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Contributed Paper

Effects of Knowledge of an Endangered Species on Recreationists' Attitudes and Stated Behaviors and the Significance of Management Compliance for Ohlone Tiger Beetle Conservation

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Abstract: *Recreation is a leading cause of species decline on public lands, yet sometimes it can be used as a tool for conservation. Engagement in recreational activities, such as hiking and biking, in endangered species habitats may even enhance public support for conservation efforts. We used the case of the endangered Ohlone tiger beetle* (Cicindela ohlone) *to investigate the effect of biking and hiking on the beetle's behavior and the role of recreationists' knowledge of and attitudes toward Ohlone tiger beetle in conservation of the species. In Inclusion Area A on the University of California Santa Cruz (U.S.A.) campus, adult Ohlone tiger beetles mate and forage in areas with bare ground, particularly on recreational trails; however, recreation disrupts these activities. We tested the effect of recreation on Ohlone tiger beetles by observing beetle behavior on trails as people walked and road bikes at slow and fast speed and on trails with no recreation. We also surveyed recreationists to investigate how their knowledge of the beetle affected their attitudes toward conservation of the beetle and stated compliance with regulations aimed at beetle conservation. Fast cycling caused the beetles to fly off the trail more often and to fly farther than slow cycling or hiking. Slow cycling and hiking did not differ in their effect on the number of times and distance the beetles flew off the trail. Recreationists' knowledge of the beetle led to increased stated compliance with regulations, and this stated compliance is likely to have tangible conservation outcomes for the beetle. Our results suggest management and education can mitigate the negative effect of recreation and promote conservation of endangered species.*

Keywords: *Cicindela ohlone*, human behavior, recreation

Efectos del Conocimiento de una Especie en Peligro sobre las Actitudes y Comportamientos Declarados de los Recreacionistas y el Significado del Manejo de la Conformidad para la Conservación del Escarabajo Tigre de Ohlone

Resumen: *La recreación es la causa principal del declive de especies en tierras públicas, aunque algunas veces puede usarse como herramienta para la conservación. Participar en actividades recreativas, como ciclismo y montañismo, en los hábitats de especies en peligro puede incluso aumentar el apoyo público para los esfuerzos de conservación. Usamos el caso del escarabajo tigre de Ohlone* (Cicindela ohlone)*, que se encuentra en peligro, para investigar el efecto del ciclismo y el montañismo sobre el comportamiento del escarabajo y el papel del conocimiento de los recreacionistas y sus actitudes hacia el escarabajo en la conservación de la especie. En el Área de Inclusión A del campus de la Universidad de California, Santa Cruz (E.U.A) los escarabajos se aparean y forrajean en áreas con suelo despejado, particularmente sobre rutas recreativas; sin embargo, la recreación interrumpe estas actividades. Probamos el efecto de las actividades recreativas sobre el escarabajo al observar el comportamiento del mismo en las rutas mientras la gente camina o pasa en bicicletas a velocidad lenta o rápida y en rutas sin actividades recreativas. También encuestamos a los recreacionistas para investigar como su conocimiento del escarabajo afectaba sus actitudes hacia la conservación del mismo y su cumplimiento de las regulaciones enfocadas a la conservación de la especie.*

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El ciclismo a altas velocidades causó que los escarabajos huyeran de la ruta más seguido y que volaran más lejos que con el ciclismo a velocidades lentas o el montañismo. El ciclismo a bajas velocidades y el montañismo no difirieron en sus efectos sobre el número de veces y la distancia que el escarabajo huía de la ruta. El conocimiento de los recreacionsitas acerca del escarabajo llevó a un mayor cumplimiento de las regulaciones, y es probable que esta conformación tenga resultados de conservación tangibles para el escarabajo. Nuestros resultados sugieren que el manejo y la educación pueden mitigar el efecto negativo de las actividades recreativas y promover la conservación de especies en peligro.

