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Refinement of a trapping method increases its utility for pocket gopher management

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ABSTRACT

Trapping is a useful and effective tool for managing detrimental pocket gopher populations, and methods to increase its effectiveness are in high demand. The Gophinator trap previously proved more efficient than the Macabee trap, primarily because of its ability to capture larger pocket gophers. However, the Macabee is still widely used given large stockpiles of these traps by land managers and pest control operators. The addition of a cable restraint to the front of the Macabee may be sufficient to keep larger individuals from escaping capture, thereby allowing trappers to more effectively use this common trap. Human scent may also impact trap success by deterring pocket gophers from entering trap sets. Therefore, we tested the capture efficiency and visitation rate of trap sets when using both Gophinator and modified Macabee traps to determine the potential utility of these trap designs. We compared these results to a previous investigation to better define the potential usefulness of the cable restraint on the Macabee. We also tested the impact of human scent on capture efficiency and visitation rate to determine the potential relevance of eliminating human scent from trap sets. Gender and weight of captured individuals were used to determine their potential impacts on capture efficiency and visitation rate. We found that the Gophinator was a more effective trap than the modified Macabee because of its ability to capture larger pocket gophers more efficiently. However, the modification did appear to increase capture efficiency of larger individuals when compared to the standard Macabee, suggesting that this modification could be used to increase the effectiveness of trapping programs when Gophinator traps are unavailable. Glove use had no impact on capture efficiency or visitation rate.

1. Introduction

Pocket gophers (*Thomomys* spp.) are found throughout most of California and are considered one of the most damaging vertebrate species in the state and throughout much of the western U.S. Common forms of damage include direct mortality of plants through root consumption or tree or vine girdling, damage to various forms of infrastructure (e.g., dams, levees, subsurface-drip irrigation tubing, buried cables), and as a tripping hazard to humans and domestic animals resulting in injuries at parks, school yards, athletic fields, and agricultural production areas because of burrows collapsing when stepped on (Marsh, 1998; Proulx, 2002). Agricultural damage is of particular concern given the extreme losses that can occur when pocket gophers are present (5.3%–8.8% reduction in profit; Baldwin et al., 2014b). Trapping has proven to be a highly effective tool at mitigating pocket gopher damage (Smeltz, 1992; Proulx, 1997a, 2002), although advances are always sought to increase the utility of this management approach.

One factor that can increase the utility of trapping is trap selection (e.g., Proulx, 1997b; Pipas et al., 2000). For example, previous research indicated that the Gophinator (Trapline Products, Menlo Park, USA) trap was more effective at capturing pocket gophers than the Macabee (The Macabee Gopher Trap Co., Los Gatos,

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USA) trap, principally because of its ability to capture larger individuals with a greater efficiency (Baldwin et al., 2013). The authors proposed that larger individuals may be able to pull out of the Macabee given weaker spring strength, combined with the upward thrusting motion of the trap that may have pushed the pocket gopher beyond the grasp of the pincer arms. However, more recent efforts suggested that the addition of a cable restraint (1.6 mm in diameter, 23 cm in length) to the front of the Macabee trap (Fig. 1) may increase capture success by limiting the ability of the pocket gopher to pull free from the trap (only 1 out of 51 pocket gophers escaped using the modified Macabee during initial field testing; C.P. Kofron, U.S. Fish and Wildlife Service, unpublished data). With this modification, a pocket gopher is underneath the cable when it springs the trap. As the opposing pincer arms snap toward each other, the upward motion forces the pocket gopher against the cable, thereby reducing the potential for escape. This modification resulted in a similar design to the CV gopher trap which was patented in 1884 and was considered highly effective (Marsh, 1997). Therefore, this simple modification could represent a substantial increase in efficacy to the standard Macabee, perhaps to a level similar to or exceeding that experienced with the Gophinator; such an investigation is worthy considering the widespread use of the Macabee trap throughout the western U.S. (Baldwin et al., 2013).

