Factors influencing Barn Owl depredation of Scripps's Murrelets on Santa Barbara Island: summary results from the 2013 field season.

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Abstract

Scripps's Murrelets (*Synthliboramphus scrippsi*) breeding on Santa Barbara Island, California, are preyed upon by Barn Owls (*Tyto alba*) in substantial numbers in some years. Island deer mice (*Peromyscus maniculatus elusus*) are also important prey for owls, and themselves consume 8-70% of murrelet eggs in a year. Therefore, it is important to understand both the direct and indirect interactions between mice, murrelets and owls, in order to inform murrelet conservation. Data collection methods that began in 2010-2012 were continued in 2013 during a critical decline phase in the mouse population cycle. Both mouse and owl abundance dropped precipitously in 2013 from the previous year, and owl predation of murrelets declined by over 50% from the previous year, to at least 80 individual murrelets found killed by owls. Owls were more often detected adjacent to murrelet habitat in 2013, where mouse activity also tended to be highest. In addition, mouse foraging patterns in experimental foraging stations were consistent with predictions of perceived predation risk with varying cover, moon phase and owl abundance. This indicates the potential for indirect effects of owls on mice that may have positive consequences for murrelets. We also used stable isotope analysis of carbon and nitrogen in collagen extracted from the bones of mice to infer the amount of murrelet eggs consumed by mice at two sites over four years. There was no evidence of substantial differences in the amount of seabird tissue in mouse diet between years or between sites. We conclude that these data will be useful for evidence-based conservation decisions to benefit Scripps's Murrelets on Santa Barbara Island.

Introduction

Scripps's Murrelets (*Synthliboramphus scrippsi*; SCMU) are small (~167g) pursuit diving alcids that have a worldwide breeding distribution of 10 island groups off the coast of Southern California and Mexico (Whitworth pers. comm., Drost and Lewis 1995, Burkett et al. 2003). The largest breeding colony of this California state-listed Threatened seabird in the U.S. is on Santa Barbara Island (SBI) with an estimated 321-638 pairs in 2009-2010 (Whitworth et al. 2011). SBI is located 63km offshore and at 2.6 sq km is the smallest of five islands comprising the Channel Islands National Park (CINP). The National Park Service (NPS) began annual monitoring of murrelet reproductive success in 1985 on SBI and since that time numbers of this rare bird have declined in some monitoring plots (Burkett et al. 2003).

Predation by Barn Owls (*Tyto alba*) may be contributing to this decline, as they will prey on substantial numbers of adult murrelets in some years (Drost 1989, Thomsen and Plumb 2014, Nur

et al 2013). In addition, deer mice consume an average of 42% of murrelet eggs laid each year, ranging from 8% to 70% (Drost and Lewis 1995). However, since Barn Owls are also important predators of deer mice, this presents a challenge for murrelet conservation. For example, management actions that might be considered to benefit murrelets, such as reducing mouse density, could have unintended negative consequences, such as increasing Barn Owl predation on murrelets. Therefore, the aim of this research was to investigate the direct and indirect interactions between mice, murrelets and owls, in order to make informed murrelet conservation and management decisions. This was the fourth year of data collection for a study that began in 2010 (Thomsen and Harvey 2012) and occurred during a critical decline phase in the mouse population cycle (Drost and Fellers 1991).

Methods

Methods are briefly summarized here but have been described in detail in previous reports (Thomsen and Harvey 2012, Thomsen et. al 2013, Thomsen and Plumb 2014). Methods included: (1) describing habitat use and abundance of Barn Owls using line transects (in April 2013) and trail surveys (in January and August 2013); (2) examining Barn Owl diet using pellets and prey remains (collected in January and August as well as those found throughout the murrelet breeding season in plots and along trails); and (3) describing rodent prey availability for Barn Owls using tracking tubes (in April, May and August 2013). Due to logistical constraints, track tubes were not put out in July 2013. Tracks tubes were also not deployed in June in all study years in order to limit disturbance to nesting Western Gulls (*Larus occidentalis*).

We investigated whether mouse foraging behavior is influenced by owl habitat use with the use of experimental mouse foraging trays in 2012 and 2013. This technique is a well-established method to measure the perceived predation risk of small rodents, where the amount of food remaining in a patch (called the "giving up density"; GUD) represents how mice balance the costs and benefits of foraging a patch (Brown 1988). To measure GUDs, we set out 36 foraging stations that contained 1L of sand mixed with 7.5mL of roasted hulled sunflower seed. The amount of seed remaining in each station was sifted out the following day and counted. We predicted that owl activity on nearby transects as well as microhabitat (open vs. under cover) and moonphase (full vs. new) would influence the amount of seed remaining. For example, high perceived predation risk would result in more seed remaining (i.e. higher GUDs) than an area with

lower risk. The completed analyses from two years of this data have been completed and will be submitted to a peer-reviewed journal (Thomsen et al, in prep).

