

Abundance and elevational range shifts of three species of burying beetle in Gunnison County, Colorado and importance of stridulation during reproduction in burying beetles

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Abstract.

Burying beetles (Silphidae: *Nicrophorus*) are obligate carrion breeders that exhibit extensive biparental brood care. Burying beetles stridulate during carcass preparation and reproduction. Study 1 determined the importance of stridulation in reproduction. Male-female pairs (N=18) of beetles had their elytra clipped as either muted or controls. Each pair was placed on a mouse carcass and monitored to determine the time to carcass burial, eggs, and larvae. There were no significant differences in these variables between muted and non-muted pairs. More precise measurements and a larger sample size are needed in future studies.

As climate warms and dries, the ranges of burying beetles are predicted to change. Study 2 determined whether the relative abundances and ranges of burying beetle species in Gunnison County, Colorado shifted in the direction predicted by a 2009 field study and climate scenario niche model. Beetles were collected in traps at ten sites (corresponding to the 2009 study) along an 850-meter elevation gradient. The species, sex, and pronotum width of each beetle was recorded. Relative abundance of three burying beetle species at each site was compared to data from 2009. Seven sites showed significant changes in relative abundance of beetles. As predicted by the niche model, *N. defodiens* decreased at lower elevations and *N. guttula* increased at higher elevations. The range of *N. investigator* was not predicted to change, and this was also supported. This study shows that niche modeling can accurately predict species reactions to climate change.

KEYWORDS: *Nicrophorus*, climate change, stridulation, range shifts, burying beetle

Introduction

Species distributions are heavily impacted by temperature and climate changes (Smith et al. 2000, Smith and Merrick 2001, Buffington 2010). Latitudinal and elevational gradients provide predictable temperature zones that can be used to study range shifts and species distribution in response to climate change. By researching range shifts, broad global patterns can be predicted for environments at similar latitudes or elevations (Buffington 2010). With warming global temperatures, it has been shown that species in general will expand their ranges to higher elevations and will experience range contraction at lower elevations (Parmesan et al. 1999, Buffington 2010). If species distributions shift, interactions between biotic and abiotic factors will

change (Walther et al. 2002). Understanding range shifts of species is important in predicting future interactions and effects of climate change.

In order to study responses to climate change, researchers have determined that ectothermic organisms, specifically large, winged insects are the best models, due to their sensitivity to changing temperatures (Parmesan 2001, Sánchez-Guillén et al. 2013). Studying the movement of mobile organisms is helpful because it can track yearly climate changes, but larger time periods are important for seeing the true climatic trends (Parmesan 2001). Range shifts is one of the easier methods for determining climate-induced responses and has been demonstrated by many insect groups including butterflies, dragonflies, and true bugs (Musolin and Saulich 2012). A study done on non-migratory European butterflies found that 63% of the species showed range shifts moving north (Parmesan et al. 1999). Another study done on damselfly species used multifaceted models to show that most damselfly species will also have range shifts towards the north (Sánchez-Guillén et al. 2013). These studies were conducted using field site censuses or by examining historical and present data from several different places.

Burying beetles (Silphidae: *Nicrophorus*) are organisms that fit the criteria for climate studies because they are mobile, easily captured, and information on their life history is substantial. Studying beetles can help predict how other insect species might react to climate change. Burying beetles are valuable organisms to the ecosystems they inhabit which makes research on their life history important for protecting them.

Burying beetles have unique behavior and important ecological roles. Burying beetles are obligate carrion feeders which means they are completely dependent on dead animals for nutrients (Scott 1998). Small dead animals such as birds, mice, voles, and shrews provide food for burying beetles (Milne and Milne 1976). When the beetles are ready to breed, they must find a small carcass to bury underground as food for their young. Several beetles will find the same carcass and the largest female and male will usually win any conflicts and become a reproductive pair (Otronen 1988, Trumbo 1994). The pair will sometimes move the carcass to a new location and then bury it by digging underneath it (Milne and Milne 1976). As they bury it, they remove hair or feathers and release an oral and anal secretion that coats the carcass to prevent decomposition of the tissues and growth of fungus (Milne and Milne 1976, Wilson and Fudge 1984). Within several hours the female will lay eggs in a side chamber near the carcass. Once hatched, the larvae will be summoned to the carcass where the parents will feed them pieces of the carrion (Milne and Milne 1976). As a unique example of biparental care, male and female parents stay underground with the brood and execute various duties such as chamber maintenance, larval feeding, and brood protection (Fetherston et al. 1990).

Burying beetles, as well as other insects produce stridulations which is the result of two body parts rubbing together to make a sound (Alexander 1957). In burying beetles, stridulations occur when an area on the ventral side of the beetle's elytra, called the *plectrum*, is rubbed against the *par stridens* which is located under the elytra along the abdomen (Milne and Milne 1976, Hall et al. 2013). Stridulation in burying beetles produces biphasic sounds of low amplitude with weak dominant frequencies (Hall et al. 2013). Studies have shown that the purpose is most likely not a "call" song because there are no differences between male and female stridulations,

and because stridulation was only observed when individuals were in close range of each other (Hall et al. 2013). From this evidence, it is likely that stridulation has other purposes such as communicating with other individuals during various activities. The sounds are commonly made during competitive encounters with other beetles, during copulation, and during brood care (Milne and Milne 1976, Hall 2011). Studies have shown that a female beetle will stand on her buried carcass to stridulate which will summon her larvae to their food (Milne and Milne 1976). A lab experiment on *N. mexicanus* showed that preventing females from stridulating negatively affected larval survival. The paper stated that a lack of stridulation in both male and female could affect brood preparation (Ratcliffe 1996).

Since burying beetles are important in decomposition and restoring nutrients into soil ("USFWS: American Burying Beetle Fact Sheet" 1997), it is important to study how their ranges might be affected by climate change. The complex behavior of burying beetles makes it difficult to determine if and how they might respond to global warming. A study done on *Nicrophorus nepalensis* in 2014 found that beetle groups that were more cooperative with each other were able to extend their niche into lower elevations and warmer areas because they worked together to secure and protect their carcasses (Sun et al. 2014). In contrast, a 2010 study done on predicting climate-induced range shifts in burying beetles predicted that as global temperature increases, beetle species will lose their range at lower elevations (Buffington 2010). Further research on burying beetle response to climate change is important for understanding how their range and behavior will change.

