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Too hot to handle? Balancing increased trapability with capture mortality in hot weather pitfall trapping

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Abstract Trapping at air temperatures close to, or exceeding, critical thermal maxima is important for comprehensive sampling of vertebrate assemblages and collection of sufficient data for impact assessment. However, pitfall trapping on hot days also potentially exposes trapped animals to stress or death through overheating or desiccation. We investigate causes of mortality from 14,305 captures over a 22 year pitfall trap study in arid South Australia and compared mortality rates with maximum temperatures, solar radiation and rainfall. Overall mortality rate was 3.2% with chewing by rodents and handling accidents the most influential cause of death recorded. The highest mortality rates were experienced by the tiny skink, *Lerista labialis*, which was difficult to detect in traps each day and hence problematic to assess the effect of weather variables on capture mortality. For all other abundant species, high maximum temperature was only a significant explanatory variable for increased death rates of the house mouse *Mus domesticus*, and increased solar radiation was positively related to capture mortality for the house mouse, the frog *Neobatrachus sudelli* and the small skink *Ctenotus schomburgkii*. However, capture rates for these taxa and eight other common species would have been significantly lower if trapping did not occur on days of 40 °C or more. We conclude that trapping in hot weather is both desirable and justifiable and suggest techniques for further reducing mortality rates in pitfall studies.

Key words: mammals, mortality rates, reptiles, thermal maxima

Introduction

Ambient temperatures in excess of 40-42 °C are typically fatal for many reptiles and small mammals (Curry-Lindahl 1979; Erskine and Hutchison 1982; Greer 1989). Critical thermal maxima can be reached at lower temperatures if trapped mammals (Wunder 1974, Walsberg 2000) are very active, which can raise their body temperatures by a further 3 °C. Recent evidence indicates that most ectotherms have very low physiological thermal-safety margins and must instead rely on their behaviour to avoid overheating at high temperatures (Sunday *et al.* 2014). Thermoregulatory strategies such as seeking shade or burrowing may not be available to trapped animals, thus increasing their likelihood of succumbing to heat stress or desiccation.

Comprehensive sampling of terrestrial vertebrates is required for thorough environmental monitoring (Garden *et al*. 2007, Thompson and Thompson 2010) and assessments of potential impacts to conservation-rated species (Thompson 2004, Mackenzie 2005). Compilation of detailed inventories, life histories and thermal preferences through monitoring in different seasons and temperatures is also necessary for modelling the likely influences of climate change on fecundity and survivorship (Adolph and Porter 1993, Sinervo 1990, Shine 2012) and ultimately conservation status of reptiles (Sunday *et al.* 2014). Therefore, autecological studies and environmental monitoring of ectotherms should ideally be conducted in a range of seasons and weather conditions, including those at and above the mean thermal preference of study animals. Optimal body temperatures for activity may exceed 38 °C in many diurnal arid zone reptiles (Pianka 1971, Vitt *et al.* 1993, Bradshaw 2003). Because many lizards maximise their performance and reproductive success at temperatures close to their upper lethal thermal limits (Pianka and Vitt 2003), reptile capture rates are typically highest during the hotter months (Read and Moseby 2001, Thompson and Thompson 2005). While nocturnal species are active at much lower temperatures than their thermal preferences and upper limits (Autumn *et al.* 1999), activity temperatures of many arid zone species exceed 25 °C (Pianka and Pianka 1976) and are thus more active on the evenings of very hot days. Therefore, scientists face an ethical dilemma of trading-off the benefits of increased sample size and survey comprehensiveness through field sampling in summer, with the increased risk of heat-related trap mortalities (Thompson and Thompson 1999).

Pitfall trapping, via an array of buckets or pipes set into the ground, is frequently used to passively and indiscriminately sample terrestrial vertebrates (Fisher *et al.* 2008; Fisher and Rochester 2012). Unlike free-ranging animals that can burrow, climb or seek shade to avoid dangerous temperatures, animals trapped in barren pitfall traps typically have limited potential behavioural responses to regulate their temperatures. Although data on mortality rates from most trapping studies are not published, pitfall trapping mortalities are clearly significant for some species, particularly small mammals with high metabolic rates. For example, mortality rates for shrews (*Sorex* spp. and *Blarina carolinensis*) have exceeded 95% (Stromgren and Sullivan 2013, Edwards and Jones 2014) and Lemckert *et al.* (2006) found that *Antechinus* spp. accounted for 95% of deaths in their appraisal of trapping mortalities in New South Wales. In a comparison of five Florida pitfall trapping studies, Enge (2001) recorded mortality rates of lizards between 5.6% and 13.9% and all taxa combined of between 5.8% and 19.4%. Even higher mortality rates (17.8-33.0%) were reported for the three most common amphibian species trapped in New Hampshire pitfalls (DeGraaf and Rudis 1990).

Sampling practitioners and animal ethics committees are therefore obliged to carefully consider both the temperatures and methods used for sampling to limit trap mortalities of both target and non-target species. This study aims to inform optimum pitfall trapping programs in hot environments by investigating the causes of mortality in a long-term trapping study of an Australian arid zone reptile and small mammal community. We also specifically compared capture rates and mortalities of abundant species if arbitrary limitations had been placed on the temperature, or months, that the trapping occurred.

Methods

Small vertebrates were trapped from 1991 to 2012 in a one hectare grid of pitfall traps in chenopod shrubland (30^0 29'S, 136^0 55$^{'}$E) near Olympic Dam in northern South Australia. Soils ranged from sandy clay at the base of a sand dune to rocky clay plains, with chenopod shrubs (*Atriplex, Maireana* and *Sclerolaena* spp.) being the dominant vegetation (Read 1995). Over 50 small reptile and 15 small mammals species have been recorded from the study region (Read 1994), with *Ctenotus* skinks, *Ctenophorus* dragons and diplodactyline geckoes the most abundant reptile captures and *Pseudomys* rodents and *Sminthopsis* marsupials comprising the majority of small mammal captures at the study site (Read *et al.* 2012).

Pits were 500mm deep sections of 150mm diameter PVC sewer pipes with tight fitting caps on the bottom and top. A total of 401 pits were spaced at 5m intervals without drift fences in one hectare. All pits were opened together for a total of 10 trapping days in both early and late summer each year, with each trapping day separated by at least one day when the pits were closed. All traps were checked and closed within 4hrs of dawn and captured animals were transported in individual white calico bags to an air-conditioned laboratory for measuring and marking with unique toe-clip combinations, where the terminal section of up to four digits was removed. Despite recommendations of some recent ethics committees for cover inside pitfall traps, no such insistence was made for this study and the only non-windblown cover in the traps was a 4cm x 4cm plastic-coated pit identification tag that was placed in bags with captures and then returned to the pit upon release. All injuries or deaths, and their cause where known, were recorded. Animals were returned to their exact point of capture in the cool of the evening on their capture day.

Due to the long term nature of this study, care was taken to minimise disturbance to both the habitat and the invertebrate communities at the study site. All traps were hand dug by spade and crowbar and accessed by foot. Activities at the site were limited to trap checking and releasing animals, with all processing conducted off site. Insecticide was rarely used in or near the traps to minimise impacts on invertebrate communities, although on rare occasions when a trail of *Iridomyrmex* ants intercepted a trap, a surface insecticide spray was used.

Weather details (maximum air temperature, rainfall, total solar radiation) were extracted for the study site from the Australian Water Availability Project high resolution (0.05 °, ca 5km^2) gridded weather product (see Jones *et al.* 2009). We included solar radiation because it interacts with air temperature to influence trap temperatures, and rainfall was included because it may lead to drownings in flooded traps. We extracted data for both the day the traps were opened and the following day when traps were checked (in the morning), as weather conditions at either time period may have affected mortality rates (e.g. for all nocturnal species, heat exposure or desiccation problems should only be related to the conditions on the morning traps were checked). A single day of trapping in November 2005 was excluded from the analysis because these deaths were not attributable to proximal weather conditions. On this day, the traps were inadvertently left open for a week due to a communication breakdown and 55 animals, mainly rodents and dunnarts died. For the 20 species with the highest capture frequency (>70 captures), we used logistic regression to assess the relationship between trap deaths and the three weather variables. We also determined the total number of live and dead captures that fell into a set of hypothetical constraints on trapping times that could conceivably be used to limit heat deaths. Specifically, we used maximum air temperature thresholds of 40-45 °C (in 1 °C intervals), with and without a prohibition on trapping during the typically hottest summer months of January and February.

