Güner et al., 2003; Polat et al., 2017) and a systematic review of the available data (Önal et al., 2019) indicates that Lyme borreliosis is a major health concern in the country;

(ii) Ground-foraging passerine birds are important hosts for *I. ricinus* and dominant hosts for *I. eldaricus*, a number of species being common for both tick species (Filippova, 1977). These bird species are not only good tick carriers, but also competent reservoirs of several genospecies of *B. burgdorferi* (Comstedt et al., 2006; Taragel'ová et al., 2008; Norte et al., 2012);

(iii) The routes of seasonal migrations of many passerine birds between Europe and Eastern Africa lie through Israel and Turkey (Inci et al., 2016) with stopover sites in both countries (Frumkin et al., 1995; Inci et al., 2016), which provides favorable conditions for circulation of ticks and tick-borne pathogens throughout the Levant.

When these facts are considered together, it appears rather likely that *B. burgdorferi* circulates between birds and ticks in forested areas of Israel, and that *I. eldaricus* is one of the tick species mediating this process.

Statement of ethics approval

Not applicable.

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Conflict of interest

There is no potential conflict of interest.

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