Palabras Clave: *Cicindela ohlone*, comportamiento humano, recreación

Introduction

Outdoor recreation has been cited as a leading cause of the decline of threatened and endangered species on public lands (Losos et al. 1995; Taylor & Knight 2003). Recreational activities can result in direct mortality of plants and animals and cause behavioral and physiological stress that results in reduction of habitat use, lower reproduction rates, and, ultimately, fewer populations (e.g., Cole 1993; Martinez-Abrain et al. 2010; Martin et al. 2011). However, engagement in recreational activities, such as hiking and biking, can increase a person's environmental knowledge, improve attitudes, and increase public support for conservation (Peterson et al. 2008; Thapa 2010). Fortunately, science-supported, expert-backed management can often mitigate the negative effects of recreation (Cole 1993; Taylor et al. 2007; Martin et al. 2011), and in certain instances, recreation can be used as a conservation tool, particularly in areas that lack natural disturbance (Knisley 2011; Cornelisse et al. 2013). The case of the endangered Ohlone tiger beetle (*Cicindela ohlone*) represents an opportunity to investigate the effect of recreation on species behavior and the role of recreationists' knowledge and attitudes in conservation.

The Ohlone tiger beetle is endemic to the coastal prairies of Santa Cruz County, California (U.S.A.), where it occurs in only 5 remnant patches. This beetle forages, finds mates, and oviposits on bare ground (i.e., free of vegetation) (Knisley & Arnold 2004; Cornelisse et al. 2013). Ohlone tiger beetle adults are generalist predators that stalk their prey and find mates on large open patches of bare ground, whereas larvae are sit and wait generalist predators that maintain burrows at the oviposition site, generally in relatively small patches of bare ground surrounded by prairie vegetation. The coastal prairie evolved with disturbances that created conditions for bare ground, such as fire, grazing, and soil disturbance by native ungulates and burrowing animals, and periodic drought (Anderson 2007; Wigand et al. 2007). After European settlement, grazing regimes changed, time between fires increased, and annual exotic plants replaced perennial bunch grasses, all of which decreased the amount of bare ground (Hayes & Holl 2003; D'Antonio et al. 2007). Today, livestock grazing maintains much of the within-prairie larval habitat of the Ohlone tiger beetle, whereas adults frequently conduct mating and foraging activities on recreational trails. The case of the Ohlone tiger beetle is unusual in that recreation can directly disrupt adult foraging and mating (personal observation), yet, paradoxically, recreation maintains bare ground for these activities.

Recreation has only recently been recognized as a tool to create and maintain habitat for this endangered species and, prior to 2005, was considered solely detrimental to the beetle because adults were occasionally found crushed on trails (C.B. Knisley, personal communication). From 2001 to 2005, trails were temporarily closed for Ohlone tiger beetle protection and a widely publicized popular article stated that recreation had an exclusively negative effect on the beetle. The article went so far as to say that cyclists were the number one cause of its demise (Phelan 2002). However, the effect of recreation on the beetle has never been evaluated systematically or quantified, and it is unknown how the trail closures and the popular article affected recreationists' perceptions of Ohlone tiger beetle conservation and management. Recreation effects and recreationist perceptions are critically important to management of the beetle because 4 of 5 of its remaining habitat patches are currently open to recreation. We tested the effect of different types of recreation on adult Ohlone tiger beetle behavior and how prior and new knowledge about the beetle affected recreationists' attitude toward the beetle and stated willingness to comply with management regulations.

Recreationists' knowledge of their effects on species may affect both their perceptions of management and attitudes toward the species and, in turn, their behavior in protected areas (Kaiser & Fuhrer 2003; Taylor & Knight 2003; Frick et al. 2004). Knowledge of ecological issues affects behavior in a substantial yet indirect way. Specifically, knowledge provides the basis through which mediators, such as attitudes, values, incentives, and social consequences, change behavior (e.g., Kaiser & Fuhrer 2003; Farrior 2005; Randler et al. 2007). We hypothesized that prior knowledge of Ohlone tiger beetle affects recreationists' attitude and stated behaviors in a negative way. We predicted that recreationists with prior knowledge would rate conservation of the beetle as less important and effect of recreation on the beetle as negative and be less likely to state compliance with

regulations in beetle habitat. We based our hypothesis on the assumption that most of recreationists' prior knowledge of the beetle was a result of the popular article and trail closures. Alternatively, we predicted that recreationists with no prior knowledge would rate the conservation of Ohlone tiger beetle as more important and be more likely to state compliance with beetle management if provided with new knowledge.