For each scenario, to test for significant effects on mortality rate, we analysed contingency tables to test for independence between the ratio of the numbers alive and dead captures on days that would have been excluded by the scenario, and the same ratio when not imposing the scenario. Similarly, to test for significant reductions in daily trapping success, we analysed contingency tables to test for independence between the ratios of captures on days included and excluded by the scenario, and the number of trap days included and excluded by the scenario.

Results

A total of 463 deaths was recorded from 14,305 small vertebrate captures over 207,317 trap nights in this study. Capture mortality for all species combined was thus 3.2%, which increased to 3.6% if the single catastrophic accident in November 2005 was included. Capture mortalities varied considerably between different taxa, with trilling frogs (*Neobatrachus sudelli*) and the small skinks *Lerista labialis* and *Menetia greyii* each at or above 7% mortality (Table 1). By contrast, capture mortality for all other species was less than 6% and was typically less than 3% (Table S1).

Significant causes of trap mortalities were attributed to handling accidents (13.6% of mortalities), chewing by house mice (10.4%), being overlooked in the traps (6.7% if the November 2005 event is excluded) and drowning and ant attack (4.3%) (Fig. 1). Handling accidents were predominantly unseen hatchlings that were fatally injured when clearing traps and animals that were apparently squashed in their bags during handling or transport. No deaths were attributed to toe-clipping, and multiple recaptures at this site of many species over several years (Read 1998a, 1999a) suggest this practice was not a significant cause of mortality. Desiccation was rarely recorded as the cause of death but since no clear cause was determined for half of the mortalities (Fig. 1), the potential for hot temperatures to be a significant factor could not be discounted without analysing weather conditions during trapping.

Although captures generally declined from the first to the last sampling day of the session, the distribution of mortality events did not depart from the expected distribution based on live captures with the exception of the lizards *Lerista labialis* and *Ctenophorus fordi* (Fig. 2). Uniform mortality rates on different trapping days for all other species suggests that environmental conditions, rather than the effects of repeated trapping or being overlooked in traps, were likely to influence mortality rates and validates investigation of weather conditions as a potential causal factor. Such an approach however was less likely to be informative for the cryptic, fossorial *Lerista labialis*, which could remain concealed, live or dead, in minimal debris in the bottom of the pit and were sometimes only revealed when the traps were exhaustively cleaned out on the last day of each trapping session, or alternatively as a dried specimen on the first day of the following trapping session. *Lerista labialis* exhibited by far the highest mortality rates of any abundant taxa and observed capture mortalities were significantly higher on the first and last days of trapping compared to days 2-9 (Fig. 2), which confirms that some individuals were overlooked in the traps. For this reason, we cannot rule out high temperatures as a contributing factor for *L. labialis* as such an effect would not necessarily be detected by our analyses.

Maximum temperatures on the day of trapping, which was the day before the morning of trap checking, ranged from 14.9 to 47.8 °C with a mode of 39.1 °C and exceeded 40 °C on 74 of the 517 trap days. Over 5mm of rainfall was recorded on 16 of the trapping days.

Of the 20 species considered in detail (>70 captures), mortality rates of 14 were sufficient for logistic regression analysis of the association between trap death and weather variables (Fig. 3). Significant relationships were typically found for conditions on the day traps were set for the diurnal taxa and on the day traps were checked for the nocturnal taxa. Only three species (the gecko *Rhynchoedura eyrensis* and rodents *Pseudomys bolami* and *Mus domesticus*) showed an effect of maximum air temperature on probability of trap death (Fig. 3a), with only *M. domesticus* showing an increase in risk of death with maximum air temperature and the other two showing a significantly decreased risk. Solar radiation on the day of capture was positively related to capture mortality for three species (*Neobatrachus sudelli*, the skink *Ctenotus schomburgkii* and *Mus domesticus* – Fig. 3b). Rainfall on the day of trapping was positively related to capture mortality for three taxa (*Ctenotus schomburgkii*, the small dasyurid *Sminthopsis crassicaudata*, and the dragon *Tympanocryptis intima* – Fig. 3c) but negatively related for the frog (*Neobatrachus sudelli*).

Considering the hypothetical effect of different restrictions on trapping, significant mortality fractions would have been avoided for two species (about 30 % for *Ctenotus schomburgkii* and about 60 % *Mus domesticus*) if trapping were restricted to days below 40 °C, but significant fractions (20-35%) of captures would have also been missed for these two taxa and eight others if trapping did not occur on days of 40 °C or more (Fig. 4a, Fig. S1). Imposing this air temperature threshold and additionally prohibiting trapping during the hottest summer months (January and February) did not result in any statistically significant reduction in mortality but had substantial effects on the proportion of animals missed for all 20 abundant taxa (ca 40-70%) (Fig. 4b). The percentage change in daily trapping success was reduced for all reptile taxa but increased for all mammal species when imposing air temperature and seasonal constraints, with substantially larger effects of the seasonal constraint. For the frog (*N. sudelli*), the air temperature restriction increased daily trapping success but the seasonal constraint decreased daily trapping success. As the threshold daily maximum air temperature was increased from 40 to 45 °C, the proportion missed declined steadily for all species except *N. sudelli* (Fig. S2), indicating value in trapping at high temperatures. The pattern of differences in mortality and trapability changed little with the air temperature threshold although at 42 °C significant reductions in mortality were found for *L. labialis* and the gecko *Diplodactlyus conspicillatus* (Figs. S3-S7).

Discussion

We found little to no evidence that hot weather was a contributing factor in trapping mortalities in our dataset of >14,000 captures, despite almost 15% of the 517 trapping days exceeding 40 °C. Abandoning trapping on days 40 °C or higher reduced trapping mortalities for four of the 20 species analysed, depending on the threshold chosen, with the introduced house mouse *Mus domesticus* being the only species where large (>30%) reductions in mortality rate were apparent.. However, abandoning trapping on these hot days would have significantly reduced capture rates for between nine and eleven of the abundant reptile species. The increased representativeness and capture rates achieved when trapping on days that exceeded 40 °C provides a strong incentive to trap in hot weather provided that measures are taken to remove or significantly reduce temperature extremes as a factor in trapping mortalities.

Although checking pitfall traps every second day is deemed satisfactory in some areas (Fitzgerald and Yantis 2012), traps set in hot environments should be checked at least every morning. Daily checking of pitfall traps resulted in reduced toad mortality rates of 4.7% in Florida (Dodd, 1995) and 1.3% for amphibians in Connecticut (Gibbs 1998). Our study supports evidence from other long-term studies that heat-related deaths are minimal for most species, even on extremely hot days, provided that narrow pits are used and checked within 4 hours of dawn, when temperatures in pitfall traps typically remain considerably lower than ambient temperature. Cold weather was not a problem in our study, which was conducted exclusively in warm seasons. However, winter cold likely contributes to more deaths of reptiles than overheating (Gregory 1982) and Lemckert *et al.* (2006) reported that most small mammal deaths in Elliott traps in New South Wales were associated with cold weather, multiple recaptures and post-capture handling.