Finally, we used stable isotope analysis of carbon and nitrogen in mouse tissues to infer the diet of mice consumed by owls across two sites (Cat Canyon and Barn Owl Cave) over four years (2010-2013). We were specifically interested in whether we could detect inter-annual differences in the amount of seabird tissue, i.e. murrelet eggs, in the diet of mice at these two sites, which are each adjacent to murrelet nest monitoring areas. To do so, we isolated bone collagen from mouse femur bones removed from owl pellets that were freshly collected each year from these two sites. Bone collagen is a tissue with a slow isotopic turnover rate and represents the lifetime average diet of individuals, which is usually <1 year for deer mice (Collins et al 1979). Collagen was extracted following methods adapted from Newsome et al (2010). Briefly, individual femur bones were soaked in 0.5 N concentration of HCL for 24 hours for the decalcification process, and then soaked in a 2:1 chloroform:methanol solution for 10 days to remove lipids. Samples were then thoroughly rinsed in deionized water and then lyophilized for 24 hours. Subsamples of collagen weighing ~1mg were packed into tin capsules. These samples were analyzed for $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotopes at the UC Davis Stable Isotope Facility using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer (Sercon Ltd., Cheshire, UK). For each site and year, we used Bayesian mixing models implemented in the R package SIAR (Parnell 2010) to determine the relative contribution of potential dietary items. We used previously published isotope values for both potential dietary items on the island (Millus 2006), and diet-tissue discrimination factors (DeNiro and Epstein 1978, 1981).

Results and Discussion

Both mouse and owl abundance declined precipitously in 2013, which is consistent with the previously observed patterns in the population cycles of these species on the island that are linked with differences in winter precipitation (Drost and Fellers 1991; Thomsen et al, in prep). Track tube scores in 2013 were the lowest observed of the three years (Figure 1; Thomsen et al. 2014).

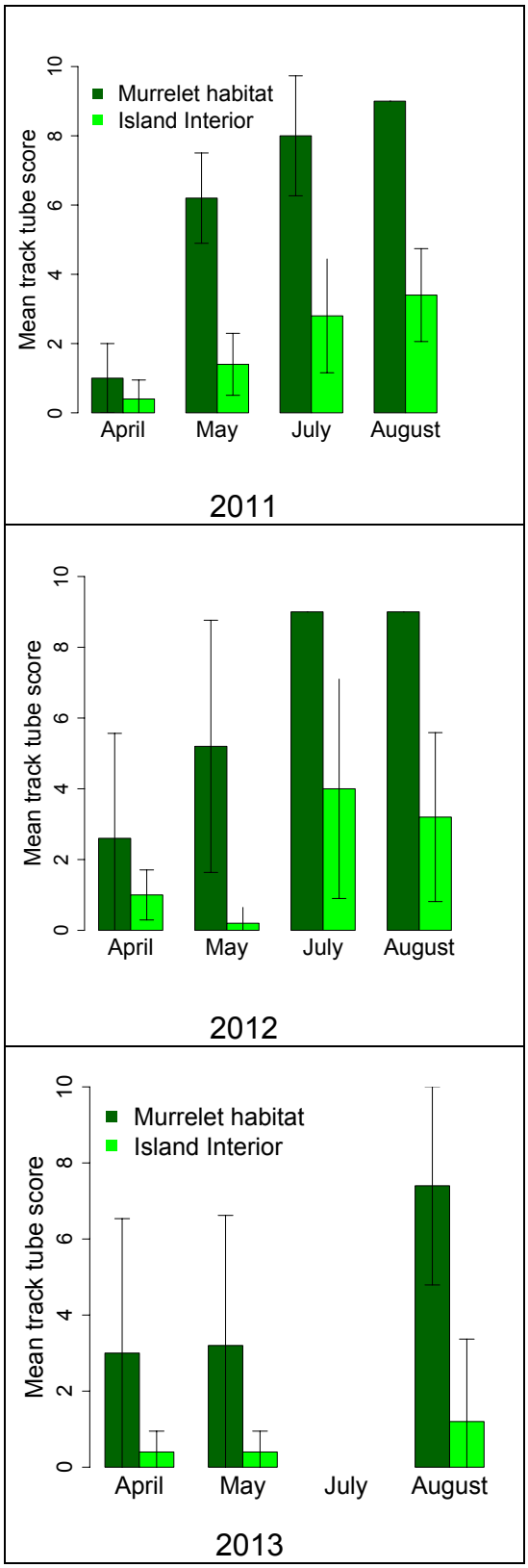

Figure 1. Track tube scores on Santa Barbara Island, 2011-2013. Scores represent the average count of track tubes that had the presence of mouse tracks for the grids in two habitat types: murrelet nesting habitat along island coastal areas and the island interior.