To complement our study of recreationists' stated compliance with management strategies, we tested the effect of different recreation types and management on beetle behavior. Our goal was to determine whether requiring cyclists to dismount their bikes (equivalent to hiking) or simply to slow down in beetle habitat would minimize the negative effect of recreation on adult beetle behavior. We hypothesized that recreational types differ in the magnitude in which they disrupt Ohlone tiger beetle behavior. We predicted that cyclists riding at fast speeds would cause adult beetles to cease their behaviors and fly off the trails more often and to fly farther than cyclists riding at slow speeds and hikers, assuming the latter 2 represent less disruptive recreational activities. We sought to identify the most effective recreation-management approaches and to increase awareness of and compliance with Ohlone tiger beetle conservation strategies.

Methods

Study Site

We conducted our study in Santa Cruz County, California (U.S.A.), in the Ohlone tiger beetle habitat known as Inclusion Area A (IAA) on the University of California Santa Cruz campus (36°N 122°W). IAA contains an 850-m fire road that is open to recreation, including cycling, and on which adult beetles are often found foraging and mating.

Effect of Recreation on Beetle Behavior

We conducted 30 trials each of hiking, slow cycling, fast cycling, and control treatments (120 total trials) during which we observed the behavior of adult beetles. We conducted trials over 8 d from 24 February to 10 March, the peak of adult beetle activity in 2012. We surveyed approximately 350 adults in IAA (T.C., unpublished data). For all trials, T.C. observed the beetles while a research assistant (hereafter recreationist) hiked or cycled the trail. Slow cycling was 8–12 km/h and fast cycling as 30–35 km/h. We measured bicycle speed with a Schwinn 20-Function Bike Computer (Schwinn, Chicago, Illinois) attached to the bicycle that was monitored by the recreationist during each trial.

To conduct the trails, we walked along the road until we sighted an individual Ohlone tiger beetle adult. Once sighted, the recreationist backed up at least 30 m away from the beetle and T.C. walked into the grassland, perpendicular to the trail and 3–5 m away from the beetle. T.C. then observed the beetle for 2 min with no recreational activity and recorded behavior and distance moved. The recreationist was then signaled verbally to begin hiking or cycling and told where on the trail to aim to avoid direct contact with the beetle (e.g., off to either side if the beetle was in the center of the trail). In all cases, the recreationist was at least 0.25–0.50 m away from the beetle. The recreationist continued the activity another 10 m down the trail before stopping. We recorded whether the beetle remained stationary, flew off the trail, walked off the trail, or walked along the trail and the distance moved by the beetle during each of these behaviors. We observed the beetle for an additional 2 min after the recreational activity ceased and recorded the beetle's behavior and distance moved. For control trials, we observed a beetle for 4 min with no recreation. We used a Bosch GLR225 Laser Distance Measurer (Bosch, Farmington Hills, Michigan) to measure the distance moved by the beetle. Once we reached the end of the fire road, trials were stopped for the day to avoid testing individual beetles more than once on a trial day.

We used a chi-square test for independence to determine whether frequency of flight off the trail differed among the recreation treatments. We used a z test of column proportions for pairwise comparisons between recreation treatments with Bonferroni adjustments to indicate significant differences at the 0.05 level. We used one-way analysis of variance (ANOVA) with post hoc Tukey's honestly significant difference (HSD) test for pairwise comparisons to determine whether distances flown by beetles off of the trail were associated with recreation treatments. We did not include controls in this analysis because the beetles never flew off the trail during the control trials, which resulted in distances being all zeroes, and we did not want to exclude recreation as a management strategy. We used one-way ANOVA with Tukey's HSD test for pairwise comparisons to determine whether total distance moved along the trail depended on recreation treatment. All statistical analyses were done with SPSS (version 19.0.0; SPSS, Chicago, Illinois).

Effect of Recreationist Knowledge on Attitude and Behaviors

We surveyed recreationists on the University of California, Santa Cruz north campus (37°N, 122°W) at a trailhead leading into campus natural lands and Wilder Ranch State Park. These trails connect to all active Ohlone tiger beetle habitats open to recreation. Over 1 year (28 June, 14 July, 21 August, 5 September, and 16 October 2011 and 4 January, 7 April, and 28 April 2012), we conducted 302 in-person surveys at the trailhead. We set up a table with copies of the survey, a lockbox, informational signs about the areas populated by the beetle, and refreshments. We asked every recreationist (cyclists, runners, and hikers)

that passed by if they would be willing to take a survey in regards to the Ohlone tiger beetle and management of the area.