Mortality rates of most small reptile and mammal species of less than 5% recorded in this study conform with the findings of Lemckert *et al.* (2006) that mortality rates of small mammals in cage or box traps exceeding 4% were unusual and typically resulted from one-off extreme mortality events. Biting deaths inflicted by rodents and handling accidents were the most common definitive causes of death identified in this study. Whilst all trap deaths should be avoided where possible and efforts should be made to reduce overall trapping mortalities below the 3.2% of captures recorded here, valuable data not accessible from live studies can be acquired from trapping mortalities. For example, mortalities from this study were dissected to provide valuable information on diet or reproductive condition (Read 1998a; 1999a,b). Trapping mortalities also need to be reconciled with the benefits accrued from wildlife studies. In this case the life history, movements, diet and fecundity rates determined through this study informed analyses of industrial (Read 1998b, Read *et al.* 2005); and farming (Read 2002) impacts along with enabling predictions of the impacts of climate change (Read *et al*. 2012) and even biological control of pests (Pedler *et al.* 2016) on small vertebrate assemblages. Whilst accidents and stochastic incidents are not entirely avoidable, mortality rates from pitfall trapping in arid Australia should be less than 4%. We propose several recommendations for reducing trap deaths even further than experienced during this study.

Relatively high death rates caused by introduced or native rodents could be alleviated by providing dry food (e.g. seeds) in the traps, which may both distract and satisfy the hunger of these rodents sufficiently to minimise their likelihood of biting or eating trapped lizards. However, supplementary food alone does not guarantee high survivorship of all trapped mammals or their potential prey. Karraker (2001) documented three pitfall studies where, despite multiple checks each day and provision of supplementary food, mortality rates for masked shrews (*Sorex cinereus*) exceeded 82% mortality. In cold climates, greasy wool and or small tubes can also provide protection for small mammals from cold and moisture. Elevated covers over pitfalls shade trapped animals, reduce entry of rainfall and reduce mesocarnivore predation in pitfalls (Fitzgerald and Yantis 2012). Although insect attack was not a significant cause of mortality in this study, ants in particular can cause significant trap mortality. Enge (2001) found prevalence of predatory ants was one of the main contributors to trap mortalities in Florida pitfall studies and also noted a 50% mortality of trapped small snake species from beetle predation. Sparing use of insecticide powder at sites or at times when invertebrate attack is most likely can protect trapped vertebrates from insect attack.

Small skinks, like *Lerista labialis*, may be particularly susceptible to hot dry conditions because, unlike other reptile families, skinks do not pant (Greer 1980). Our experience from other trapping studies suggests that along with *Lerista* spp., other fossorial reptiles including blind snakes also have relatively low tolerance to hot dry conditions in empty pitfall traps (JLR pers. obs), possibly because of reduced desiccation tolerance. In contrast to wide shallow buckets that are often used for pitfall traps, deeper narrower pits provide greater insulation (Fisher and Rochester 2012) and shield direct sunlight (Read *et al.* 2015). Shading of pits and inclusion of sand and possibly other shelter (Thompson and Thompson 2010) inside pits should reduce the risk of heat-related death of these desiccation-sensitive fossorial species.

Lerista and *Menetia* were also likely over-represented in our trapping mortalities because they are small bodied (often <0.5g) and hence were more likely to be either overlooked in traps or to remain concealed in even a partial covering of sand or litter on the base of the trap. Unique aspects of this research program designed to determine movement patterns and influence of climatic variables on small vertebrate activity required lengthy trapping sessions of approximately 25 days , which undoubtedly contributed to the relatively high mortality rates of tiny cryptic lizards. In more typical trapping scenarios when sessions are completed within 4-10 consecutive days (Fisher and Rochester 2012) and the precise date of capture is less relevant, small or fossorial species can shelter with greater safety amongst greater depth of soil or litter in the base of the pit. Detection and safe removal of small or neonate lizards, particularly those that burrow under leaf litter or soil, from pitfall traps will always be problematic. Handling deaths are likely to be minimised by leaving fossorial species in the pitfall trap litter until the end of the trapping session when they can be scooped out of the pit and into a pit lid with the aid of a calico bag spread over the sampler's hand. All other captures should be placed individually each morning into labelled bags. Inclusion of cool moist sand in the bags containing fossorial reptiles and frogs, and storage and transport of all captured animals out of direct sunlight and inside insulated boxes or air-conditioning should be conducted whenever ambient temperatures exceed 30 °C.

Minimising mortalities of burrowing frogs is particularly problematic for several reasons. Our finding that capture rates of frogs would have been increased if trapping was abandoned on hot days, but not during the summer months when heavy rain was more likely, reflects the activity patterns of *Neobatrachus sudelli* on or immediately after rainy days (Read 1999b) when temperatures are likely lower than average. During or immediately after rain, high densities of calling frogs can result in dozens, sometimes over 200 frogs, being attracted into a single pitfall trap (Read 1999c), which may lead to crowding deaths. However even more significant is the threat of dehydration when low numbers of frogs emerge from wet soil on dry nights and fall into dry pits. Being predisposed to dehydration, these frogs can rapidly desiccate if there is no supplementary moisture provided by a wet sponge (Fisher *et al*. 2008) or moist substrate in the pit to burrow into. Wet sponges in pits can be valuable in keeping trapped amphibians hydrated, but care must be taken to not attract ants that can then injure or kill small trapped vertebrates (Fisher *et al.* 2008). Polystyrene sheets (Thompson and Thompson 1999) or foil covered sheets (Hobbs and James 1999) have also been suggested to provide shelter for trapped animals and have the added benefit that they form a floating raft if the pits are flooded. However, any artificial shelters are likely to be chewed by trapped rodents.

In conclusion, our analysis of an extensive dataset of pitfall trapping records in a hot environment indicates that pitfall trapping can be undertaken during hot weather without a high risk of heat-related trap mortality. We caution that our findings are limited to narrow and relatively deep pitfall traps) and may not generalise to other, less thermally-buffered traps. Nonetheless, the methods we used are neither unusual nor difficult to implement. With the additional precautions we have proposed, the significant advantages of trapping in hot weather in terms of higher capture rates, especially for ectothermic species, and more representative pictures of seasonal activity patterns can be safely exploited.

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Table 1. Summary of mortality causes and incidents for the main vertebrate groups over the study period, excluding the exceptional day in November 2000 discussed in the text

Cause of death	Invertebrate	Vertebrate	Weather	Overlooked	Handling	Unknown	Total deaths	total captures	% mortality
Dragons	6	8	6	4	5	7	36	2021	1.8
Skinks	20	42	11	20	31	93	217	4001	5.4
Geckoes	14	18	4	6	6	19	67	3451	1.9
Snakes and goannas	0	0	0	0	1	0	1	78	1.3
Mammals	3	5	4	0	19	44	75	3796	2
Frogs	0	0	8	1	1	57	67	958	7
Total	**43**	**72**	**32**	**31**	**63**	**218**	**459**	**14360**	**3.2**

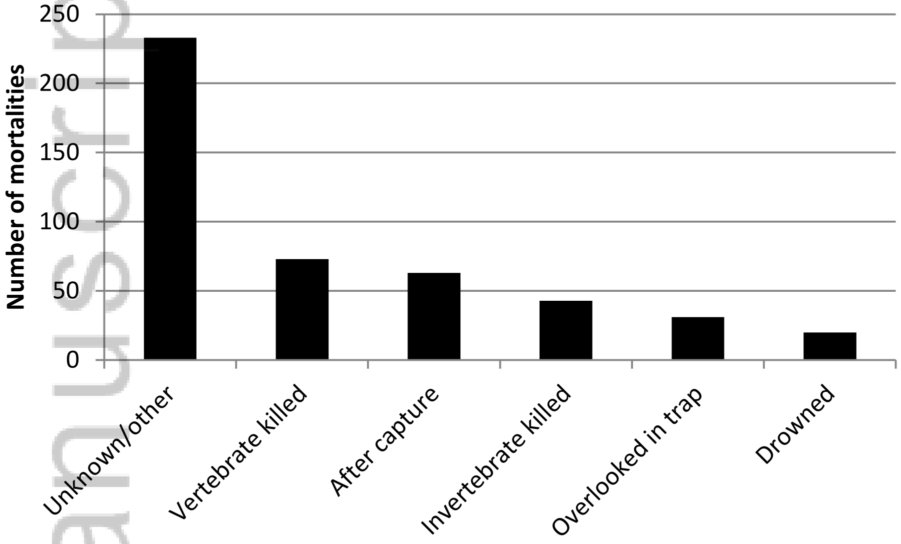

Figure 1 Causes of mortality of 463 mortalities from the 14306 small vertebrate captures in the Olympic Dam PITGRID (NB data excludes a single catastrophic event where 55 deaths occurred due to sampling error in November 2005).