Gunnison County, Colorado provides an elevational and temperature gradient that can be used to predict climate-induced distribution shifts in burying beetles. It also provides several habitats for multiple species of beetles. Different species of burying beetles can coexist in an area due to distinct niche partitioning. Patterns of emergence and sexual maturity vary between species (Scott 1998). Four species of burying beetle live in Gunnison County: *Nicrophorus investigator*, *Nicrophorus defodiens*, *Nicrophorus marginatus* and *Nicrophorus guttula*.

N. investigator beetles are 13-18mm long and is distinguished by its completely orange epipleuron, black metapimeron, and orange antennae (Hanely and Cuthrell 2008). It is a habitat generalist and is the most common in Gunnison County. *N. investigator* reproductive period spans from July to October and they overwinter as pre-pupae (Scott 1998).

N. defodiens are 10-18mm in length and distinguished by their black antennae and black and orange epipleuron (Hanely and Cuthrell 2008). They overwinter as adults, emerge earlier than other species and are reproductively active from June to August (Scott 1998). *N. defodiens* is less common in Gunnison county and prefers forest and moist habitats.

N. guttula measures at 12-20mm long and has orange antennae, black and orange epipleuron, and a hairy golden metapimeron (Hanely and Cuthrell 2008). This species can live in habitats including dry forests, prairies, deserts and sage dominated areas. They overwinter as adults (Anderson and Peck 1985).

N. marginatus has a length of 13-22mm with orange antennae, completely orange epipleuron, and hairy golden metapimeron (Hanely and Cuthrell 2008). Their habitat is open fields and meadows. They overwinter as adults and are reproductively active from May to June

with teneral adults emerging in July and August (Anderson and Peck 1985). This species is very rare in Gunnison County.

In 2010, master's student Kevin Buffington completed a study on three species of burying beetles in Gunnison County, Colorado (*N. investigator*, *N. defodiens*, and *N. guttula*). He used ecological niche monitoring and maximum entropy models to make predictions about how beetle ranges would shift in response to various climate change scenarios (Buffington 2010). The National Oceanic and Atmospheric Association (NOAA) data on past and current climates shows an increase in average, minimum, and maximum temperature in Gunnison County during June through August (Table 1). NOAA data also shows a decrease in precipitation (Table 1). With warmer and drier conditions, Buffington's model predicted that *N. defodiens* will become active earlier in the spring and will lose suitable habitat at lower elevations. The model predicted that *N. guttula* will expand in higher elevations to take advantage of resources before *N. investigator* emerges later in the summer. *N. investigator* was predicted to remain abundant at all sites.

Table 1
Summary of Climate Data in Gunnison County Summers

Climate Measurement	2009	2020	Change Per Decade (1980 -2020)
Average Temperature: June - August (°F)	55.6	59.3	+ 0.5°F/decade
Change from 1901-2000 Average (°F)	-0.5	+ 3.2	
Average Maximum Temperature: June - August (°F)	69.8	74.4	+ 0.7°F/decade
Change from 1901-2000 Average (°F)	-0.4	+ 4.2	
Average Minimum Temperature: June - August (°F)	41.3	44.1	+0.3°F/decade
Change from 1901-2000 Average (°F)	-0.7	+2.1	
Average Precipitation: June - August (in.)	3.7	3.29	-0.39 in/decade
Change from 1901-2000 Average (in.)	-1.53	- 1.94	

This two-part study that examined the ecology and behavior of burying beetles. Study 1 examined the importance of stridulation in burying beetle carcass burial and brood care behavior. I hypothesized that stridulation is an important aspect of burying beetle behavior. If stridulation is necessary, then beetles that are muted will be less successful in completing carcass burial and brood care activities. To conduct this study, I used a controlled experiment in the lab to compare the successful activities of 9 pairs of muted beetles to 9 pairs of unmuted beetles. The goals of study 2 was to: 1) determine the current range and abundance of burying beetle species in Gunnison county 2) determine if ranges have shifted since 2009 due to climate change and 3) test the accuracy of Buffington's Maxent model predictions. I studied the ranges of *N. investigator*, *N. guttula*, and *N. defodiens* because they are the most abundant in the area and were included in the 2009 study. I hypothesized that the ranges and abundances of burying

beetles will be influenced by climatic changes over the past 12 years. If the climate has changed, then species abundances and ranges will change. I tested the model prediction that *N. guttula* will increase at higher elevations and *N. defodiens* will decrease at lower elevations.

Methods

Study 1 – Stridulation

This study was conducted on *Nicrophorus investigator* beetles collected from beetle census traps at the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado. Experimentation occurred during July 2021 at the RMBL townsite.

A male and female *N. investigator* were randomly paired together to become a mated pair. Nine pairs of beetles had their plectrum removed by clipping a small triangle from the center bottom corner of their elytra. This muted the beetles and prevented them from making stridulatory sounds. Another nine pairs also had their elytra clipped on the outer corner, but their plectrum was not removed so they were still able to stridulate. Each pair was placed in a 1L clear plastic box with adequate damp soil, ventilation, and a dead mouse (*Peromyscus maniculatus*) between 20 and 25g in weight. The boxes were placed outdoors in a location that received sufficient shade. Treatments were assigned randomly in a blind setup to reduce observer bias.

Every few hours, the pairs were checked and their progress on carcass burial and larval stage was recorded. Notes were taken on when the beetles buried the carcass, laid eggs, how many eggs, when they hatched, and how large the larvae grew. Once the larvae finished eating and had left the carcass, they were separated from the adults, weighed, counted, and returned to the container.

Comparisons between the muted and non-muted beetles were completed using unpaired t-tests to determine if stridulation is important for burial and brood care activities. Muted beetles were compared to sound-producing beetles in the amount of time it took for burial, to lay eggs, to hatch larvae, and the number and average mass of full-grown larvae.

Study 2 – Abundance and Range

For this study, 10 of Buffington's 29 collection sites were revisited for my own data collection. These sites were selected based on similar habitats and elevations that spanned from 1.75 km south of Almont, Colorado to 4km north of Gothic, Colorado. Sites used by Buffington with less than 20 captures were not resampled. Beetle traps were set from June 30th to August 2th, 2021. These weeks were identified to accommodate for the peak capture rates of each beetle species as indicated by Buffington's study. Study organisms will include *Nicrophorus investigator*, *Nicrophorus defodiens*, *Nicrophorus guttula* and *Nicrophorus marginatus*.