On each survey date, we gave information about the Ohlone tiger beetle to half of the participants prior to providing them with the survey. In particular, we provided 3 types of knowledge recognized as important precursors to changing attitudes: systems knowledge (i.e., understanding of ecosystem properties in which a behavior is conducted); effectiveness knowledge (i.e., understanding of how actions affect the environment); and action-related knowledge (i.e., understanding of what can be done about a problem) (Frick et al. 2004). We told half the participants "the Ohlone tiger beetle finds food and mates on bare ground, including trails" (systems knowledge), "while recreation can harm and directly kill beetles, it also creates essential bare-ground habitat for the population as a whole" (effectiveness knowledge), and "complying with management and posted signs can reduce the negative affect of recreation on the Ohlone tiger beetle" (action-related knowledge). The other half of participants on that date received no information prior to the survey. We coded the surveys with a small 1 for new knowledge and 0 for no new knowledge at the top of the paper. The numbers were hidden under the clip of the clipboard. On the survey, we asked participants if they had heard of the Ohlone tiger beetle, and we interpreted an affirmative response as prior knowledge of the beetle. Thus, we had 4 experimental groups: recreationists with neither prior nor new knowledge, recreationists with prior knowledge but no new knowledge, recreationists with new knowledge but no prior knowledge, and recreationists with both prior and new knowledge.

To determine participants' attitude toward Ohlone tiger beetle conservation and their perception of the effect of recreation, we asked participants to rank the importance of Ohlone tiger beetle conservation and how they thought recreation affected the beetle, respectively. We also asked participants whether they "do," "would," or "would not" comply with 5 different management regulations, including stay off closed trails and dismount and walk bike and slow down in beetle habitat. Finally, we asked participants to answer demographic questions on place of residence, sex, age, income, and education. The complete survey is included in Supporting Information.

We coded survey responses for statistical analyses by assigning each response a number and combined would-comply and do-comply responses to the management strategy questions as one number. To determine how participant responses to the question "How do you feel recreation affects the Ohlone tiger beetle?" depended on experimental group, we compared the frequency of responses among groups with a chi-square test for independence. We also used a chi-square test for independence to determine how the frequency of participant compliance to management strategies depended on experimental group. To determine how participant responses to the question "How important is conservation of the Ohlone tiger beetle to you?" depended on experimental group, we used a nonparametric Mann-Whitney U test to compare ranked responses among experimental groups. We used chi-square tests for independence to compare the frequency of responses to the questions on both the importance of Ohlone tiger beetle conservation and how recreation affects the beetle between participants that stated compliance or noncompliance with management regulations. We used a built-in z test with Bonferroni adjustments in pairwise comparisons of responses.

We used summary statistics to describe participant demographics. We compared participant ages among survey dates and among experimental groups with one-way ANOVA with Tukey's HSD for both tests. We compared participant income and education among survey dates with Kruskal-Wallis sum of ranks and among experimental groups with Mann Whitney U tests. We compared participant sex among survey dates and among experiment groups with a chi-square test for independence. We compared place of residence between participants with prior knowledge and those without prior knowledge of the beetle with a chi-square test for independence. To determine whether stated compliance with the various management regulations depended on participant demographics, we used a chi-square test for independence to compare frequency of responses (would or do comply vs. would not comply) between participants residing in Santa Cruz County and those residing outside of the county and among education levels, income levels, and between sexes. We used logistic regression to compare compliance responses among participant ages. All analyses were done in SPSS (version 19.0.0).