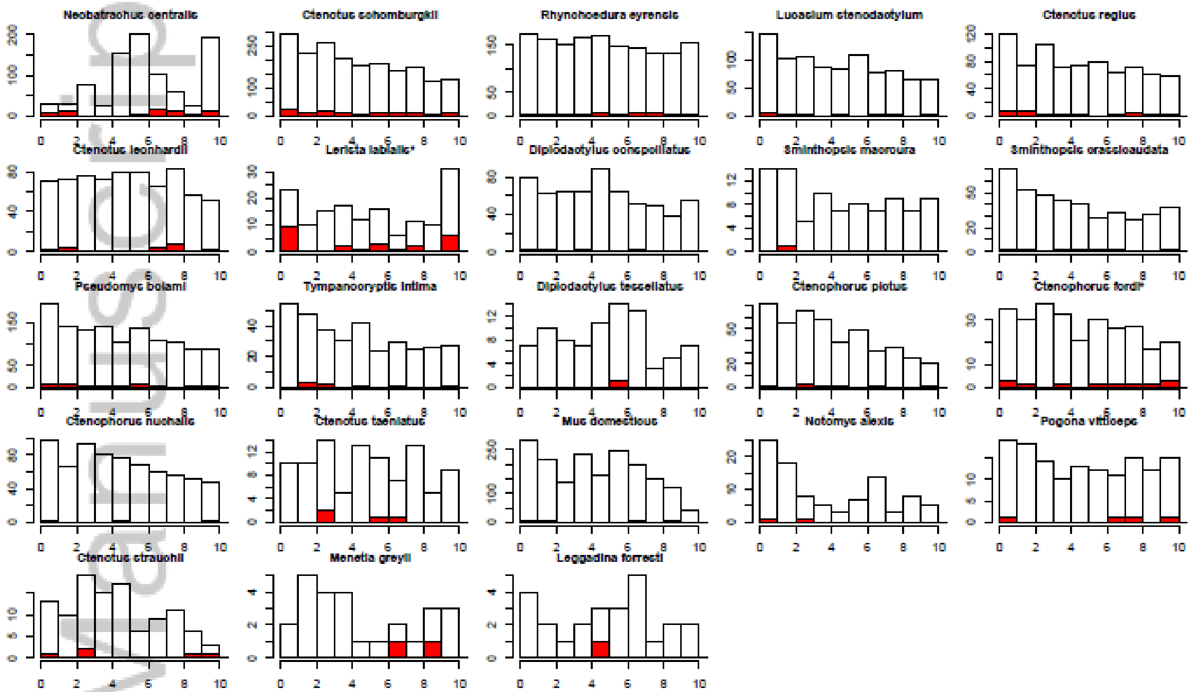

Figure 2. Capture (open columns) and mortality (shaded columns) frequencies for abundant species on sequential trapping days each session. * indicates species where significant interactions were found between the relative frequencies of live vs. dead captures on days 1 and 10 vs. days 2-9 (χ^2 test, $P < 0.05$).

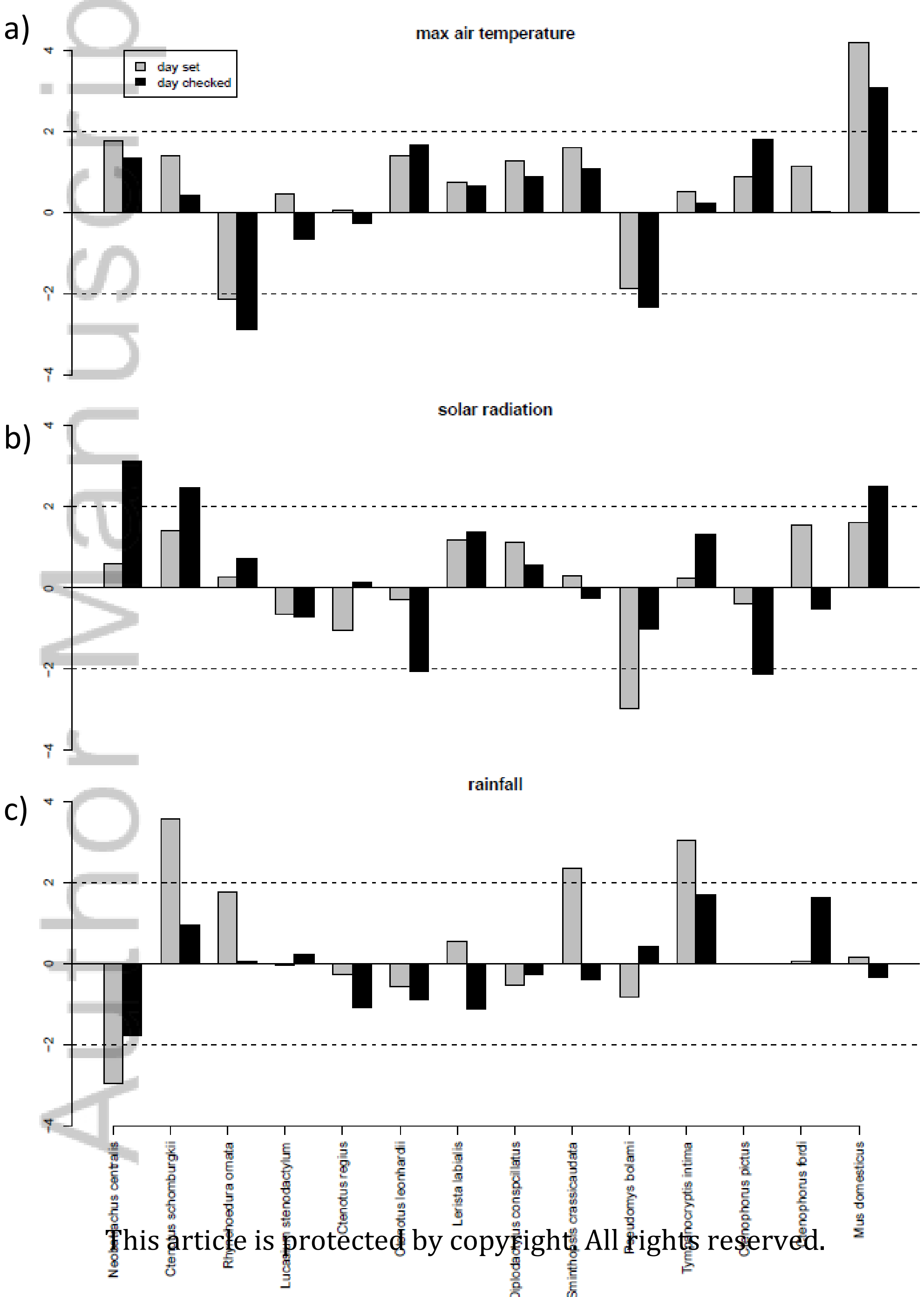
a)
max air temperature
day set
day checked
b)
solar radiation
c)
rainfall
4
2
0
-2
-4
Neobatrachus centralis
Ctenotus schomburgkii
Rhynchoedura ornata
Lucasium stenodactylum
Ctenotus regius
Ctenotus leonhardii
Lerista labialis
Diplodactylus conspicillatus
Sminthopsis crassicaudata
Pseudomys bolami
Tympanocryptis intima
Ctenophorus pictus
Ctenophorus fordi
Mus domesticus

Figure 3. z-scores from logistic regressions of probability of trap death against weather variables, where absolute values of >2 (dotted line) are statistically significant ($P < 0.05$) and positive z values indicate an effect of increasing death rate.