At each site, two burying beetle traps were set up 30 - 100 meters apart. A trap consisted of a metal can that is 17cm deep with a 15cm diameter. The can was filled a third of the way with soil and a raw chicken drumstick served as bait. An 18cm² piece of aluminum screening with a 1cm diameter hole in the center was secured to the top of the metal can with a large rubber band. The cans were elevated off the ground and secured with wire to a metal or wooden stake or a tree and covered with chicken-wire mesh to deter vertebrate scavengers from breaking into the trap.

Every 3 to 5 days, beetles in the trap were collected and measured. The pronotum width, species, and sex of each beetle was recorded. Beetles that accidentally died in the traps were collected and taken back to the lab for future projects involving stable isotope analysis. All live beetles were marked using an insect-pin tattoo technique and released at the same site after data was collected. Notes were made on recaptured beetles. For data analysis, a chi-squared test was completed to compare the frequencies of each species in a sample in 2009 and 2021. ANOVA's were conducted to compare body size among sites, species, and between the sexes.

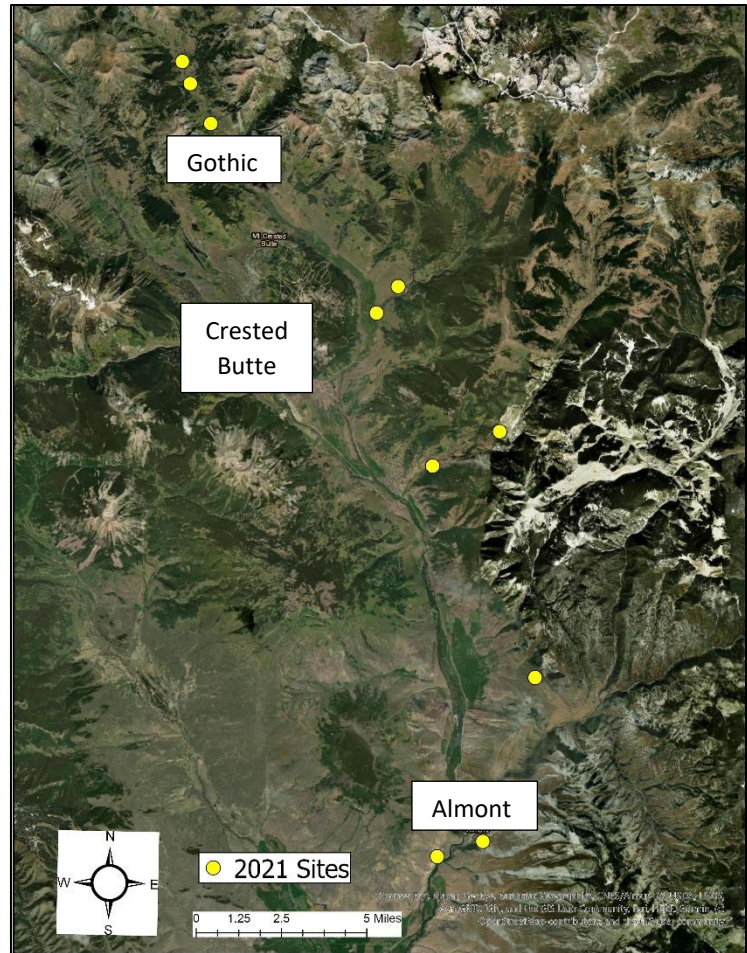


Figure 1. Map of 2021 burying beetle sites

Results

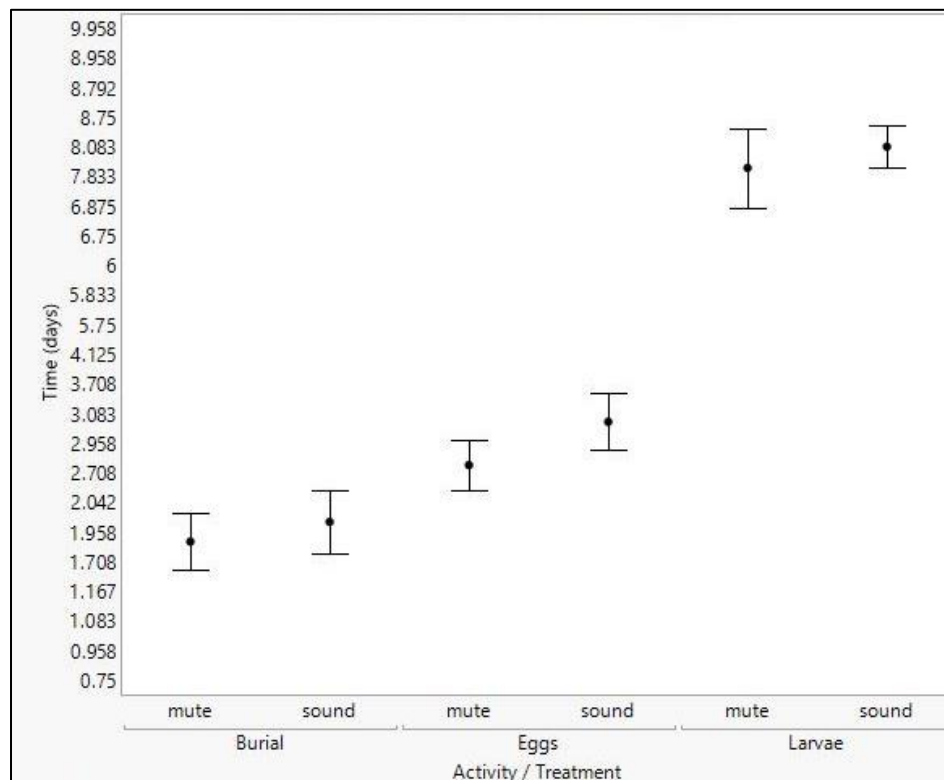
Study 1 – Stridulation

Muted and sound-producing beetles did not differ in the time that it took to bury, lay eggs, or for larvae to arrive at the carcass (Table 2, Fig. 2, Fig. 3). There were also no differences between the number of larvae or weight of larvae for muted and non-muted beetles (Fig. 3).