Results

Effect of Recreation on Beetle Behavior

All recreation treatments (hiking, slow cycling, and fast cycling) caused the beetles to fly off the trail significantly more than no recreation. With no recreation beetles never flew off the trail in 30 trials ($\chi^2 = 43.125$, df $= 3$, $p < 0.0001$). Among the recreation treatments, fast cycling caused the beetles to fly off the trails 25 times, which was significantly more ($p = 0.014$) than slow cycling (15 times) and hiking (14 times). Effects of hiking and slow cycling did not differ significantly. Similarly, beetles flew significantly farther off the trail when approached by fast cycling than hiking or slow cycling ($F = 6.433$, df $= 2$, $p = 0.002$) (Fig. 1). Thus, the distance of beetle displacement caused by fast bikes was significantly greater than that of slow bikes and hiking. Effects of slow cycling and hiking did not differ significantly. There was no difference in the total distance moved along the trail among the 3 recreation types and control treatment ($F = 0.822$,

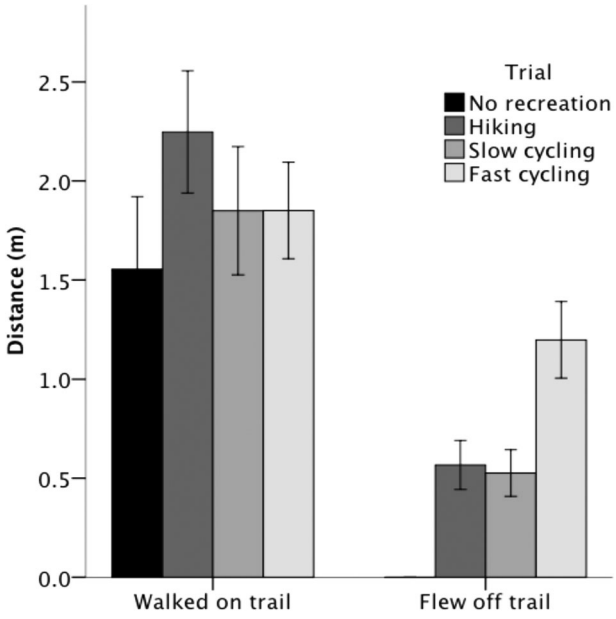

*Figure 1. Mean distance walked by an individual beetle when it remained on the trail during each type of recreation trial (*p *= 0.484) and mean distance flown by an individual beetle when it left the trail during each type of recreation trial (error bars, SE).*

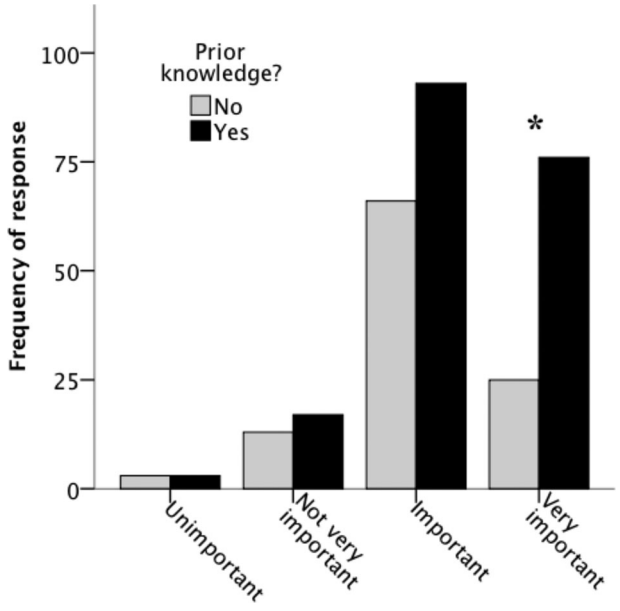

Figure 2. Frequency of responses to the survey question "How important is conservation of the Oblone tiger beetle to you?" between participants with prior knowledge of the beetle and those with no prior knowledge (*p *= 0.005).*

df = 3, $p = 0.484$) (Fig. 1). Therefore, if the beetle stayed on the trail during a recreation event, it did not move along the trail any more than if there was no recreation.

Effect of Recreationist Knowledge on Attitude and Behaviors

Ninety-five percent of recreationists agreed to take the survey. On average, survey participants were 40 years old (SD 13) (range 18–70 years), held bachelor's degrees, earned $50,000/year, and had recreated in the area for 11 years (SD 10.2) (range from first time to 40 years). Seventy-seven percent of the participants were from Santa Cruz County and 16% were from the counties surrounding the San Francisco Bay Area and Monterey County. One percent of participants were from California counties outside the San Francisco Bay Area or Monterey, 3% lived outside California, and 3% did not provide zip codes.