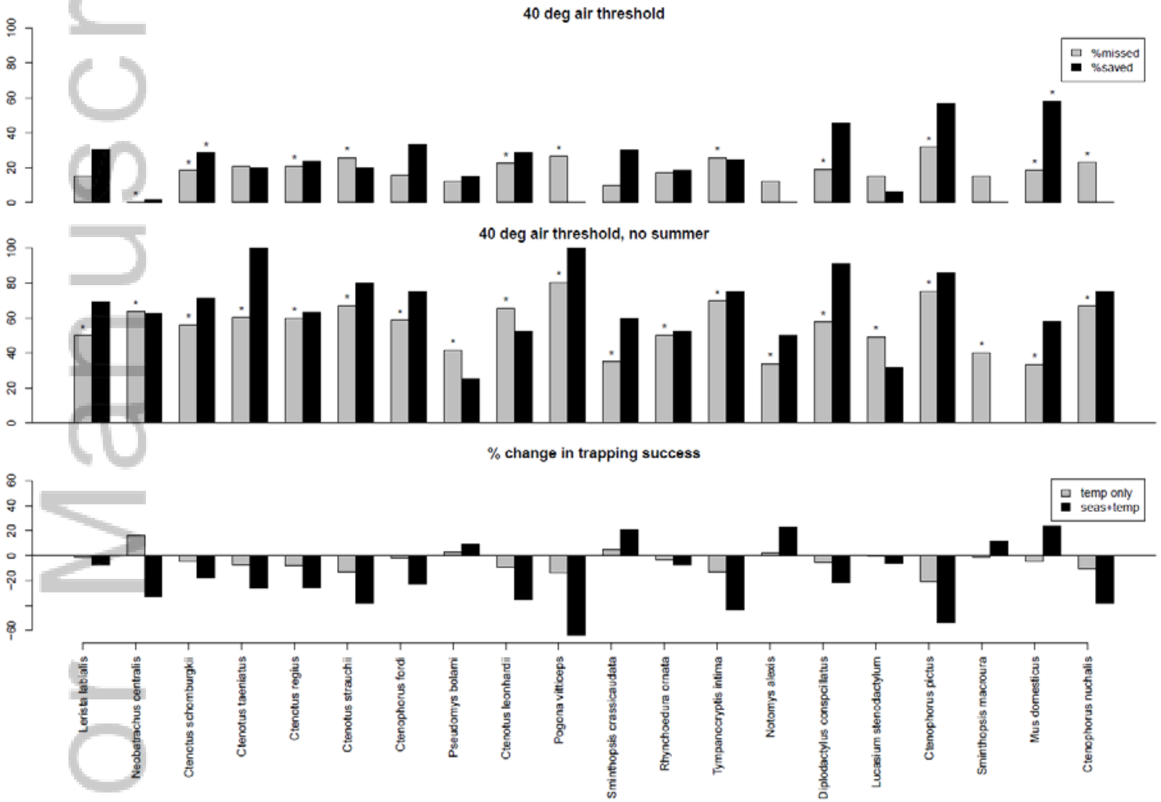

Figure 4. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 40 °C, or b) limited to days below 40 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented.

Suppl Table 1 Capture rates and causes of mortality of all vertebrate species captured during the study period. Overlooked mortalities in parenthesis occurred on an exceptional day in November 2000 that is discussed in the text.

	Invertebrates			**Vertebrates**										% Mortality	
Row Labels	**Ant**	**Centipede**	**Other**	**Nat. Rodent**	**House Mouse**	**Other**	**Desicc.**	**Drown**	**Unknown**	**Overlook**	**Handl**	**Total Deaths**	**Total Caps**	**Total**	**exclud Nov05**
Ramphotyphlops bituberculatus										0	1	1	1	100.0	100.0
Lerista labialis									19	7		26	168	15.5	15.5
Menetia greyii								1		1		2	28	7.1	7.1
Neobatrachus sudelli							7	1	57	1	1	67	958	7.0	7.0
Ctenotus schomburgkii	4	4	4	8	12		3	6	52	11(2)	14	119	1981	6.0	5.9
Ctenotus taeniatus		1		1					1	0	2	5	104	4.8	4.8

Ctenotus regius	2	1		4	8	2			12	0	9	38	815	4.7	4.7
Ctenotus strauchii									1	0	4	5	109	4.6	4.6
Ctenophorus fordi	5								4	1	2	12	295	4.1	4.1
Leggadina forresti										0	1	1	25	4.0	4.0
Pseudomys bolami			1		4	1		3	21	23(23)	12	65	1327	4.9	3.2
Ctenotus leonhardii		4			4	2	1		7	1	2	21	723	2.9	2.9
Pogona vitticeps					2			1		1		4	143	2.8	2.8
Rhynchoedura eyrensis	6	2	2	1	5			2	13	5(1)	3	40	1620	2.5	2.4
Sminthopsis crassicaudata	1							1	6	27(27)	2	37	447	8.3	2.4
Tympanocryptis intima		1			1		2		1	2	1	8	347	2.3	2.3
Sminthopsis macroura	1									1(1)		2	93	2.2	2.2
Tympanocryptis lineata								1		0		1	52	1.9	1.9
Diplodactylus conspicillatus		1		1	4			1	3	0	1	11	647	1.7	1.7
Lucasium stenodactylum	2	1		3	3				3	2	2	16	963	1.7	1.7
Ctenophorus pictus					3				2	0	2	7	458	1.5	1.5
Mus domesticus									15	1(1)	4	20	1807	1.1	1.1
Diplodactylus tessellatus								1		0		1	91	1.1	1.1
Notomys alexis									2	0		2	97	2.1	1.0
Ctenophorus nuchalis					2			2		0		4	719	0.6	0.6

Nephrurus levis												0	77	0.0	0.0
Varanus gouldii												0	52	0.0	0.0
Tiliqua rugosa												0	37	0.0	0.0
Heteronotia binoei												0	30	0.0	0.0
Pseudomys hermannsburgensis												0	26	0.0	0.0
Pseudomys australis												0	20	0.0	0.0
Lucasium damaeum												0	16	0.0	0.0
Eremiascincus richardsonii												0	15	0.0	0.0
Ramphotyphlops endoterus												0	11	0.0	0.0
Gehyra sp.												0	8	0.0	0.0
Tympanocryptis tetraporophora												0	7	0.0	0.0
Pseudonaja modesta												0	6	0.0	0.0
Ctenotus leae												0	4	0.0	0.0
Oryctolagus cuniculus												0	4	0.0	0.0
Pseudonaja nuchalis												0	3	0.0	0.0
Suta suta												0	2	0.0	0.0
Lerista timida												0	1	0.0	0.0
Planigale gilesi												0	1	0.0	0.0
Pseudomys desertor												0	1	0.0	0.0
Brachyurophis												0	1	0.0	0.0

fasciolatus														
Pseudechis australis											0	1	0.0	0.0
Simoselaps bertholdi											0	1	0.0	0.0
Grand Total	**21**	**15**	**7**	**18**	**48**	**6**	**12**	**20**	**218**	**86(55)**	**63**	**515**	**14342**	**3.6**	**3.2**