Table 2

Statistics summary for stridulation study

Activity	Comparison	Mean	Standard Deviation	N	t statistic	Degrees of Freedom	p value
Time to burial (days)	Mute	1.9396	0.9195	9	0.4200	15.7555	0.6802
	Sound	2.1341	1.0421	9			
Time to eggs (days)	Mute	2.6768	0.5039	4	1.0963	8.3503	0.3035
	Sound	3.2916	1.3255	7			
Time to larvae (days)	Mute	7.7736	1.501	7	0.4316	9.3578	0.6758
	Sound	8.0521	0.8706	8			
Number of Larvae	Mute	10.25	1.7078	4	1.2686	4.6592	0.2643
	Sound	12.5	3.1091	4			
Average Weight of Larvae (g)	Mute	0.3467	0.0574	4	-0.0753	4.8421	0.4863
	Sound	0.3217	0.0336	4			

**Figure 2.** Average time of burial, eggs, and larvae for muted and sound-producing beetles. P values shown in Table 2.

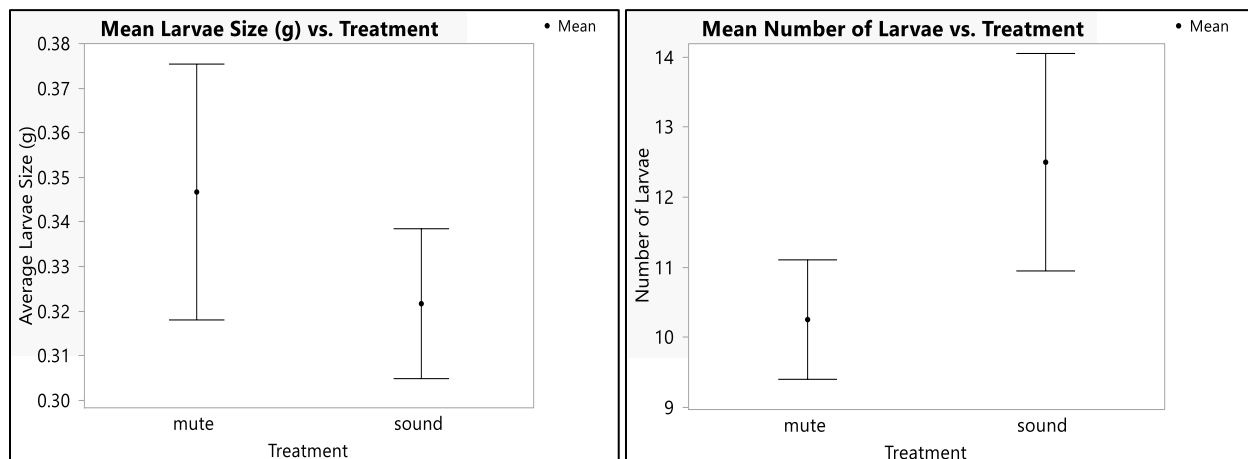


Figure 3. Average weight of larvae and number of larvae for muted and sound-producing beetles. Statistics are shown in Table 2.

Study 2 – Abundance and Range

The three species peak in their abundance at different times in the summer. *N. defodiens* and *N. guttula* peak earlier than *N. investigator* and *N. marginatus* (Figure 4).

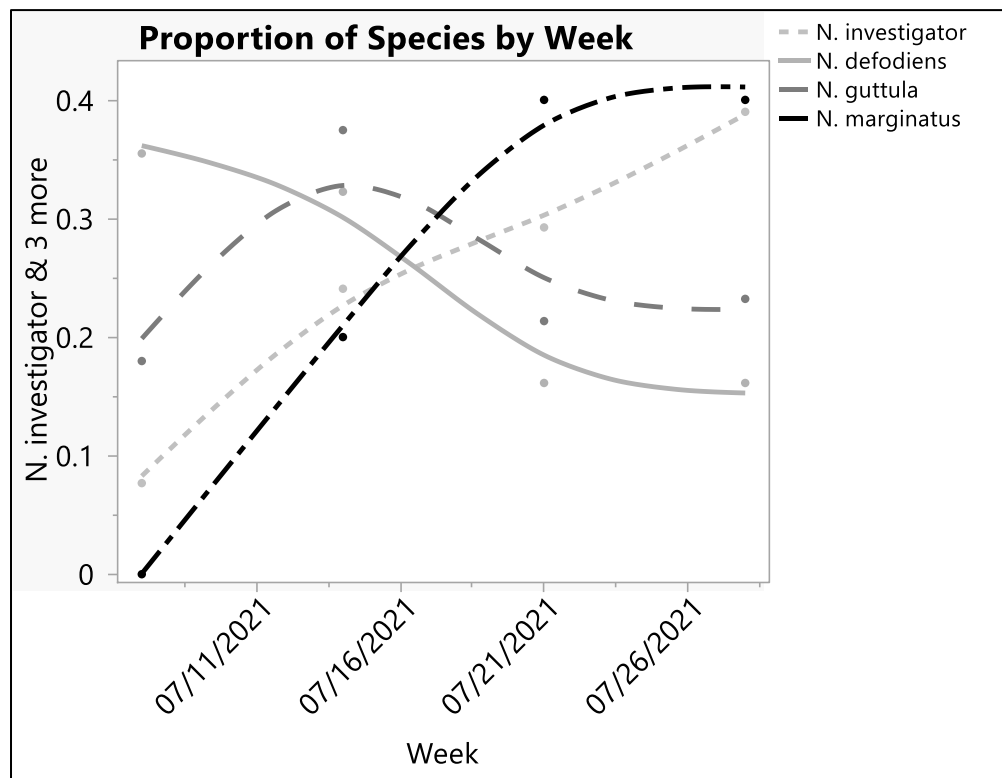


Figure 4. Proportion of total beetles caught for each species for each week of the summer. *N. defodiens* and *N. guttula* are more abundant in the earlier weeks. *N. investigator* and *N. marginatus* peak later in the summer.

The relative abundance of each species at seven out of ten sites was significantly different than the abundances from 2009 (Fig. 5 and Fig. 6). At lower elevations, *N. guttula* increased in relative abundance. *N. defodiens* shifted their range upwards by decreasing at lower elevations and increasing at higher elevations.