Participant demographics were generally not clustered on a survey date; yet, participants on 16 October 2011 were significantly older (mean [SD] = 51 years old [9.7]) than participants on 14 July 2011 (39 years old [13], $p = 0.022$), 7 April 2012 (37 years old [13], $p = 0.001$), and 28 April 2012 (38 years old [14], $p = 0.004$). There were no demographic differences (age, sex, income, and education level) among experimental groups. Sex was the only demographic factor that significantly affected stated compliance with management regulations. Women were significantly more likely to state that they would slow down ($\chi^2 = 5.065$, df = 1, $p = 0.023$) and dismount their bike ($\chi^2 = 9.445$, df = 1, $p = 0.003$) than men. We also found no difference in stated compliance between participants from Santa Cruz County and those from surrounding counties.

Participants who had heard of the beetle prior to taking the survey were significantly older (mean [SD] = 43 years old [13], $F = 16.534$, df = 1, $p < 0.0001$) and had a higher level of education (bachelor's degree, $U = 7825.5$, $p = 0.039$) than those who had not heard of the beetle, who were younger (36 years old [13]) and had a lower level of education (between some college and a bachelor's degree). Participants living in Santa Cruz County had heard of the beetle significantly more than those who lived in surrounding counties ($\chi^2 = 26.356$, df = 1, $p < 0.0001$).

There was no difference in the number of participants who had previously heard of the beetle between those who were given new knowledge and those who were not ($\chi^2 = 0.642$, df = 1, $p = 0.423$). Participants given new knowledge did not rank the importance of beetle conservation higher than those who were not given new knowledge ($U = 10263$, $p = 0.297$). However, participants who had heard of the beetle prior to the survey ranked its conservation as very important significantly more than those who had not heard of the beetle before the survey ($U = 8318$, $p = 0.005$) (Fig. 2). Participants

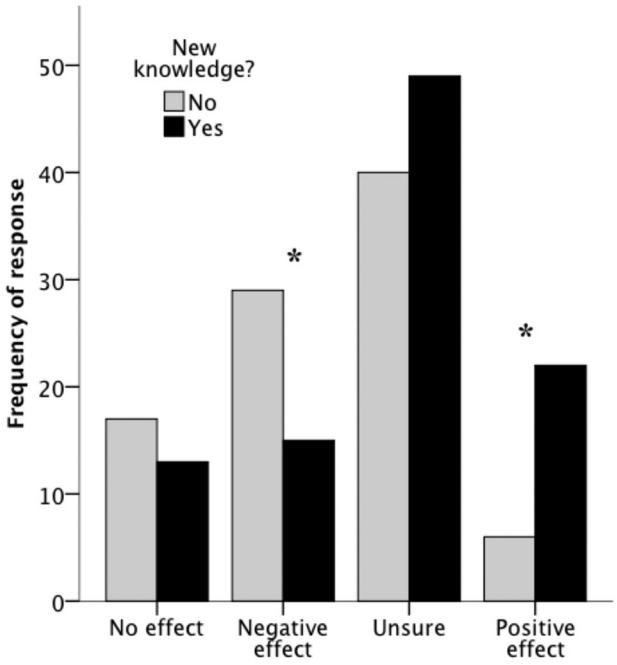

*Figure 3. Frequency of responses to the survey question "How do you feel recreation affects the Ohlone tiger beetle?" from participants with prior knowledge of the beetle that either received new knowledge of the beetle or received no new knowledge (*p = 0.002).*

who had both heard of the beetle prior to the survey and were given new knowledge at the time of the survey rated the effect of recreation as positive significantly more and negative significantly less, than those with prior knowledge but no new knowledge of the beetle ($\chi^2 = 14.804$, df = 3, $p = 0.002$) (Fig. 3).

Stated compliance was high for all management regulations: 90% for slow down in beetle habitat, 90% for stay off closed trails, 95% for use alternative trails, 89% for create new trails, and 62% for dismount bike. Neither prior knowledge, new knowledge, nor their interaction significantly affected stated compliance. Stated compliance was, however, affected by participant's ranking of Ohlone tiger beetle conservation importance and rating of recreation's effect on the beetle. In particular, participants who marked their conservation as very important were more likely to state that they would (or do) slow down in beetle habitat ($\chi^2 = 24.671$, df = 3, $p < 0.0001$) (Fig. 4a) and more likely to state that they would dismount their bike in beetle habitat ($\chi^2 = 16.380$, df = 3, $p = 0.001$) (Fig. 4b). If participants who received no new knowledge thought recreation had no effect on the beetle, then they were more likely to state that they would not slow down in beetle habitat ($\chi^2 = 10.347$, df = 3, $p = 0.016$).