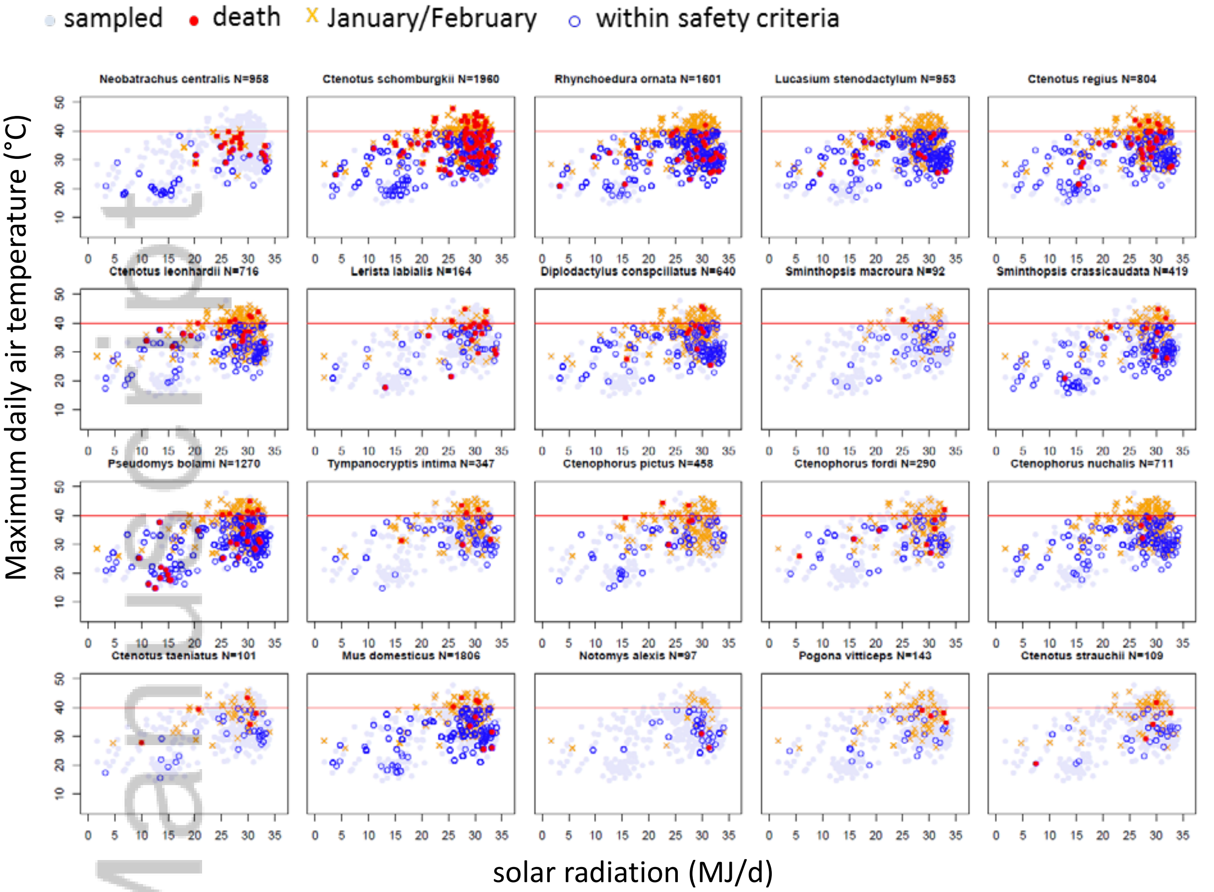

Figure S1 1. The relationship between daily maximum air temperature and daily total solar radiation for the day of trapping, distinguishing between sampled days (for all species – grey dots), and for each species the trap deaths (red dots), captures that would be excluded by summer (Jan/Feb) sampling (orange crosses) and captures on days below 40 °C outside of the summer sampling period (open blue circles).

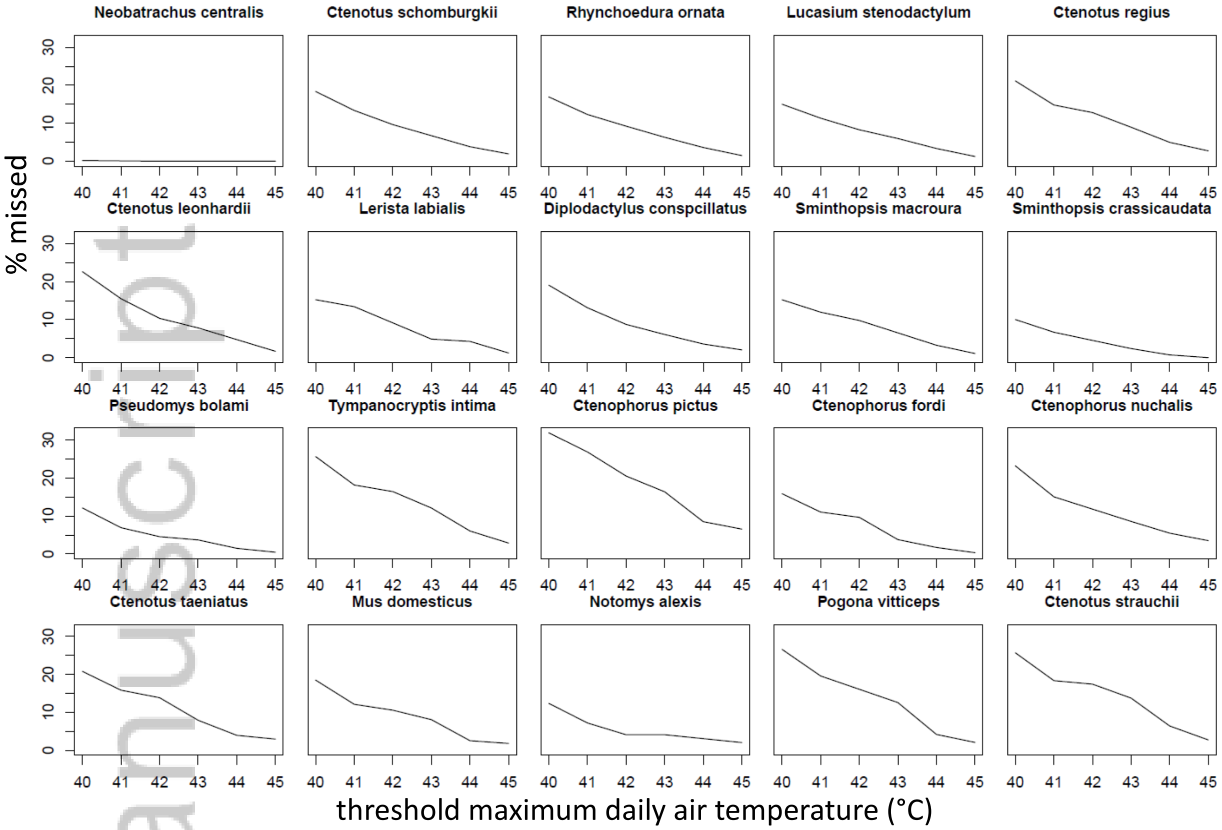

Figure S2. The proportion of individuals missed by the survey as a function of increasing air temperature thresholds for limiting pitfall trapping.