This is also consistent with extremely low numbers of mice caught during the mouse trapping efforts in March (NPS unpubl. data). A trail survey for owls was conducted in January and August 2013 with a count of 4-6 owls, the lowest numbers seen since early 2010. Owl detections on the line transects in April were also rare, with 91% of transect surveys having zero observations of owls.

We assessed the diet of Barn Owls through the collection of both pellets and avian prey remains (Scripps's Murrelets and Cassin's Auklets (*Ptychoramphus aleuticus*, CAAU)) collected from trails, murrelet monitoring plots, habitat restoration plots and owl roost sites (Thomsen et al. 2013). There were 80 murrelet carcasses collected in 2013, representing the minimum number of individuals (MNI) presumably killed by owls. This is a drop of over 50% from the previous year, when the remains of 172 murrelets were collected (Table 1; Thomsen, unpubl. data). Owl pellet analysis is ongoing, but the percent frequency of occurrence for murrelets, mice and lizards was 9%, 87%, and 66%, respectively (n=147 pellets from which 733 prey items were identified to species). This is a drop from a high of 22% of pellets containing murrelet remains in 2012 (total n=237 pellets), and suggests a decline in the importance of murrelets in owl diet in 2013.

Table 1. Seabird predation by owls, 2012-2013, on Santa Barbara Island. Numbers represent the minimum number of individuals (MNI) represented for Scripps's Murrelets and Cassin's Auklets found as prey remains in owl roost sites and in murrelet nest monitoring habitat.

	2012	**2013**
Scripps's Murrelets	172	80
Cassin's Auklets	19	12

Owls were more frequently detected along line transects located adjacent to coastal murrelet habitat (0.61 owls/km) rather than in the island interior (0.28 owls/km). This pattern is consistent with space use of individually marked Barn Owls on the island, where they tended to be re-sighted near the edges of the island (Thomsen et al. 2014). In addition, there was also higher mouse activity (e.g. the proportion of tracking tubes with mouse tracks) within the murrelet plots than the interior habitats, which was also consistent with previous years (Figure 1).

This indicates a continued spatial overlap of mice, owls, and murrelets along island edges that appears generally persist throughout the mouse population cycle. This spatial overlap also indicates the potential for positive indirect effects of owls through consuming murrelet egg predators precisely where murrelets would benefit. Even relatively modest decreases in egg

predation could influence murrelet population dynamics (Sydeman et al. 1998, Nur et al. 2013). Predators not only impact prey populations through consumption (i.e. a density mediated effect), but can also influence the behavior of their prey, when they seek to avoid high-risk situations. The magnitude of these changes in prey behavior can equal or even exceed density-mediated effects on prey demographics (Preisser et al. 2005). We measured giving up densities (GUDs) of mice in order to assess the potential effects of owls on mice during a high owl year (2012) and a low owl year (2013). In 2013, mean GUDs were higher in the open than under cover and higher during the full moon than the new moon. Mean GUDs tended to be higher with greater numbers of owls counted on nearby transects. This is consistent with our a priori predictions of perceived predation risk, and similar patterns have been observed with deer mice in response to island foxes on nearby San Miguel Island (Orrock and Fletcher 2014). This suggests that patterns in egg predation could also be related to how mice respond to predation risk from owls. Evidence for this idea and more extensive statistical analyses that accounts for both repeated measures and mixed effects in the GUD measurements will be included in a forthcoming manuscript that combines both years of data.

Based on results from Bayesian mixing models of stable carbon and nitrogen isotope ratios in mouse bone collagen, we found no evidence suggesting that seabird tissue (e.g. murrelet eggs) comprised a large component of the overall diet of deer mice (Figure 2). In addition, there were only minor variations between sites and years, and these differences did not reflect known patterns in murrelet egg predation, which was highest in 2013 at Cat Canyon (Howard et al 2014). However, these results should be interpreted with some caution, as it is based on the assumption that this is an unbiased sample from the mouse population. Because the collagen samples are from mice that the owls had preyed upon, we could not control for potential differences in owl foraging or prey selection patterns, which could have influenced what dietary items were available to the mice prior to the time of their death. Nonetheless, these results are consistent with a previous study that used carbon and nitrogen stable isotope analysis on several different tissues of mice obtained by trapping and sacrificing them directly, which also found that seabird tissue apparently contributed little to the overall diet of deer mice (Millus and Stapp 2008). Therefore, mouse diet apparently consists primarily of a wide variety of native and non-native terrestrial sources.