Another factor that may impact pocket gopher trap success is scent. For example, Proulx (2004) showed that pheromones can increase capture success during select periods of the year, although other olfactory attractants did not yield substantial differences in capture efficiency, particularly when used with uncovered trap sets (Baldwin et al., 2014a). These previous research efforts have focused on factors that might attract pocket gophers to trap sites rather than on scents that might negatively impact capture success. Many professional trappers believe that human scent within tunnels and on traps can reduce efficacy of trap sets by increasing the wariness of pocket gophers around trap sets (Marsh, 2013). However, this has not been formally tested. Therefore, we proposed the following objectives: 1.) determine if capture efficiency or trap visitation differed between modified Macabee and Gophinator traps, 2.) determine if human scent impacted pocket gopher capture efficiency or trap visitation, 3.) determine if weight or gender influenced capture efficiency between trap types or human-scent treatments, and 4.) compare capture efficiency of different weights of individuals captured with modified and unaltered Macabee traps to assess any potential impact from the inclusion of the cable restraint.

2. Study sites

We selected 6 sites from throughout California for this study. These sites were located in the southern (sites 1–2), central (sites 3–4), and northern (sites 5–6) portions of the state (Fig. 2). Site 1 was a pasture, while site 2 was fallow ground. Both sites 3 and 4 were wine-grape vineyards, while sites 5 and 6 were alfalfa fields.

3. Methods

3.1. Trapping protocols

We captured pocket gophers during winter (19 January–5 March) 2015. We used Gophinator and modified Macabee traps described earlier for this study (see Marsh, 1997, 2011 for additional description and dimensions of traps). We thoroughly rinsed all traps with water before initial use to help eliminate previous scent. No human contact with the traps occurred for > two months prior to use, although they had been in contact with human skin at some point prior. Although it is potentially possible that this may have left some residual human odour on the trap, elimination of all

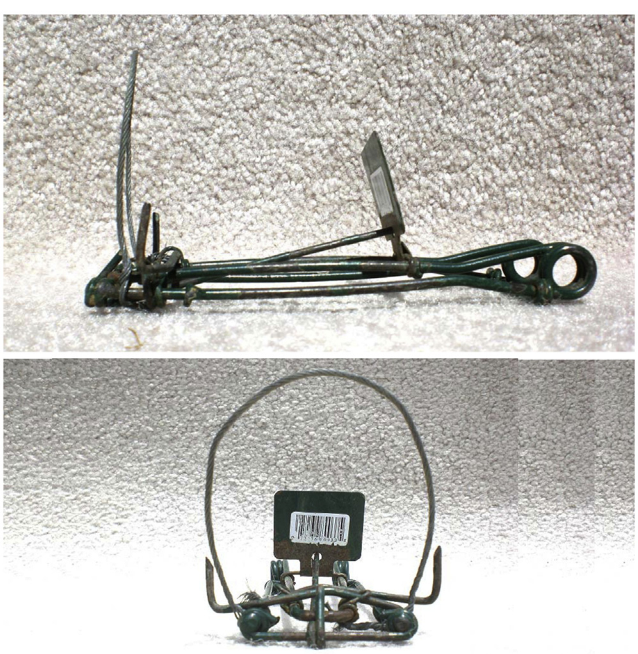

Fig. 1. Modified Macabee trap for capturing pocket gophers: side (top) and front (bottom) views. A strand of cable (1.6 mm in diameter, 23 cm in length) was attached to the front of the Macabee trap. The cable was formed into an upside-down U shape, with each end knotted (overhand knot) or twisted (strands separated then rejoined) onto either side of the trap anterior to the opposing pincer arms. The height of the attached cable was approximately 7 cm.

Fig. 2. The location of field sites in California for this study.

possible human scent was considered impractical and impossible to gauge. Additionally, this trap-cleansing process is consistent with or exceeds that used by almost any professional pocket gopher trapper.

Once cleansed, we divided traps into two groups; one group was handled only when wearing leather gloves, while the other group was handled with bare hands. We never handled the gloved cohort with bare hands for the entire duration of the study to prevent human scent from contacting the traps. When setting traps, we wore gloves the entire trap-setting process for the gloved subset of traps. For the human-scent cohort, trap sets were placed without gloves to introduce human scent on to the trap and into the tunnel system.