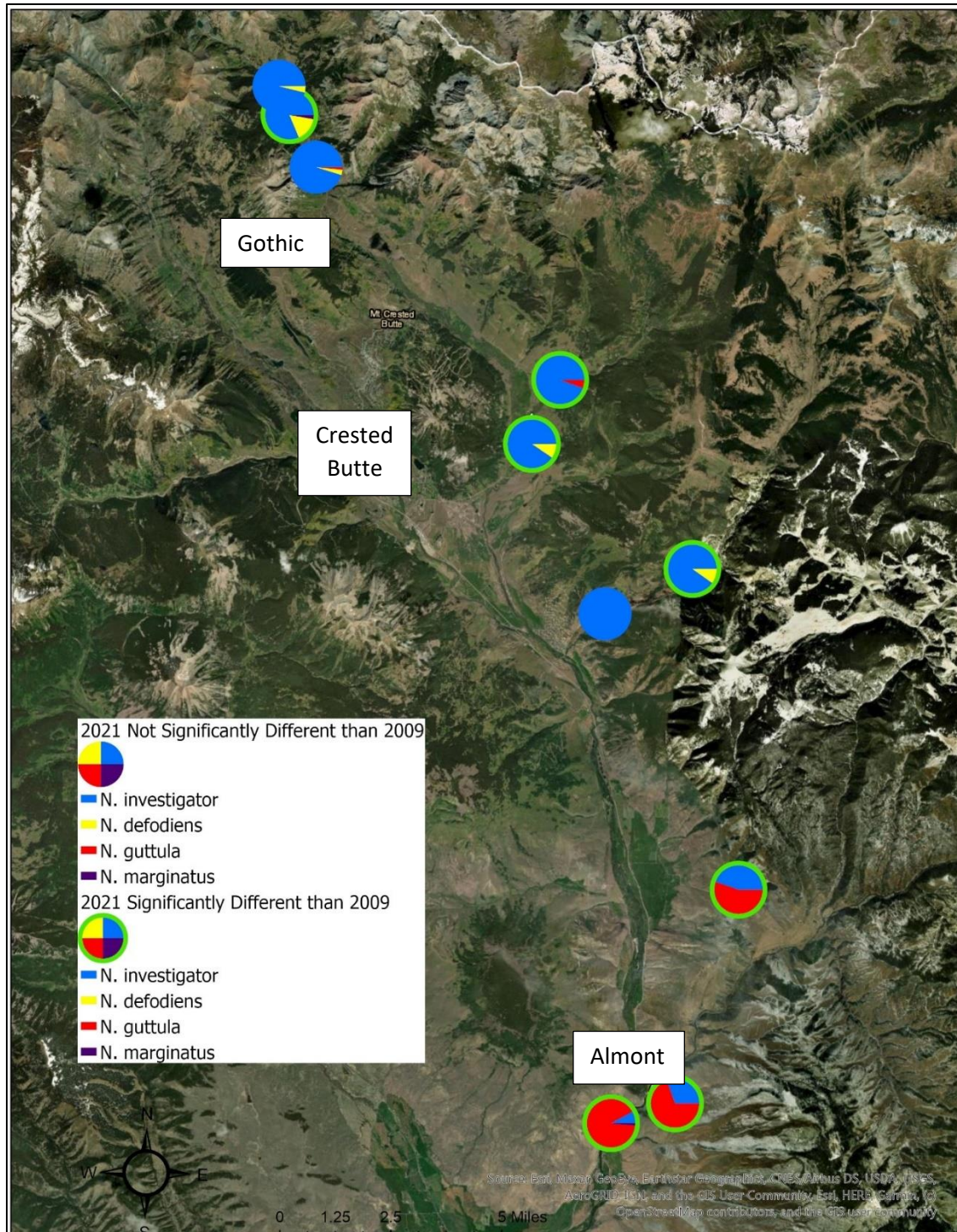


Figure 5. Map of 2021 sites with relative abundance and significance indicated. Green outlines represent sites that were significantly different in relative abundance than in 2009.