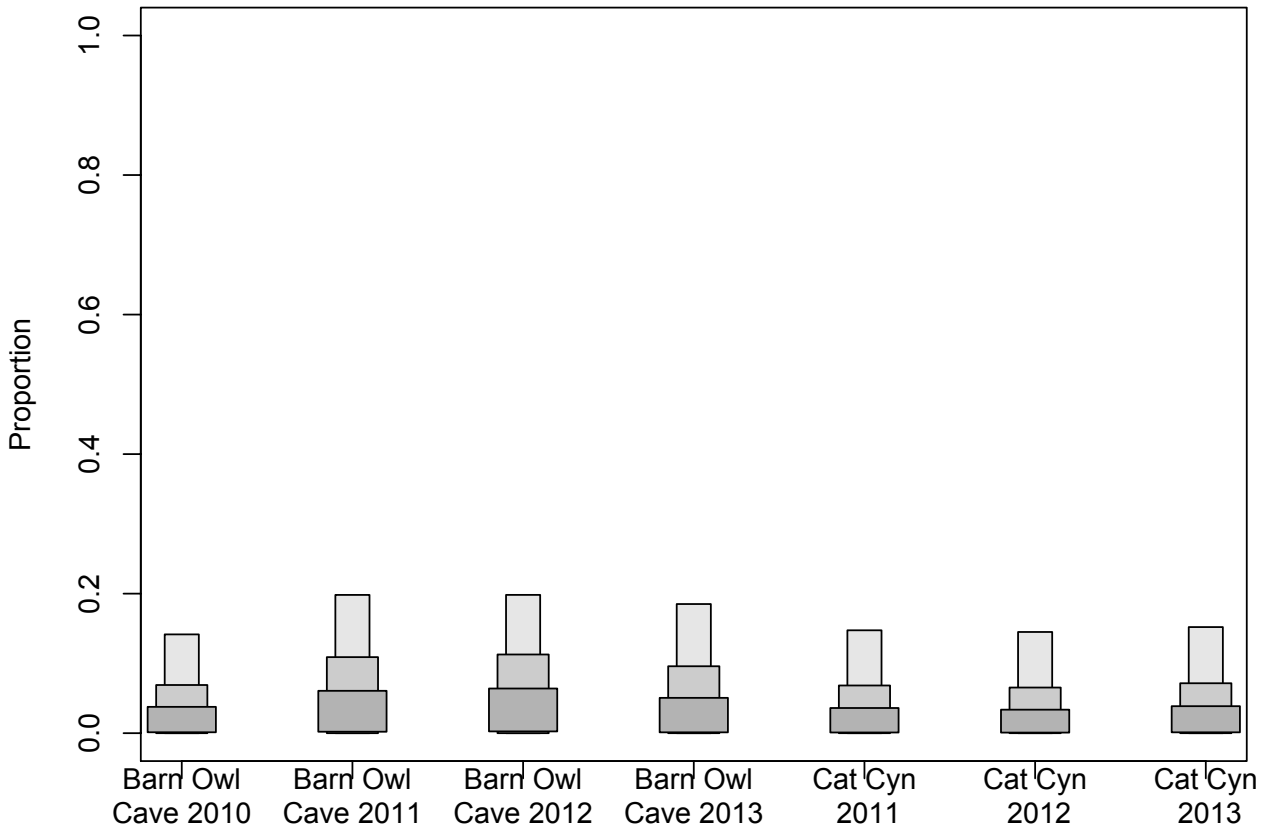

Figure 2. Dual-isotope Bayesian mixing model (SIAR) results showing the estimated proportion of seabird tissue in mouse diet from two sites, Barn Owl Cave and Cat Canyon, from 2010-2013. Shades of grey represent the 50%, 75%, 95% credible intervals.

Summary and Conclusions

This was a critical year of data collection that documented a decline in the mouse and owl populations from the year before, as well as a concurrent decline in the importance of seabirds in owl diet. Over the last four years, we have found that owls are generalist predators and consume prey in accordance with the alternative prey hypothesis, in that the magnitude of predation on murrelets is mediated by the density of mice, and not owl density alone. In addition, mouse foraging patterns appear to be related to owl activity, which suggests the potential for positive indirect effects of owls through reducing egg predation by mice, which forthcoming work will examine in more detail. We conclude that these data will be useful for evidence-based conservation decisions and the potential development of an adaptive management plan to benefit Scripps's Murrelets on Santa Barbara Island.

Management Recommendations

Given the dynamic nature of the predator-prey interactions on Santa Barbara Island, we highly recommend continuing related research through both long and short-term studies. Specifically, we recommend continuing long-term data collection on owl abundance (annual trail surveys in January and August) and mouse density (in March), as well as indices of murrelet mortality and murrelet nest success. More detailed management recommendations will be included in the published manuscripts regarding evaluating thresholds for potential interventions, but at this time we recommend consideration of other factors influencing murrelet population trends before adopting intensive actions.

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