Regardless of trap type or glove-usage category, we placed traps into main tunnels of pocket gopher runways and staked them down with wire flags. All trap sets were left uncovered and without any attractant given little benefit to covering trap sets or using attractants (Baldwin et al., 2013, 2014a; Vantassel et al., 2014). We randomly rotated through a cycle of setting gloved and ungloved Gophinator and modified Macabee trap sets until we ended up with 25 of each trap-set type for each site (100 total). Traps were set one day and checked the next. We removed the traps after checking, resulting in one operational day for each trap set. Upon capture, we identified gender following Baldwin and Meinerz (in press) and placed them in plastic freezer bags for weight determination in the lab. Capture protocols were approved by the University of California, Davis's Institutional Animal Care and Use Committee (protocol no. 17283).

3.2. Analysis

We calculated capture efficiency at each study site for each trap-set type (i.e., Gophinator gloved, Gophinator no gloves, modified Macabee gloved, and modified Macabee no gloves) by dividing the number of captures by the number of trap sets receiving a visit (visit was defined by a capture, a sprung trap, or a plugged trap) by a pocket gopher, and we calculated visitation rates for each trap-set type by dividing the number of trap sets that were visited by the number of traps that were set. We tested for differences in the proportion of captures for male and female pocket gophers across sites using Fisher's exact test (Zar, 1999). We used the Cochran-Mantel-Haenszel test (Cochran, 1954; Mantel and Haenszel, 1959) to determine the potential impact of trap type and glove usage on capture efficiency, visitation rate, and gender composition of captures while accounting for potential site variability. We analysed the trap and glove usage comparisons separately, as we felt there was no potential biological meaning for an interaction between these two factors. If we determined significant differences between either trap type or glove usage and capture rate, visitation rate, or gender composition, then we used odds ratios to describe this relationship (Agresti, 1996). For our study, the odds ratios represented the likelihood that a particular trap type or use of gloves would result in increased capture rate, increased visitation rate, or skewed gender ratio. We used the Breslow–Day test (Breslow and Day, 1987) to ensure that odds ratios did not differ across sites.

We analysed the weights of captured pocket gophers as a three-factor analysis-of-variance with site as the blocking effect that received all combinations of trap type, glove use, and gender. Following Baldwin et al. (2013), if weight did influence capture success, we graphically represented the impact of weight on capture efficiency (number of captures for each trap type or glove-use category for a specific weight class divided by the number of trap sites visited for that respective trap type or glove-use category) through the use of 45-g categories to illustrate how capture efficiency varied as weight increased. We used regression analysis to relate the median value of each weight class to the ratio of modified Macabee vs. Gophinator and ungloved vs. gloved capture rates (i.e., the capture efficiency of modified Macabee or ungloved trap sets divided by the capture efficiency of Gophinator or gloved trap sets, respectively) to quantify how trap type or glove status ratios varied across weight classes (Zar, 1999).

We were also interested in how the weight of captured pocket gophers compared between the modified and standard Macabee traps to determine if the addition of a cable restraint increased capture efficiency of larger pocket gophers. For this, we compared pocket gopher weight data from modified Macabee traps from the current study to similar data for standard Macabee traps from Baldwin et al. (2013). To accomplish this, we divided the number of pocket gophers captured in each weight class for each particular trap type (i.e., modified Macabee and Gophinator traps from current study and standard Macabee and Gophinator traps from Baldwin et al., 2013) by the total number of traps visited for the same trap type. We then divided the Macabee capture efficiency values by the capture efficiency values for the Gophinator for both the current study and Baldwin et al. (2013), respectively, to provide a ratio value that would reflect how the two traps compared within each study. For example, a ratio of 100% would mean that capture efficiency was equivalent between the Macabee and Gophinator traps, while a ratio of 50% would indicate that the Macabee was only 50% as efficient as the Gophinator. We then graphically represented these ratios across the different weight categories to illustrate potential differences between the modified and standard Macabee traps. Although the two versions of the Macabee trap were not operated at the same time, we felt this general comparison was appropriate given that three of the locations used in the current study were within several km of sites used in the previous study, and the other three sites were representative of sites used in Baldwin et al. (2013). Furthermore, we relativized captures for the two Macabee designs by dividing their capture efficiency values by capture efficiency values for Gophinator traps from the same sampling period, thereby making ratios more comparable. Because temperature and other climatic factors can influence pocket gopher activity (Cox and Hunt, 1992; Werner et al., 2005; Baldwin et al., 2013), we only used data collected during autumn from the Baldwin et al. (2013) study given the similarity in these climatic factors during the autumn and winter seasons in our study areas (i.e., cool, wet Mediterranean season). We also only used data from uncovered trap sets from the Baldwin et al. (2013) study to maintain consistency between the two investigations. Although a direct comparison between all three trap types would have been more concise, we felt that our approach allowed us to compare capture efficiencies across all three trap designs while minimizing the number of pocket gophers removed during capture efforts.