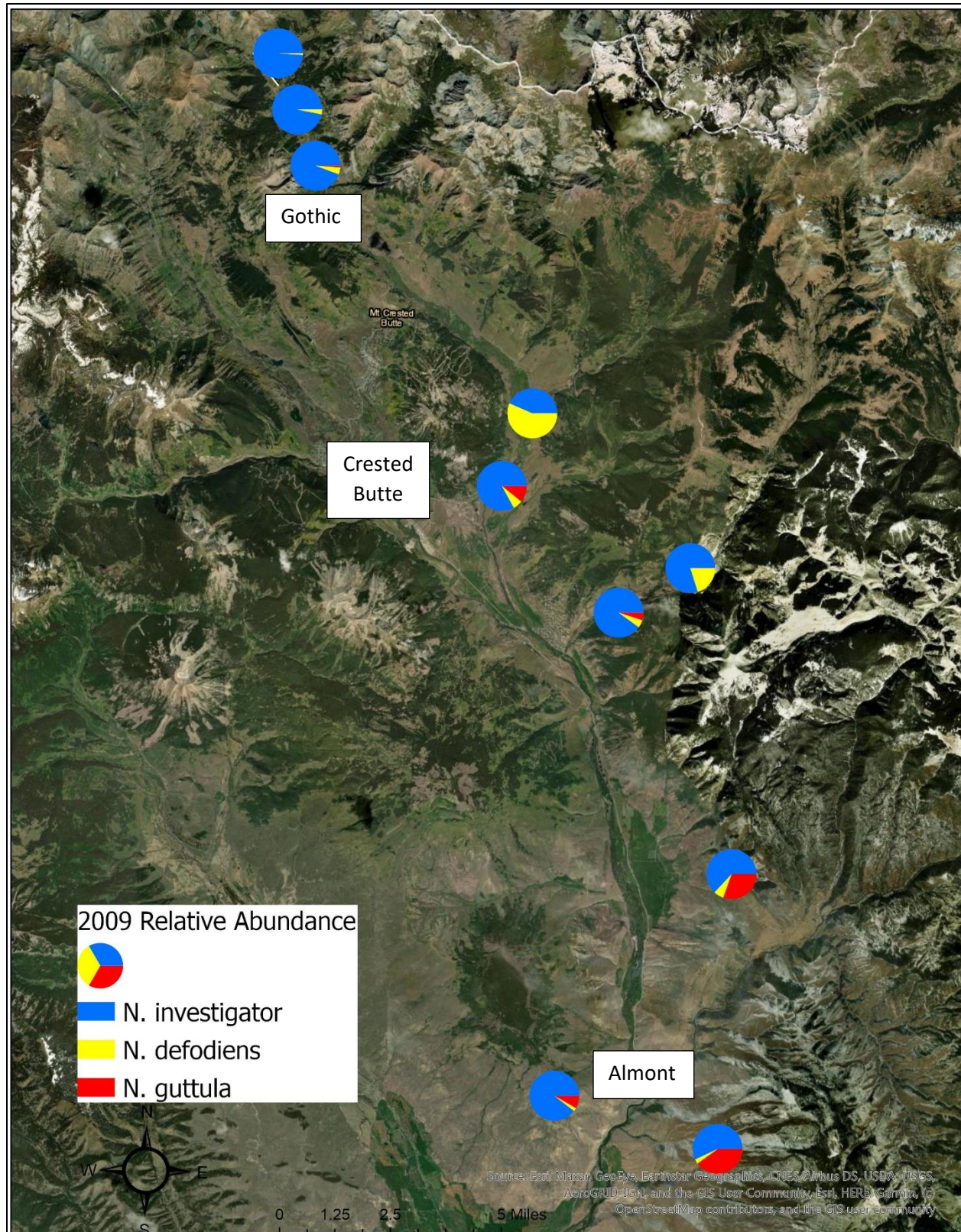


Figure 6. Map of 2009 sites with relative abundance indicated. In the 2009 study, there were originally 29 sites, but this map shows the subset of sites that were selected for the 2021 study.

When comparing 2021 relative abundances to 2009 relative abundances, there were significant differences at seven out of 10 site-site comparisons (Table 3). When sites were grouped into low, medium, and high elevations, there were significant differences in relative abundance for each elevation comparison (Table 4 and Fig. 7).

Table 3

Summary of relative Abundances at each site for each year including p values

Site	Elevation (m)	Year	<i>N. investigator</i> Relative Abundance	<i>N. defodiens</i> Relative Abundance	<i>N. guttula</i> Relative Abundance	<i>N. marginatus</i> Relative Abundance	Total Beetles	Relative Abundance P value 2009 vs. 2021 *excluding <i>N. marginatus</i>
Weather Station	2477.67 (low)	2009	0.8949	0.0217	0.0833	0.0000	276	< 0.0001
		2021	0.0781	0.0000	0.9063	0.0156	63	
Almont	2653.45 (low)	2009	0.5700	0.0300	0.4000	0.0000	300	< 0.0001
		2021	0.3034	0.0056	0.6910	0.0000	178	
Lower Cement Creek	2667.44 (low)	2009	0.9000	0.0500	0.0500	0.0000	20	0.2146
		2021	1.0000	0.0000	0.0000	0.0000	22	
Lower Brush Creek	2731.06 (medium)	2009	0.4348	0.5652	0.0000	0.0000	23	0.0006
		2021	0.9048	0.0952	0.0000	0.0000	21	
Jack's Cabin	2769.43 (medium)	2009	0.6304	0.0652	0.3043	0.0000	46	0.0005
		2021	0.4436	0.0000	0.5489	0.0075	132	
Upper Brush Creek	2812.35 (medium)	2009	0.8295	0.0620	0.1085	0.0000	129	< 0.0001
		2021	0.9398	0.0000	0.0556	0.0046	215	
Upper Cement Creek	2881.09 (medium)	2009	0.7984	0.2016	0.0000	0.0000	129	0.0281
		2021	0.9020	0.0980	0.0000	0.0000	102	
Judd Falls	2927.43 (high)	2009	0.9432	0.0455	0.0114	0.0000	88	0.8883
		2021	0.9524	0.0317	0.0159	0.0000	63	
Gothic Campground	2932.27 (high)	2009	0.9688	0.0313	0.0000	0.0000	32	0.0341
		2021	0.8133	0.1600	0.0000	0.0267	73	
Rustler's Gulch	2968.35 (high)	2009	0.9892	0.0108	0.0000	0.0000	186	0.1275
		2021	0.9623	0.0377	0.0000	0.0000	106	

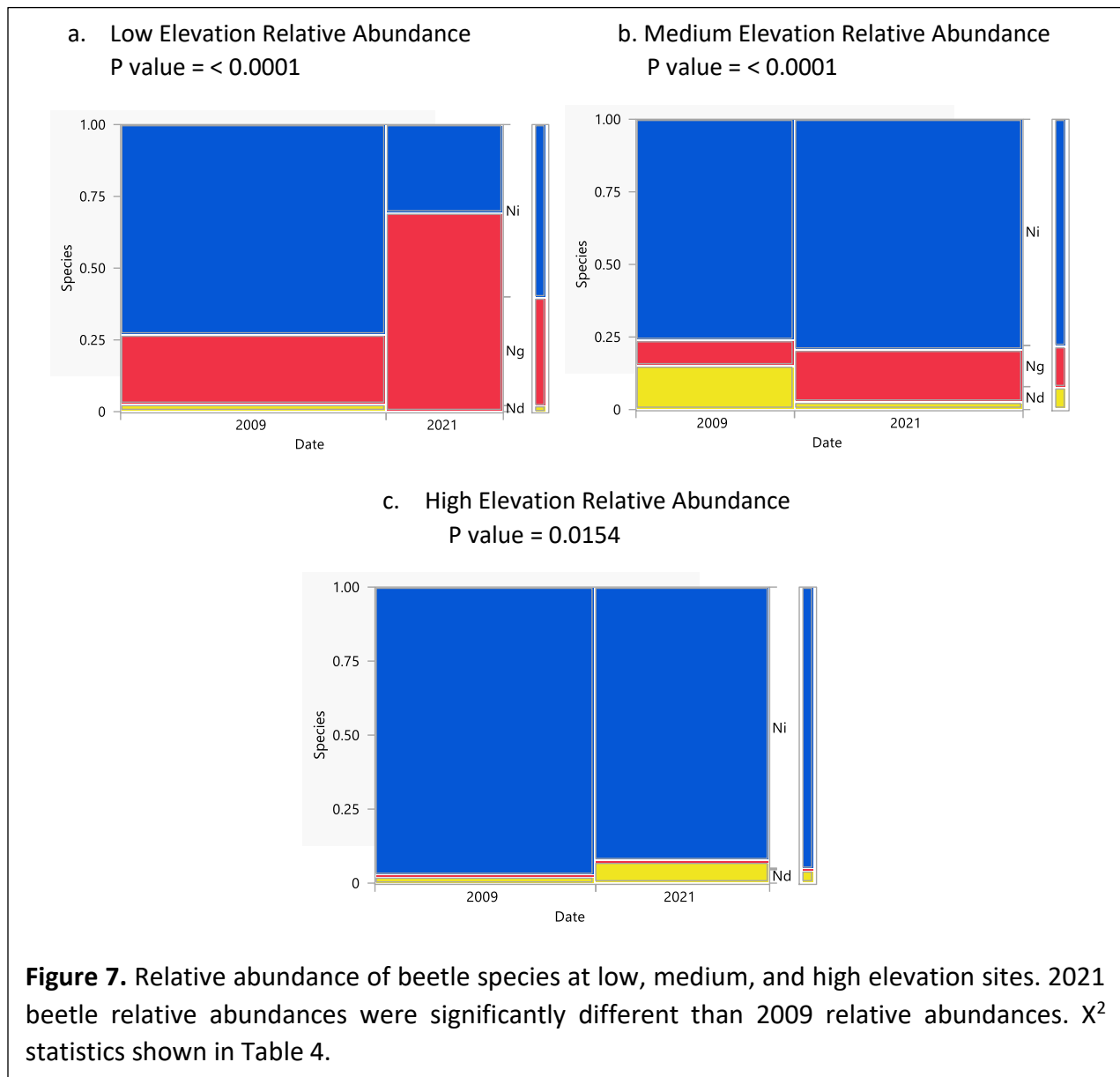
Red p values indicate significant differences between 2009 and 2021 relative abundances (less than 0.05).