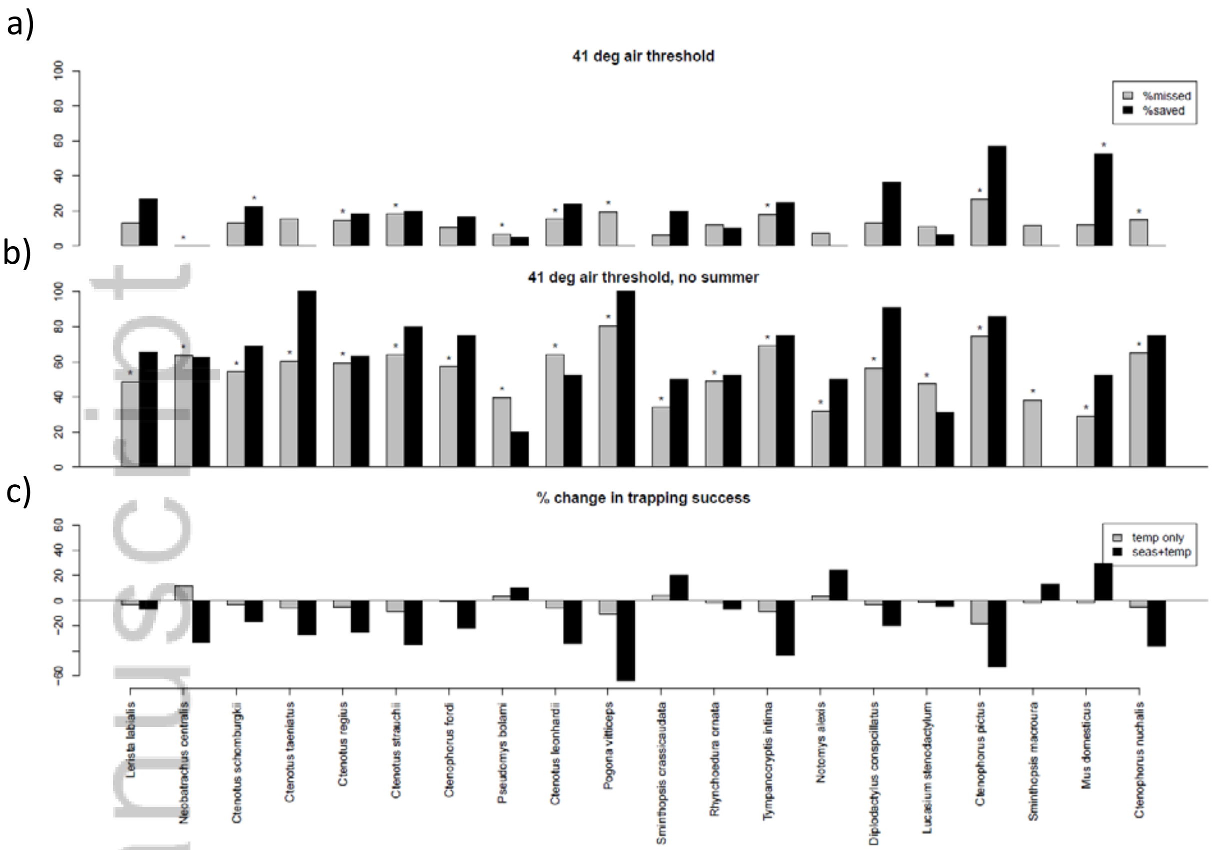

Figure S3. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 41 °C, or b) limited to days below 41 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented

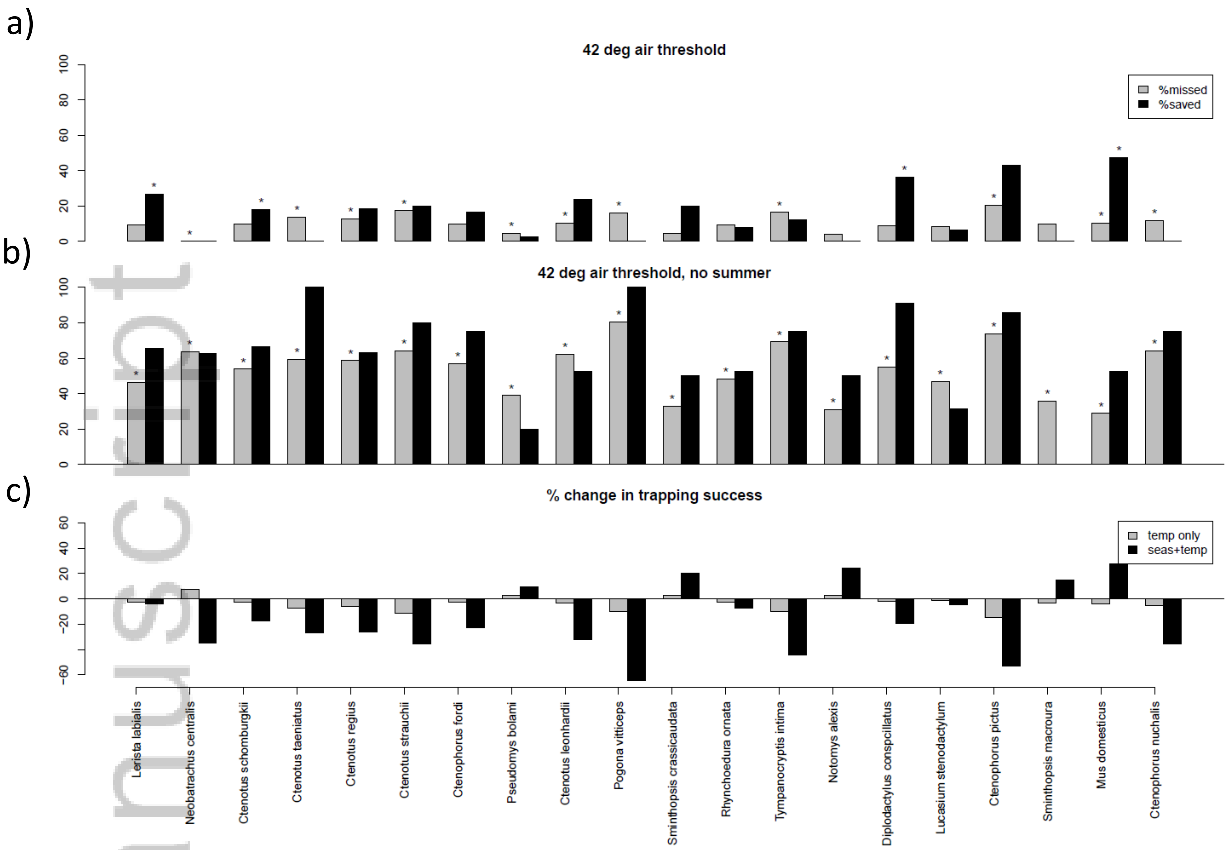

Figure S4. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 42 °C, or b) limited to days below 40 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented

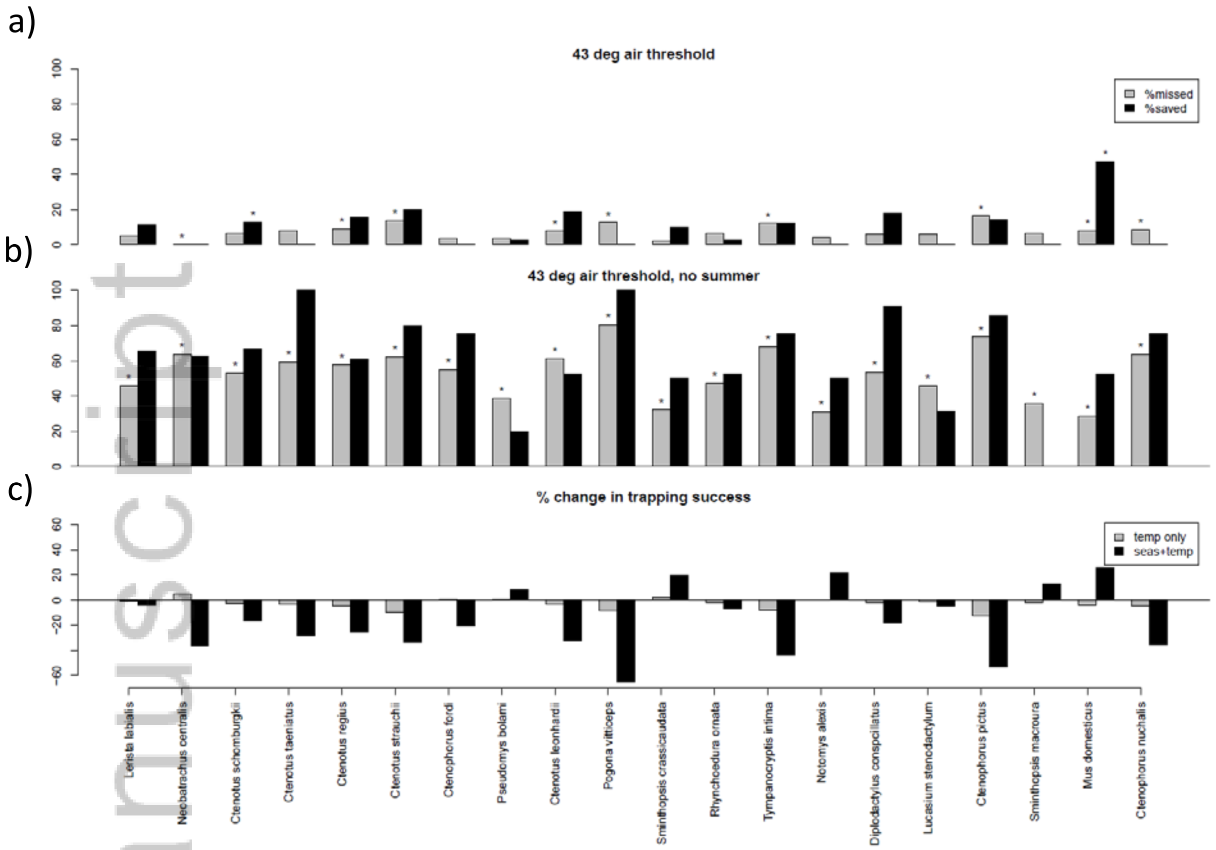

Figure S5. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 43 °C, or b) limited to days below 43 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented

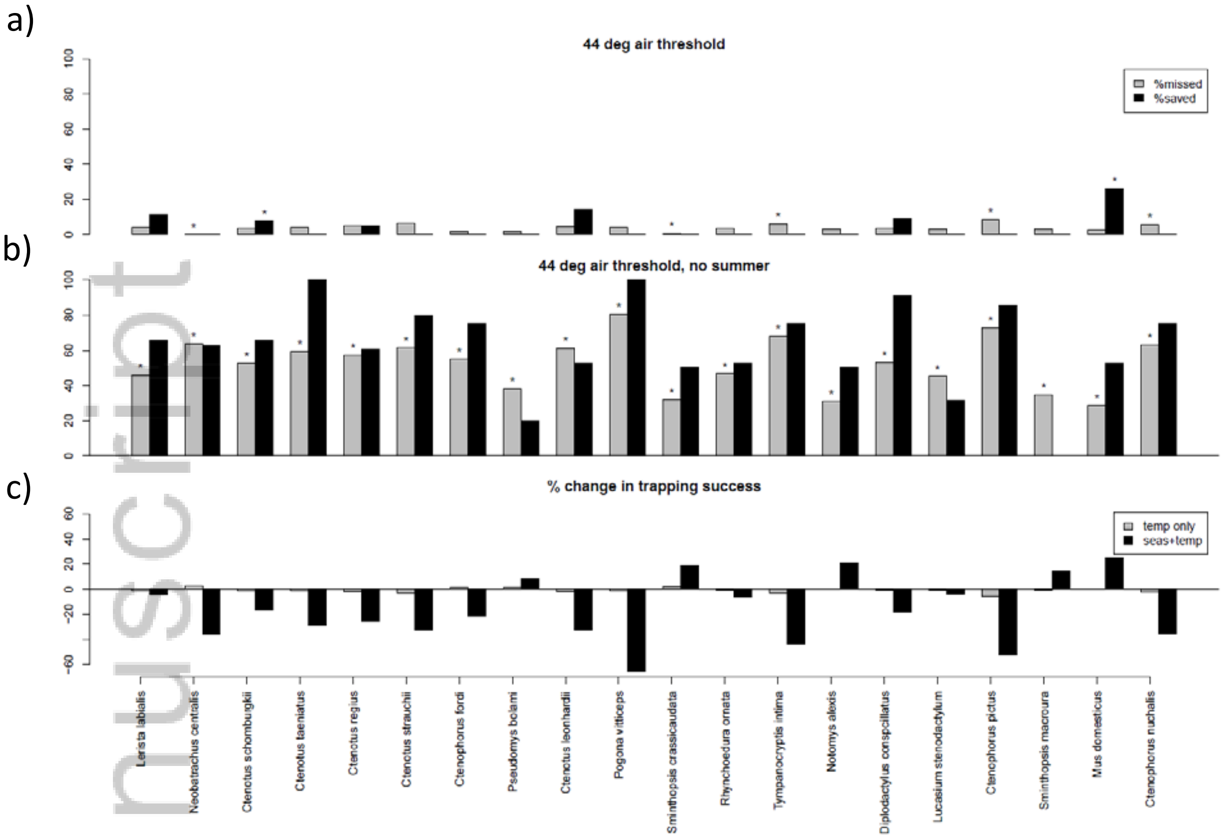

Figure S6. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 44 °C, or b) limited to days below 44 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented

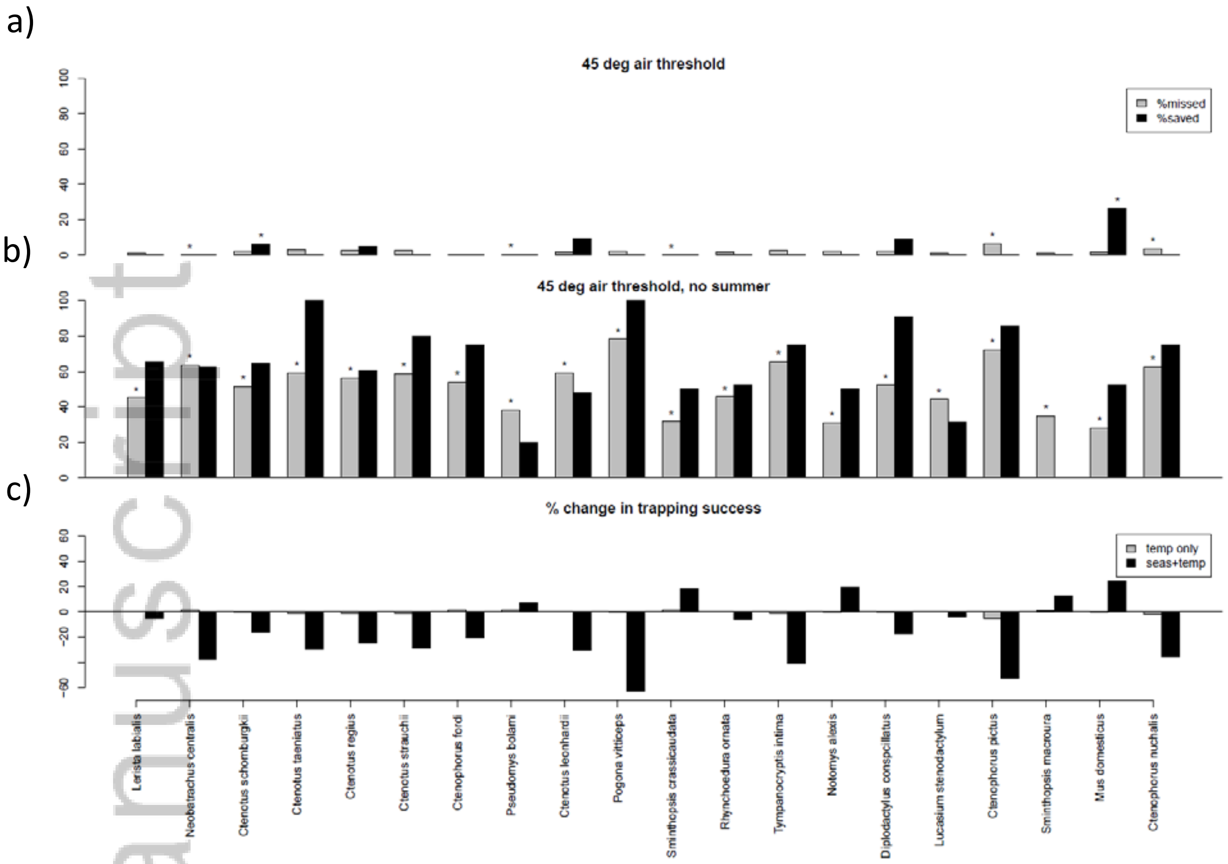

Figure S7. The proportion of individuals saved from death or missed from the survey if trapping were a) limited to days below 45 °C, or b) limited to days below 45 °C and also excluding hot summer months (January and February), as well as c) the percentage change in trapping success imposed by these two scenarios of trapping restriction. * indicates significantly different mortality or capture rates for species if the different trap closing scenarios had been implemented