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Black Bears (*Ursus americanus*) as a Novel Potential Predator of Agassiz's Desert Tortoises (*Gopherus agassizii*) at a California Wind Energy Facility

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Areas of significant topographic relief often form ecoclines, resulting in stratified life zones each with distinct communities of plants and animals (Attrill and Rundle 2002). Contact zones, or ecological boundaries along ecoclines, allow unique plant and animal assemblages that are not normally considered to be syntopic, to mix in varying degrees. The boundaries of ecoclines are thus both spatial and ecological and when these boundaries are crossed unique interactions can occur, including unexpected predator and prey interactions.

The eastern San Bernardino Mountains in southern California range from about 300–3,506 m and support a wide range of as many as 11 distinct life zones along an ecocline extending from Sonoran Desert on the east side and Mojave Desert on the north side, to an alpine ecosystem near the summit (Schoenherr 1992). In this paper we report an interaction between black bears (*Ursus americanus*) and Agassiz's desert tortoises (*Gopherus agassizii*). These two species have not previously been reported to interact due to their substantially different habitat preferences. In addition, given the paucity of bear and turtle interactions in general, we provide a review of the scientific literature on the topic, since bears are known to eat turtles on an opportunistic basis.

The study site is located in the foothills of the southeastern San Bernardino Mountains in Riverside County, California, near the city of Palm Springs (33°57′06″N, 116°40′02″W, WGS84). Known locally as ''Mesa,'' the site is located on land administered by the Bureau of Land Management for wind energy generation since 1983. Extensive studies of *G. agasszii* have been conducted at the site since 1994, including investigations on growth, demography and survivorship (Lovich et al. 2011b), fire ecology (Lovich et al. 2011c), habitat selection (Lovich and Daniels 2000), the effects of climate on behavior and reproductive ecology (Ennen et al. 2012b; Lovich et al. 2012; Lovich et al. 1999), nesting ecology (Ennen et al. 2012a) and the impacts of wind energy operation and maintenance on tortoises (Lovich and Ennen 2013; Lovich et al. 2011a).

Mesa is at the extreme western edge of the Lower Colorado River Subdivision of the Sonoran Desert ecosystem, commonly referred to as the ''Colorado Desert'' (Turner and Brown 1994). Because of its location near several major ecosystems, vegetation at the site

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Fig. 1. Example of a Reconyx trail camera setup at an active Agassiz's desert tortoise (*Gopherus agassizii*) burrow in the San Bernardino Mountains northwest of Palm Springs, California in 2013. Cameras were attached to fence posts within 1–2 m of burrows and would trigger on wildlife activity.

is a mixture of species from the Mojave and Sonoran deserts as well as cis- and trans-montane (sensu Schoenherr 1992) chaparral and coastal sage scrub plants. Anthropogenic features include 460 wind turbines and an infrastructure of dirt roads, transformers, a substation, and a maintenance shop staffed on weekdays. More detailed descriptions of the study site are given by Lovich and Daniels (2000) and Lovich et al. (2012).

During the summer of 2013, 37 Reconyx trail cameras (models HC500 and PC800) were deployed at *G. agassizii* and California ground squirrel (*Otospermophilus beecheyi*) burrows as part of an ongoing study to investigate the effects of noise and vibration on these species. Cameras were programmed to take five high definition photographs when triggered (0.2 sec trigger speed) by wildlife activity and were positioned 1–2 m from burrow entrances (Figure 1). Cameras were checked monthly for wildlife photos. In addition, 14 *G. agassizii* were fitted with radio transmitters as part of ongoing research on the fire ecology and reproductive biology of the species (Lovich et al. 2011c). Tortoises were located at approximately 10 day intervals from April–July, 2013 and females were X-radiographed (Hinton et al. 1997) to determine gravidity, clutch size and clutch frequency (Lovich et al. 2012).

On June 22, 2013, starting at 0050 h, we recorded a series of 28 photographs showing a female black bear and at least one cub at the entrance to a tortoise burrow. The female directly faced the opening of the burrow in one photograph (Figure 2) as if smelling its occupant(s). In another photograph, the cub was looking at the burrow (Figure 3). The bears were not observed digging in the photos. On that date we suspected that there was at least one female tortoise in the burrow (based on radio-telemetry and trail camera monitoring), but two males were known to have visited and co-occupied that burrow four times during the spring and summer of 2013. It is not unlikely that two or more tortoises were in the burrow at the time it was investigated by the bears. One male tortoise was verified as a co-occupant of the burrow on July 19.