4. Results

We captured 316 pocket gophers out of 600 trap sets (Table 1). A greater proportion of the captures were female (ratio = 126 males/187 females), although this varied across sites (Fisher's exact test, $p < 0.001$; Tables 1 and 2). Of the two trap types (Gophinator and modified Macabee), the Gophinator was more efficient (Gophinator $\bar{x} = 81\%$, SE = 3%; modified Macabee $\bar{x} = 62\%$, SE = 5%; $\chi^2_1 = 18.2$, $p < 0.001$). Odds ratios were not significantly different between the study sites ($\chi^2_5 = 3.3$, $p = 0.659$); the Gophinator was 2.6 times (95% CI = 1.7–4.1) as likely to be more efficient at capturing pocket gophers than was the modified Macabee. Neither visitation rate (Gophinator $\bar{x} = 72\%$, SE = 8%; modified Macabee $\bar{x} = 72\%$, SE = 8%; $\chi^2_1 = 0.0$, $p = 1.000$) nor gender (Gophinator $\bar{x}$ male = 42%, SE = 5%; modified Macabee $\bar{x} = 39\%$, SE = 9%; $\chi^2_1 = 0.7$, $p = 0.398$) differed between the two traps (Table 1). We also did not observe any

Table 1
The number of male (M cap), female (F cap), and total captures (T cap) of pocket gophers, the number of visited trap sets (N vis), the rate of capture (T Cap/N vis), and the trap visitation rate (N vis/number of operational trap sets [$n = 50$]) for Gophinator and Modified Macabee trap sets across 6 sites in California during winter 2015. Composite (Comp) data are provided for comparative purposes.

Site	Gophinator						Modified Macabee					
	M cap	F cap	T cap	N vis	Cap %	Vis %	M cap	F cap	T cap	N vis	Cap %	Vis %
1	12	23	35	43	81	86	5	30	35	44	80	88
2[a]	14	27	43	47	91	94	10	20	31	47	66	94
3	4	11	15	20	75	40	3	6	9	18	50	36
4	8	12	20	28	71	56	10	6	16	34	47	68
5	20	16	36	42	86	84	18	9	27	37	73	74
6	17	12	29	35	83	70	5	15	20	35	57	70
Comp	75	101	178	215	81	72	51	86	138	215	62	72

[a] Gender data missing for 3 pocket gophers.

Table 2
The number of male (M cap), female (F cap), and total captures (T cap) of pocket gophers, the number of visited trap sets (N vis), the rate of capture (T Cap/N vis), and the trap visitation rate (N vis/number of operational trap sets [$n = 50$]) for trap sets where human scent was eliminated (Gloved) and where human scent was present (No gloves) across 6 sites in California during winter 2015. Composite (Comp) data are provided for comparative purposes.

