Biodiversity associated with Constructed Hibernacula at a Coastal Restoration Project

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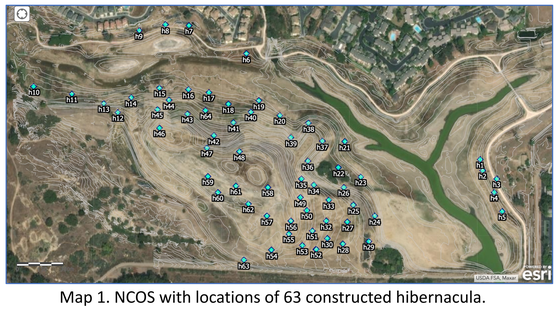
What is a hibernaculum?
Usually, this word describes an overwintering refuge. However, we define a hibernaculum as a structure for an animal to seek refuge, whether its throughout the day or over the dry summer.

North Campus Open Space (NCOS) restoration project in Santa Barbara, CA.
UCSB's North Campus Open Space comprises 136 acres of upland and wetland habitats adjacent to the Coal Oil Point and Ellwood-Devereux open spaces. The upper arms of this slough were filled in 1960 to create a golf course, but in 2017 major excavation reshaped the slough and mesa which historically existed there. This provided a barren landscape that has since been subject to intensive ecological restoration, including major planting, weeding, and monitoring efforts. During this initial transformation, 63 hibernacula were dug into the ground and stacked with pieces of the urbanite from the former golf course paths. The goal of these structures was to provide refuge for animals colonizing NCOS, facilitating food web reassembly.

Constructed hibernacula/refugia at NCOS.
Holes (5 x 5 x 5 feet) are filled with one-third mixed wood chips and soil, and carefully placed piles of 'urbanite' (concrete rubble) from demolished golf course paths to create passageways and narrow entrances for small vertebrates[1].

Study goals.
- Compile a list of species that use and occupy constructed hibernacula at NCOS using motion-activated camera traps.
- Determine frequency of hibernacula use by species across multiple habitat types.
- Evaluate the benefits of hibernacula to the NCOS restoration project, food web, and species recolonization.
- Provide a preliminary report of hibernacula use to generate future questions for undergraduate research.



Map 1. NCOS with locations of 63 constructed hibernacula.

Camera trap methods.
- Over the first five-week study period during winter 2021, 29 of the 63 hibernacula were randomly chosen and sampled for five nights (120 camera trapping hours) each.
- Sites were sampled across multiple habitat types including 11 grassland, 8 coastal scrub, and 10 salt marsh hibernacula.
- Two Bushnell Essential E2 motion-activated cameras were placed on opposite sides of each hibernacula. Cameras were set to 3-photo burst mode and operated continuously.
- One observation of species was recorded each minute it appeared on camera touching the structure; if both cameras recorded the same species the same minute it was counted as one observation.
- Student assistants manually sorted, identified, and compiled photos into a dataset containing 5,545 observations.


Image 1. Burrowing Owls and California ground squirrels colonize and cohabitate constructed hibernacula on the North Campus Open Space grassland.

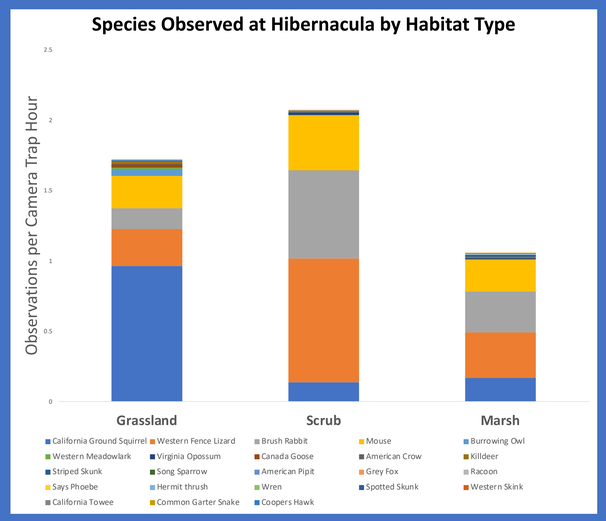


Figure 1. A total of 23 species were recorded visiting the hibernacula in various habitat types during the study. Visitation frequency (observations per camera trap hour) and species composition varied by habitat type. Coastal scrub had the highest visitation rate but the lowest species richness (n=13). Conversely, salt marsh had the lowest visitation rate and the highest species richness (n=17). 14 species were observed in the grassland, with California ground squirrels constituting the majority. All hibernacula (N=29) were occupied in this study with an average species richness of 5.28 ± 1.62. Squirrels, rabbits, and mice were observed at over 70% of the hibernacula (table 1).

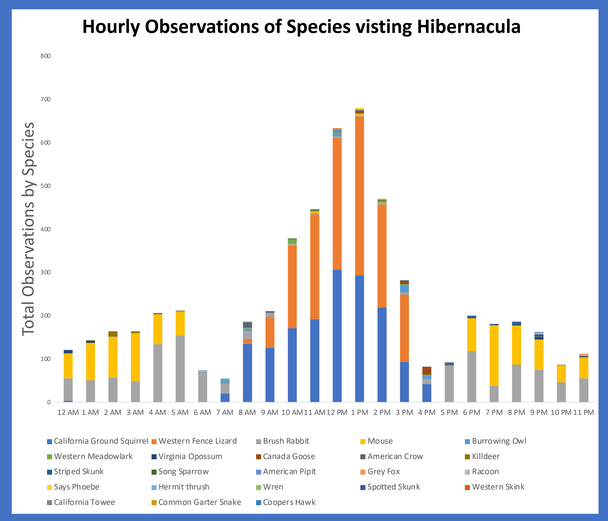


Figure 2. Different species use the hibernacula at different times of the day. Observations by hour are compiled and stacked by order of most frequently observed species. Most observations during the day are of California ground squirrels which use the hibernacula as colony sites and use the stacked urbanite to keep watch. Additionally fence lizards are commonly seen basking on the urbanite slabs. At night, brush rabbits and mice are usually seen darting in and out of the hibernacula where they likely take shelter in during the day. Meso-carnivores (Virginia Opossum, Striped Skunk, Grey Fox, Spotted Skunk, Racoon) are seen at night investigating the entrances.