Fig. 2. An adult female black bear (*Ursus americanus*) investigating an occupied Agassiz's desert tortoise (*Gopherus agassizii*) burrow in the San Bernardino Mountains near Palm Springs, California. The site is an active wind energy generation facility. Date and time stamps of the wildlife trail camera are shown at the top of the image along with air temperature.

The burrow, about 3 m in length, has been used regularly by the same female from 2009–2013. Female tortoises at this site deposit clutches of eggs in or near the burrow entrance (Ennen et al. 2012a), but the only female that uses the burrow visited by the bears has never produced a clutch of shelled eggs since monitoring began in 1997 (Lovich et al. 1999). It is thus unlikely that tortoise eggs were in the burrow entrance at the time it was visited by the bears. The last bear photo was taken at 0051 h on June 22, 2013. No evidence of digging by bears was observed on subsequent visits to the burrow by researchers during the remainder of the field season (last visit November 14, 2013).

Black bears occupy an astonishing diversity of habitats across their range in North America, from tundra to the edge of desert ecosystems, because of their ecological plasticity (Stirling and Derocher 1990). Despite this broad range of habitats, they are generally fond of treed areas, especially when found with grizzly bears (*Ursus arctos*) (Herrero 1972), and this is mirrored in their California distribution (Brown et al. 2009). In the San Bernardino Mountains black bears occupy a similarly broad range of habitats but prefer montane forests with a wide variety of seral stages (Novick and Stewart 1982; Stephenson and Calcarone 1999). Bears do occasionally move down into the desert from the San Bernardino Mountains as confirmed by Burghduff (1935), occasional newspaper reports, rare sightings by Mesa maintenance staff, and a bear sighting in nearby Big Morongo Canyon on 27 July, 1993 by one of the authors (JEL). However, the xeric habitat types occupied by tortoises render expected encounters by these two species occasional at best. The "Hathaway Fire" that burned near Banning, California from 9–20 June, 2013, about 13 km northwest of our study site, may have pushed the bears into our study area from occupied habitat (Novick and Stewart 1982). Fire and fire management have dramatic impacts on bears and their habitat (Mattson 1990).

Black bears in California, including those in the San Bernardino and nearby San Gabriel Mountains of California, subsist largely on herbaceous plant material and acorns

Fig. 3. A black bear (*Ursus americanus*) cub investigating an occupied Agassiz's desert tortoise (*Gopherus agassizii*) burrow in the San Bernardino Mountains near Palm Springs, California. The cub's mother was nearby (see Figure 2). The site is an active wind energy generation facility. Date and time stamps of the wildlife trail camera are shown at the top of the image along with air temperature.

in the spring, fruit and acorns in the summer, and fruit, acorns and other nuts in the fall (Boyer 1976; Stubblefield 1993). Although we did not observe a predatory event *per se*, the omnivorous diet of bears (including black bears) does include turtles (Table 1), so the potential exists for predatory encounters when the species meet. Comparatively few publications document turtle predation by bears and none document predation on *G. agassizii*. The earliest published record we found of bears eating turtles was Romans (1775 (a facsimile reproduction, 1962)) account of "droves" of black bears coming down to Florida beaches to eat the eggs of nesting loggerhead sea turtles (*Caretta caretta*). In their review of the ecology of turtles of the United States and Canada, Ernst and Lovich (2009) reported that bears are included in the list of predators of turtles or their eggs for loggerhead sea turtles (as cited by Dodd, 1988 who, in turn, cited Romans, 1775), common snapping turtles (*Chelydra serpentina*), western pond turtles (*Actinemys marmorata*: see also Vander Haegen et al., 2009), peninsula cooters (*Pseudemys peninsularis*), and Florida softshell turtles (*Apalone ferox*). Behrend and Sage (1974) observed an adult snapping turtle that they presumed to be a nesting female shortly after it was killed and partially consumed by a black bear, leaving only one egg and various body parts.

Turtle predation is not limited to black bears. Krofel (2012) found a Hermann's tortoise (*Testudo hermanni*) in northern Greece that appeared to have been killed by a brown bear (*Ursus arctos*). Krofel then used the percentage of brown bear scats reported by Paralikidis (2010) from northern Greece that contained unspecified turtle remains to estimate that around 28,000 tortoises could be consumed by the brown bear population in his study region annually. The diet of Malayan sun bears (*Helarctos malayanus*) in Malaysian Borneo also included turtles such as the Asian brown giant tortoise (*Manouria emys*). Turtle remains occurred in 5.77% of the sun bear scats examined (Wong 2002).