Site	Gloved						No gloves					
	M cap	F cap	T cap	N vis	Cap %	Vis %	M cap	F cap	T cap	N vis	Cap %	Vis %
1	10	26	36	44	82	88	7	27	34	43	79	86
2[a]	13	21	35	47	74	94	11	26	39	47	83	94
3	5	4	9	16	56	32	2	13	15	22	68	44
4	10	8	18	30	60	60	8	10	18	32	56	64
5	19	12	31	39	79	78	19	13	32	40	80	80
6	9	13	22	35	63	70	13	14	27	35	77	70
Comp	66	84	151	211	69	70	60	103	165	219	74	73

[a] Gender data missing for 3 pocket gophers.

substantial impact of glove use on capture efficiency (gloved $\bar{x} = 69\%$, SE = 4%; no glove $\bar{x} = 74\%$, SE = 4%; $\chi^2_1 = 0.6$, $p = 0.424$), visitation rate (gloved $\bar{x} = 70\%$, SE = 9%; no glove $\bar{x} = 73\%$, SE = 7%; $\chi^2_1 = 0.6$, $p = 0.430$) or gender composition (gloved $\bar{x}$ male = 50%, SE = 5%; no glove $\bar{x}$ male = 36%, SE = 7%; $\chi^2_1 = 1.7$, $p = 0.186$) of pocket gophers (Table 2).

Not surprisingly, pocket gopher weights varied regionally ($F_{5,302} = 21.0$, $p < 0.001$), and males ($\bar{x}$= 166 g, SE = 5 g) were larger than females ($\bar{x}$= 125 g, SE = 3 g; $F_{1,302} = 87.5$, $p < 0.001$). Neither human scent ($F_{1,302} = 0.2$, $p = 0.646$) nor a human scent × gender interaction ($F_{1,302} = 0.4$, $p = 0.555$) exhibited a significant relationship to weight. However, we did observe a difference in the weight of pocket gophers captured between the two traps ($F_{1,302} = 2.9$, $p = 0.090$), as heavier individuals were captured using the Gophinator ($\bar{x}$= 146 g, SE = 4 g) than with the modified Macabee ($\bar{x}$= 136 g, SE = 4 g). A trap × gender interaction suggested an impact on capture efficiency, although this impact was marginal ($F_{1,302} = 2.6$, $p = 0.106$).

As with past research (Baldwin et al., 2013), the disparity in capture efficiency between the Gophinator and modified Macabee was greatest with the largest pocket gophers (Fig. 3). However, in contrast to the linear relationship between the Gophinator and standard Macabee (Baldwin et al., 2013), the relationship between the Gophinator and the modified Macabee was curvilinear ($F_{2,2} = 13.8$, $p = 0.067$, $R^2 = 0.93$; Fig. 3). This suggests that the modified Macabee was more effective at capturing individuals of intermediate and larger sizes than the standard Macabee (Fig. 4), even though the modified Macabee was still 3 and 2 times less efficient at capturing the heaviest and second-heaviest size class of pocket gophers when compared to the Gophinator (Fig. 3).

5. Discussion

As with past research (Baldwin et al., 2013), the Gophinator was the more effective trap, driven primarily by its ability to capture larger pocket gophers more efficiently. The ability of the Gophinator to capture larger individuals is of importance as large females are responsible for much of the reproduction that occurs within the population (Miller, 1946). Furthermore, larger pocket gophers are likely to cause more extensive damage given the greater caloric intake required by larger individuals. Given the difficulty in capturing these experienced pocket gophers, using a trap that maximizes capture efficiency of large individuals should lead to substantial benefits for management programs.

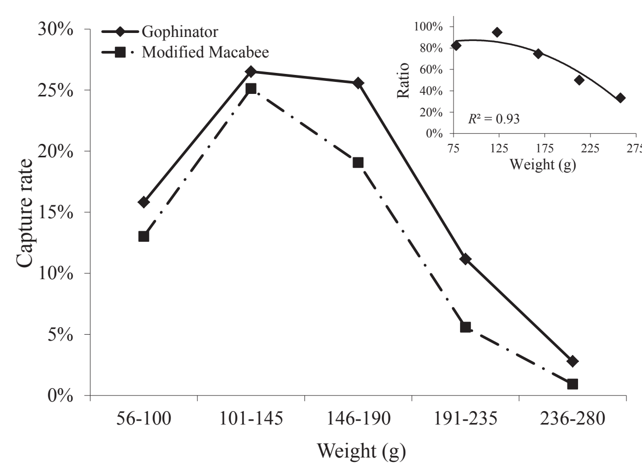

Fig. 3. The percentage of visited trap sets with captures (Capture efficiency) for 45-g weight categories of pocket gophers. Comparisons are provided for Gophinator vs. modified Macabee traps. Also included are polynomial regressions of weight classes compared to the ratio of modified Macabee vs. Gophinator capture efficiencies (Ratio).