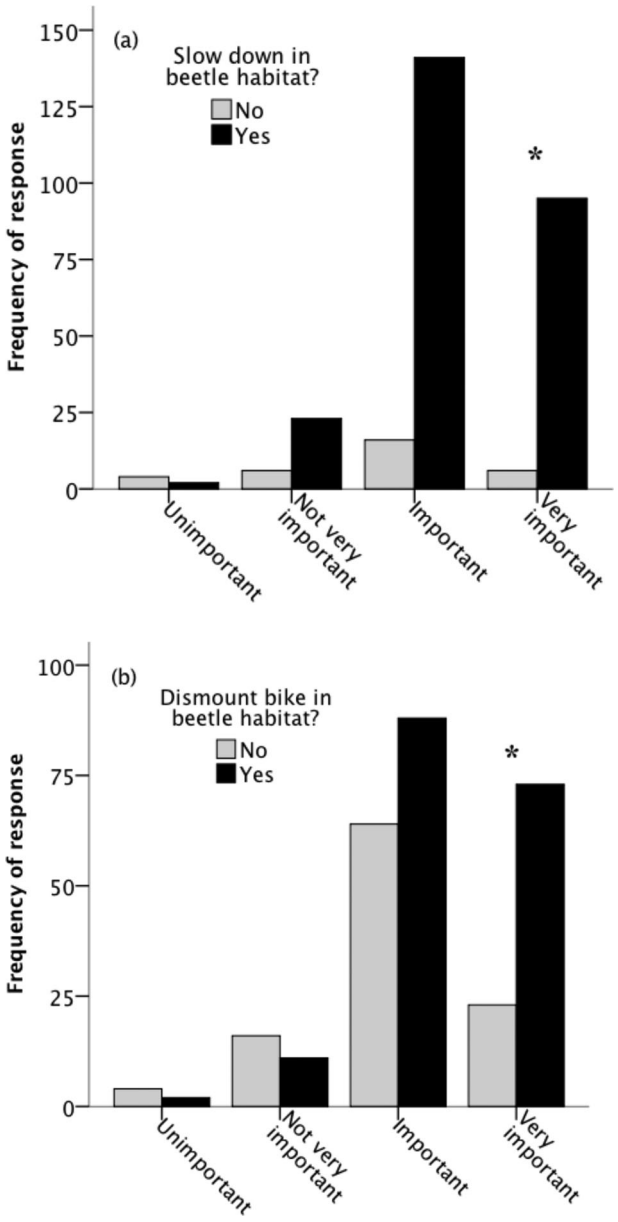

*Figure 4. Frequency of biking participants stated compliance (yes) and stated noncompliance (no) with (a) slowing down in beetle habitat (*p < 0.0001) and (b) dismounting in beetle habitat (*p = 0.001) as it related to participants' responses to the question "How important is conservation of the Ohlone tiger beetle to you?"*

Discussion

In line with the knowledge, attitude, behavior literature, we found a direct link between recreationists' knowledge and attitudes toward Ohlone tiger beetle conservation and their rating of the effect of recreation on the beetle (e.g., Kaiser & Fuhrer 2003; Frick et al. 2004; Farrior 2005). Recreationists were more likely to rate the beetle's

conservation as very important if they had heard of the beetle prior to taking the survey. This finding was contrary to our hypothesis and may be a result of the 10 years that have passed since the publicized conflict between beetle conservation and recreation; time can significantly reduce perceived conflict (Watson et al. 1997). In addition, recreationists negatively affected by the conflict may have been displaced from the area due to the trail closures and management in beetle habitat (Schneider & Hammitt 1995; Vorkinn 1998). Alternatively, because prior knowledge of the beetle was associated with older and more educated participants, this finding may be a result of greater awareness and experience, which results in reduced conflict perception (Cessford 2003) and increased support for conservation efforts (Peterson et al. 2008; Thapa 2010). In line with our hypothesis, however, gaining new and different types of knowledge on top of prior awareness was a significant indicator of the correct and more positive understanding of recreation's effect on Ohlone tiger beetles. This result indicates that building on prior knowledge was central to impart the correct understanding of environmental interactions (Kaiser & Fuhrer 2003; Frick et al. 2004).