Table 1. Published records for bear predation, or possible predation, on various turtles. The reader is referred to Ernst and Lovich (2009) for additional primary literature citations for species listed below other than those given here.

Bear species	Turtle species	Location	Citation
Helarctos malayanus	*Manouria emys*	Malaysian Borneo	Wong et al. (2002)
Ursus americanus	*Caretta caretta*	USA	Ernst and Lovich (2009)
Ursus americanus	*Chelydra serpentina*	USA	Behrend and Sage (1974), Ernst and Lovich (2009)
Ursus americanus	*Actinemys marmorata*	USA	Holland (1994), Ernst and Lovich (2009)
Ursus americanus	*Pseudemys floridana (=P. f. concinna)*	USA	Thomas and Jansen (2006)
Ursus americanus	*Pseudemys peninsularis*	USA	Ernst and Lovich (2009)
Ursus americanus	*Apalone ferox*	USA	Pope (1939), Ernst and Lovich (2009)
Ursus arctos	*Testudo hermanni* and others	northern Greece	Krofel (2012)
Ursus arctos	Unspecified	western Greece	Paralikidis et al. (2010)

Agassiz's desert tortoises have a large number of predators including other medium to large mammals like mountain lions (*Felis concolor*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and domestic dogs (*Canis familiaris*) (Ernst and Lovich 2009). All of these predators are also present at or near our Mesa study site. Given our observation of bears at the study site, there is a risk of predation on desert tortoises by this potentially novel predator. The probability of bear predation is very likely low due to minimal range and habitat overlap between the species and the fact that California black bears have a diet dominated by plant material (Boyer 1976; Stubblefield 1993). However, the fact that turtles are included in the diets of bears worldwide supports the possibility that it can occur. Bears are known for developing unique foraging behaviors through learning so it is possible that individual bears might develop a preference for tortoises if given the opportunity (Stirling and Derocher 1990). Krofel (2012) suggested that predation and partial consumption of tortoises was a learned behavior and that some bears could become specialized tortoise eaters.

It is unlikely that *G. agassizii* experienced predation by black bears in historical times, especially since the latter were not native to southern California during that time period. Indeed, we found no published evidence to support such an interaction. Grizzly bears (*Ursus arctos horribilis*) were the only bears in central coastal and southern California just prior to European colonization (Brown et al. 2009). Although *U. arctos* are known to eat different tortoise species elsewhere in the world (Krofel 2012; Paralikidis et al. 2010), we could find no evidence that they ate *G. agassizii*. Following the extirpation of grizzly bears in California *ca*. 1920 (Mattson and Merrill 2002), 16 black bears from the Sierra Nevada near Yosemite were released in the San Bernardino Mountains in 1933 (Burghduff 1935), an event still reflected in their genotypes (Brown et al. 2009). Thus black bears in southern California are an introduced species and tortoises may not be well-adapted to possible predation by that species.

Even a single individual of a novel predator can have significant effects on small populations of Agassiz's desert tortoises. An example was provided by Medica and Greger (2009) who recorded a mortality event attributed to a mountain lion (*Felis concolor*) that killed eight *G. agassizii* at a Mojave Desert study site in southern Nevada in

2003. This predation event was the first observed during their 45 year study. The authors suggested that this was an example of a learned behavior in a mountain lion passing through low elevation, normally unsuitable Mojave Desert habitat in late summer or early fall. Although mountain lions and jaguars (*Panthera onca*) are known predators of various tortoise species in the Western Hemisphere (Averill-Murray et al. 2002; Emmons 1989) including other desert tortoises (*G. morafkai*), published instances of big cats feeding on tortoises appear to be as rare as those involving bears and tortoises. However, if a single black bear developed a taste for tortoises, it could have negative effects on a small population of desert tortoises similar to what was observed by Medica and Greger as a result of mountain lion predation. A single adult tortoise can "easily" satisfy the estimated daily food requirements of a large predator like a jaguar (Emmons 1989), so it would be energetically advantageous for black bears to eat tortoises when they are encountered.

If tortoise predation is eventually practiced by black bears at our Mesa study site, it could have negative effects on the small resident tortoise population (Lovich et al. 2011b). Researchers and resource managers need to be aware of the potential for novel introduced predators like black bears to affect federally threatened species like *G. agassizii*.

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