Although the Gophinator was clearly the more effective trap, the Macabee is still used quite extensively throughout the western U.S.

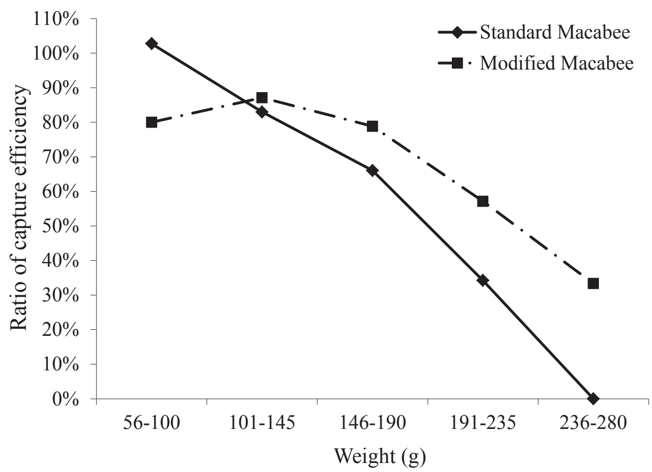

Fig. 4. The ratio of capture efficiencies between standard Macabee and Gophinator traps used in Baldwin et al. (2013; Standard Macabee) and modified Macabee and Gophinator traps used in the current study (Modified Macabee). A ratio of 100% indicates that capture efficiency was equivalent between the Macabee and Gophinator traps, while a ratio of 50% indicates that the Macabee was only 50% as efficient as the Gophinator.

Purchasing all new traps is often not cost effective, so utilizing traps on hand may be the only practical option until natural turnover allows for their gradual replacement with more effective options. As such, the modified Macabee may be a practical short-term option, as this modification allowed us to capture larger pocket gophers more efficiently than the standard Macabee. For example, the curvilinear relationship we observed between weight and capture efficiency between the Gophinator and modified Macabee indicated relatively equivalent capture efficiency up to around 130 g in weight (Fig. 3). This is particularly relevant from a management perspective, as most of the female pocket gophers captured in the current study were at or below this weight threshold. Because pocket gophers are polygynous breeders (Lay, 1978), removal of female pocket gophers is particularly important to the efficacy of any management program. Therefore, the provided modification should result in an improvement to any pocket gopher management plan that utilizes Macabee traps.

That being said, we did observe slightly lower capture efficiency for the smallest individuals captured with the modified Macabee trap when compared to the standard Macabee (Figs. 3 and 4). Reasons are unclear, but could be due to the smaller diameter of tunnels of small, juvenile pocket gophers. When placed in small tunnels, the cable loop from the modified Macabee was bent substantially backward toward the trigger mechanism, as there was not enough space within the tunnel to accommodate a vertical positioning of the loop. This may have obstructed pocket gophers as they moved toward the trigger mechanism. Further research could be conducted to better define this impact. In the interim, a simple solution would be to use unmodified Macabee traps in small tunnels, as unmodified Macabee traps capture small pocket gophers efficiently (Baldwin et al., 2013).

Although trap type did substantially impact capture efficiency, the use of gloves did not have any negative impact on capture efficiency or visitation rate by pocket gophers. In fact, if any trend was present, it was toward increased efficacy when wearing no gloves. Some trappers prefer to wear no gloves as it allows an increased ability to detect nuances in tunnel bends, forks, and obstructions. However, most trappers we know use gloves to reduce wear and tear on hands during the trapping process. Either way, the use of gloves, and subsequently human scent, appears to have little impact on management programs.

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