Table 4

Chi-squared statistics for 2009 vs. 2021 comparisons

Site	N	Degrees of Freedom	X ²	p value
Almont	487	2	39.843	< .0001
Gothic Campground	105	1	4.491	0.0341
Jack's Cabin	178	2	15.094	<.0001
Judd Falls	151	2	0.237	0.8883
Lower Brush Creek	44	1	11.763	0.0006
Lower Cement Creek	42	2	3.078	0.2146
Rustler's Gulch	292	1	2.323	0.1275
Upper Brush Creek	344	2	19.738	0.0002
Upper Cement Creek	231	1	4.824	0.0281
Weather Station	339	2	179.775	<.0001

Elevation	N	Degrees of Freedom	X ²	p value
Low	859	2	155.489	< .0001
Medium	797	2	54.231	< .0001
High	548	2	8.352	0.0154



An analysis on the size of each species based on sex and elevation, a few comparisons were significant (Figure 8). There were no significant differences between the sizes of males and females in *N. defodiens* and *N. guttula*. Male *N. investigators* were significantly larger than females. When the sexes were grouped together for all species, there were no differences between *N. defodiens*, *N. guttula*, and *N. investigator*. The rare *N. marginatus* ($N=5$) was significantly larger than all the other species. A comparison between size and elevation of each species showed no obvious trends, so it is likely that other factors besides elevation are affecting beetle size.

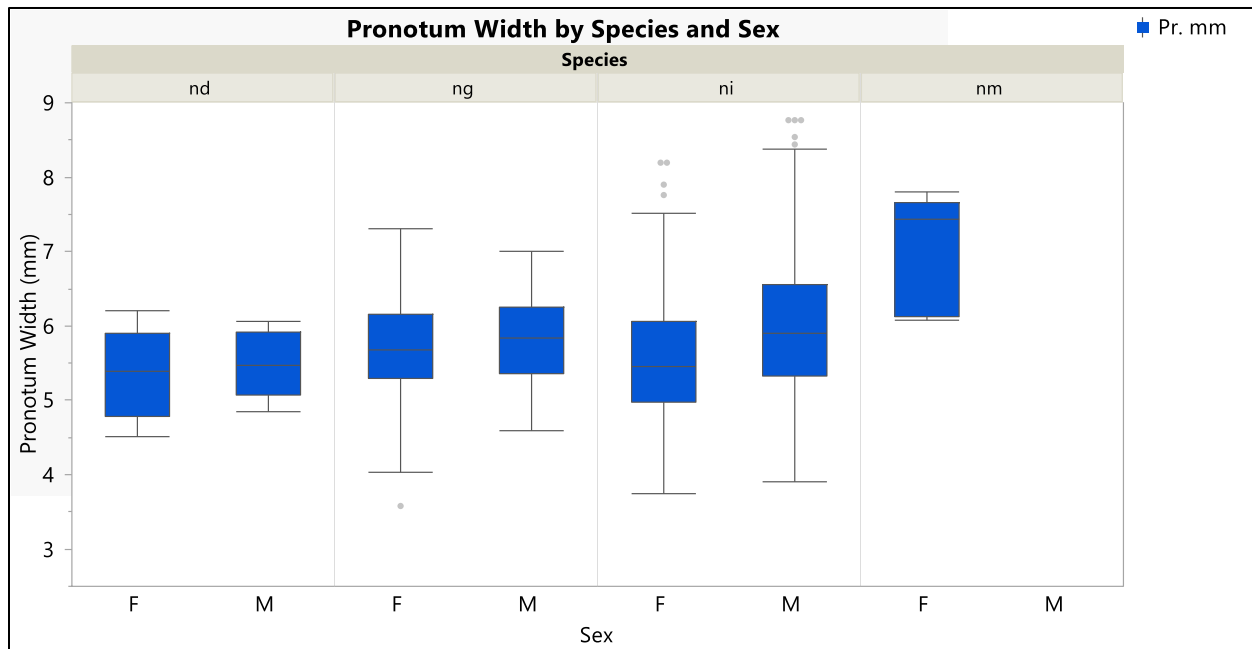


Figure 8. Mean size of beetles separated by sex and species. Male *N. investigators* were significantly different than females. *N. marginatus* was significantly larger than all the other species. All other comparisons were not significant.

Discussion

Study 1 – Stridulation

There were no significant differences between muted and sound-producing beetles in the time it took them to bury a carcass, lay eggs, and raise larvae (Table 2, Fig. 2, Fig 3). This finding did not support the hypothesis and prediction that stridulation is a necessary component of reproduction and parental care. It is likely that patterns were not seen because of a small sample size and because the frequency of observations (every 6-12 hours) was likely too long to detect small differences in the lengths of the different stages of reproduction. Although a study done on *N. mexicanus* predicted that preventing stridulation would negatively impact brood preparation (Ratcliffe 1996), it is possible that stridulation might not be significantly important for reproductive activities in burying beetles. The beetles might not be communicating to the extent that is expected, or they could be using other forms of communication such as pheromones. Future experiments would benefit from an increased sample size and more precise measurement techniques. High precision sound and video equipment might be used to document if and when beetles are stridulating during the reproduction process. It has been observed that female beetles will stand on a carcass and stridulate to attract her young to their food source (Milne and Milne 1976). Future studies could explore the significance of this behavior to determine what the mothers are communicating to their young. Another possibility for research could record stridulation during various activities to determine more specific reasons

and patterns in their communication. In conclusion, although no significant differences were found, this study opens doors to answering further questions about how and why burying beetles communicate through stridulation.