Images 2-5: At night, meso-carnivores (images 2-4) were frequently observed to be passing by or investigating the hibernacula, potentially attracted by the scent of prey species such as deer mice (image 5). The most frequently observed medium-sized mammal was the Virginia opossum which usually spent a few minutes investigating the entrances. Grey foxes, and spotted skunks were species that had not previously been observed at NCOS and the knowledge of their presence brings greater understanding to the depth of the NCOS food web. In fact, this may be the first known observation of a spotted skunk in the Goleta, California area. Finally, deer mice were particularly active around the hibernacula at night and were observed in 79.3% of the hibernacula (table 1).


Image 2. Virginia Opossum, *Didelphis virginiana.*


Image 3. Grey Fox, *Urocyon cinereoargenteus.*


Image 4. Spotted Skunk, *Spilogale gracilis.*


Image 5. Deer Mouse, *Peromyscus maniculatus.*

Table 1. Confirmed Species List.

Class	Common Name	Scientific Name	Percentage of Sites with Observations	Average Observations per Camera Trap Hour
Reptiles	Western Fence Lizard	*Sceloperous occidentalis*	44.83%	0.4543
Reptiles	Western Skink	*Plestiodon skiltonianus*	3.45%	0.0006
Reptiles	California Red-sided Garter Snake	*Thamnophis sirtalis infernalis*	3.45%	0.0003
Mammals	California Ground Squirrel	*Otospermophilus beecheyi*	72.41%	0.4606
Mammals	Brush Rabbit	*Sylvilagus bachmani*	79.31%	0.3287
Mammals	Deer Mice*	*Peromyscus maniculatus*	79.31%	0.2727
Mammals	Virginia Opossum	*Didelphis virginiana*	37.93%	0.0078
Mammals	Striped Skunk	*Mephitis mephitis*	37.93%	0.0060
Mammals	Grey Fox	*Urocyon cinereoargenteus*	6.90%	0.0014
Mammals	Racoon	*Procyon lotor*	6.90%	0.0014
Mammals	Spotted Skunk	*Spilogale gracilis*	6.90%	0.0006
Birds	Burrowing Owl	*Athene cunicularia*	10.34%	0.0161
Birds	Western Meadowlark	*Sturnella neglecta*	37.93%	0.0083
Birds	Canada Goose	*Branta canadensis*	3.45%	0.0075
Birds	American Crow	*Corvus brachyrhynchos*	31.03%	0.0072
Birds	Killdeer	*Charadrius vociferus*	10.34%	0.0063
Birds	Song Sparrow	*Melospiza melodia*	20.69%	0.0026
Birds	American Pipit	*Anthus rubescens*	10.34%	0.0023
Birds	Says Phoebe	*Sayornis saya*	3.45%	0.0014
Birds	Hermit thrush	*Catharus guttatus*	3.45%	0.0009
Birds	Bewick's or House Wren	*Thryomanes spp.*	6.90%	0.0009
Birds	California Towee	*Melozone crissalis*	3.45%	0.0003
Birds	Cooper's Hawk	*Accipiter cooperii*	3.45%	0.0003

Discussion.
- California ground squirrels, western fence lizards, brush rabbits, and mice were the most frequently observed species at the hibernacula and are likely occupants based on their behavior. These species are primary and secondary consumers that constitute an important food source for the many top predators at NCOS. This includes the meso-carnivores observed in the study and avian raptors which are relatively abundant at NCOS[2] despite ongoing restoration efforts only beginning in 2017.
- The most abundant occupant of the hibernacula, the California ground squirrel (*Otospermophilus beecheyi*), is a highly interactive species in the restored food web, because it acts as an ecosystem engineer and prey source[3]. Observed colony site abundance on the constructed hibernacula emphasizes their utility in facilitating ecological restoration by attracting native ecological engineers[4].
- Mice species were frequently seen at night, but camera trap images cannot reliably differentiate between species. We attempted to do so with footprint tracking tunnels, but the results were unclear. Seasonal Sherman trapping efforts have reveled that deer mice (*Peromyscus maniculatus*), and much less abundantly harvest mice (*Reithrodontomys megalotis*) occur near the hibernacula. Some of our crisp photos were identified as deer mice* (image 5).
- Unexpectedly, we observed at least 12 bird species during this five-week study period, including many song and shorebird species. These observations are likely incidental but could be facilitated by potential insect prey abundance at the hibernacula or seeds brought by squirrels.

Future Directions.
- Complete a comparison study between hibernacula and other habitat structures (salvaged logs and boulders). During spring 2021 we conducted a second five-week study with camera traps investigating multiple habitat structures at NCOS. Currently, we are looking into AI software to aid in processing hundreds of thousands of photos rather than manual processing.
- Quantify the ground squirrel population at NCOS, with regard to their reliance on hibernacula as colony sites.
- Survey invertebrate communities of constructed hibernacula.
- Upon creation of any new hibernacula, observe colonization behavior and dynamics over time.

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