It was through recreationists' attitudes and perceptions that knowledge positively affected stated behavior in our study. Of the 5 management regulations we suggested on our survey, only "slow down in beetle habitat" had a positive association with both recreationists' importance rank of beetle conservation and perception of recreation's effect on the beetle. If knowledge does affect attitude and understanding, as our results indicate, then education could lead to increased compliance with signs explaining the positive effect of slowing down on the beetle and rules on slowing down in beetle habitat. Although we investigated only stated behaviors, theory and empirical research show that stated behavioral intentions account for a large portion of variance in actual behavior (Ajzen 1991; Hughes et al. 2009), particularly if the behavioral intention is made while conducting the activity of interest (Lehman & Geller 2004), such as learning of and committing to slowing down while on the trail, as in our study. On the basis of our results of the effects of recreation on beetle behavior, detailed below, we believe this behavior change is likely to have positive outcomes on Ohlone tiger beetle adult survival and conservation.

Despite the limitations of the scope of the behavioral trials, the effect of cycling on adult Ohlone tiger beetle behavior could be reduced by 50% if cyclists slow down to speeds of 8–12 km/h in beetle habitat. Beetles tended to stay on or near the trail more often when cyclers go slowly through their habitat, allowing the beetles to remain closer to their area of activity (i.e., the trail). Tiger beetles are highly active insects that expend upwards of 56% of their energy maintaining an internal body temperature just below their lethal limit (Pearson & Lederhouse 1987). The relatively constant thermal energy tiger beetles receive in open, bare habitats allows them to maintain an optimal foraging temperature (Schultz 1998) and to visually locate and capture prey (Layne et al. 2006). When an Ohlone tiger beetle flies off the trail away from a disturbance (i.e., recreationist), it flies into the surrounding tall, dense grassland, and the beetle leaves a microenvironment of high thermal quality to one of low thermal quality (Schultz 1998) and expends energy escaping the disturbance. This behavioral response also takes the beetle away from its optimal foraging location, the trail, and reduced prey capture has been shown to significantly decrease the number of eggs produced by female tiger beetles (Pearson & Knisley 1985). Although our study is limited in space and time due to the endangered and ephemeral nature of the Ohlone tiger beetle, it is the only empirically based depiction of the effect of recreation on behavior of adults of this species. No recreation would be least disturbing to the beetle's behavior, but it would be detrimental to the overall population because lack of recreation would be followed by loss of critical bare-ground habitat. Thus, requiring cyclists to slow down in beetle habitat is likely to reduce the negative effect of recreation on adult beetles, and we found evidence that providing knowledge enhances compliance with this regulation.

Outreach campaigns should therefore be geared toward educating recreationists with little or no knowledge of Ohlone tiger beetle; thus, the factors associated with that demographic are important to consider when planning management foci. Our results show that older and more educated participants were more likely to have heard of the Ohlone tiger beetle prior to the survey. This indicates that educational outreach should be geared toward younger, less-educated recreationists, such as those local schools and in youth mountain-bike clubs. In addition, because recreationists from Santa Cruz County are more likely to have heard of the beetle, we suggest educational campaigns extend to surrounding counties. Of course, it is important to educate the entire public because not all veteran recreationists will have heard of the beetle. In addition, because both larval and adult stages of the Ohlone tiger beetle depend on bare ground, the recreation community can be directly involved in habitat creation, such as by creation of new and more beetle-friendly trails for adults or removal of prairie grasses to create bare patches for larvae (Cornelisse et al. 2013).

We investigated the ecological effects and the social considerations of managed recreation in a conservation area with the unique attribute of using human disturbance to create habitat for an endangered species. Reconciling and balancing species habitat requirements with human activity is an essential component of species conservation in the Anthropocene (e.g., Kareiva et al. 2007; Caro et al. 2012; Ramalho & Hobbs 2012). By engaging stakeholders in the management or science of species conservation, environmental literacy and support

for biological diversity conservation can be enhanced (Bickford et al. 2012) and conservation may be more effective.

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Supporting Information

The complete survey (Appendix S1) is available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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