Study 2 – Abundance and Range

The relative abundances and ranges of burying beetle species in Gunnison County shifted as predicted by a climate change model. At seven out of ten sites, the relative abundances of *N. investigator*, *N. defodiens*, and *N. guttula* were significantly different than the same research sites in 2009 (Fig. 4, Fig. 5, Table 3). The ten research sites were grouped into low, medium, and high elevation categories and were compared to 2009 data. There were significant difference between the relative abundances from 2009 at each elevation (Table 4 and Fig. 6). *N. defodiens* shifted their range northward which resulted in a decrease in abundance at lower elevations and an increase at higher elevations. This matched the predictions made by Buffington's niche model under drier and warmer climates. *N. guttula* expanded to higher elevations, which also matches the climate model predictions.

Other studies have also shown that insects shift their range northward likely in response to climate change (Parmesan et al. 1999, Sánchez-Guillén et al. 2013). The century of the 1900's warmed by 0.8°C in Europe and this most likely influenced the 32-140km northward shift of 63% of studied European butterfly species (Parmesan et al. 1999). The average temperature in Gunnison county summers has increased by 0.28°C per decade since 1980 (Table 1). *N. defodiens* was absent at the southern sites near Almont and Jack's Cabin and became less abundant at Cement Creek moving upward (Fig. 5 and Fig. 6). This could potentially be a 24km shift in response to a 0.28°C per decade increase in temperature. It will be important to study if this pattern continues. Another study that used Maxent modeling predicted that habitat suitability would decrease for all but one studied damselfly species and that their ranges would shift northward (Sánchez-Guillén et al. 2013).

Nicrophorus defodiens prefer moist habitats such as aspen forests (Scott 1998). It is likely that they have physiological limitations that prevent them from surviving in drier and warmer climates. These limits could affect their heat tolerances and ability to survive harsher environments. If this trend of shifting northward continues, the species could become threatened. In areas of the United States that *N. defodiens* compete with *N. orbicollis*, cooler temperatures are necessary for *N. defodiens* to win a carcass. As temperatures increase, *N. defodiens* might not be able to compete for food as effectively (Sloan Wilson et al. 1984). Future research should investigate the reasons why *N. defodiens* can not tolerate warmer and drier climates and further model the habitats with favorable microclimates which may be available to them under future climate scenarios.

Nicrophorus guttula thrive in a variety of dry habitats such as deserts, sage lands, and prairies (Ratcliffe 1996). The expansion of *N. guttula* into higher elevations can be explained by the warmer and drier climates that Gunnison County is experiencing. This expansion may continue in the future and should be monitored. As *N. guttula* expands, it might interact more frequently with *N. investigator* and shift ecological balances. A study on range shifts on insects used a maxent model that predicted increased overlap between damselfly species as their ranges shifted (Sánchez-Guillén et al. 2013). More frequent interactions increases the

potential of hybridization in burying beetle species as well. It has been observed that larger beetles win the competition for carcasses, leaving smaller beetles with no carcass for breeding (Otronen 1988). My study showed that there were no significant differences in overall size between *N. investigator* and *N. guttula* (Fig. 8). However, when the species sizes at each elevation were compared, there were greater differences. In areas with increased interactions, this indicates that the success of each species might be dependent on their body size. Future studies could examine this further to determine if beetles are able to choose to raise fewer, larger larvae in order to increase their odds for carcass competitions.

The presence of *N. marginatus* is an interesting finding that needs further exploration. This species is widespread across the United States but there are very few records of it in Gunnison County and on the western slope of the Rocky Mountains (gbif.org 2021). It was not documented in Buffington 2010 due to its absence in the area or misidentification. Without knowing where the nearest potential source population of this species is, it is difficult to know if it is shifting its range. A recent 2021 study on *N. marginatus* found that slight temperature increases decreased brood size and reproductive success (Keller et al. 2021). Brood size was reduced with just a 0.5°C increase from the 26°C baseline temperature, and reproductive success was greatly decreased at 27.5°C (Keller et al. 2021). The average temperature in Gunnison County for 2020 was 15.16°C which is well below the temperature used in the Keller et al. study. This indicates that temperatures in Gunnison County is suitable for *N. marginatus* so they might be shifting here to escape areas where temperatures are too high. Further investigation is needed to determine from where, why and if *N. marginatus* is increasing in Gunnison County.

My study shows that the ranges and abundances of burying beetle species shifted as predicted by a climate change model in only 12 years. This study should be continued in the future to better understand the rate at which the species are shifting. More frequent monitoring, perhaps every 4 or 5 years would allow for accounting for expected inter-annual differences in *Nicrophorus* populations and improve rate calculations. Other studies could also choose other locations higher than Gothic or lower than Almont. Continuing to collect data will increase our knowledge of how these burying beetle species respond to changing climates and will allow us to better predict and plan for that change.

Limitations

There were a few limitations to this project that should be discussed. For Study 1, the biggest limitation was knowing how often to document changes in the reproductive status of each beetle pair. For some of the pairs, eggs were not visible and received no time data. There was also no certainty that the beetles were stridulating at all.

For Study 2, choosing which and how many of Buffington's sites to revisit was difficult. Some sites were inaccessible due to land ownership changes and some did not collect enough beetles in 2009 to be statistically worthwhile to revisit. I ended up choosing sites that spanned the entire 850-meter elevation gradient and covered all different habitat types. Another difficulty was figuring out where to place the beetle traps so they would have sufficient shade throughout the day.

Conclusions

Study 1 found that there were no differences between muted and non-muted beetles which might indicate that stridulation is not extremely important for reproductive success. A larger sample size and more precise measurements are needed to further explore the significance of stridulation in reproductive activities. Study 2 found that the ranges and relative abundances of three burying beetle species shifted as predicted by a 2009 climate scenario model. This study gives evidence that using niche models is an accurate way to predict species responses to changing climates. Importantly, if temperatures continue to increase, burying beetle survival and fitness will be threatened (Keller et al. 2021). It is necessary to continue studying burying beetles to gain knowledge and ensure their protection.

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