



2013-2015 Deer Mouse Monitoring Annual Report

Channel Islands National Park

Natural Resource Data Series NPS/MEDN/NRDS—2016/1070





ON THIS PAGE

Deer mice on Santa Barbara Island, Channel Islands National Park
Photograph by National Park Service

ON THE COVER

Deer mouse and coreopsis, Santa Barbara Island, Channel Islands National Park
Photograph by Catherin Schwemm

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Abstract

In spring 2013 through spring 2015 staff at Channel Islands National Park conducted population monitoring of deer mice (*Peromyscus maniculatus*) on three islands, completing 23 years of deer mouse monitoring at the park. Population monitoring was conducted using capture-mark-recapture methods at Santa Barbara Island (2 sites), Anacapa Island (1 site) and San Miguel Island (3 sites). Each site is a 10 by 10 grid of small box traps and is trapped for 3 consecutive nights in the spring and in the fall. Captured mice are marked with eartags, sexed and aged. We used the number of unique individuals caught on a grid as an index of mouse abundance, since that metric is highly correlated with density estimated from programs CAPTURE, MARK and DENSITY. Mouse abundance over time showed extensive fluctuation and evidence of seasonal variability, with fall numbers being generally higher than spring numbers, due to annual summer recruitment following winter mortality. There was evidence of multi-year cycles on Santa Barbara and San Miguel islands. However, when island foxes (*Urocyon littoralis*) were absent from the wild on San Miguel during a period of captive breeding (2000-2004), deer mouse cycles appeared to be more annual in nature, and abundance was generally higher than before or after the captive breeding period.

On San Miguel, deer mice are still at population lows, and they have stayed at low numbers throughout the current drought (2011-2015). High island fox density may be suppressing mouse numbers, preventing them from increasing. In contrast, on Santa Barbara Island, mouse populations have begun to increase from lows in 2012-2014, and if they follow the typical 3-4 year cycle, may be increase to high numbers in 2016. Santa Barbara lacks the generalist island fox, and barn owls (*Tyto alba*), a specialist predator, typically decline as mice decline. Mice on East Anacapa exhibited typical spring lows and fall highs, with little evidence of multi-year cycles.

Mouse weight may be an indication of body condition and thus habitat quality. Comparing spring male weights over time showed that Santa Barbara mouse weights appeared to decrease during the drought, but San Miguel weights increased in the latter part of the recent drought. As an indicator of habitat quality, there was little difference between the two Santa Barbara grids, one of which is in grassland, and the other in coreopsis scrub. The three San Miguel grids showed no difference in mouse weights during the drought, but some consistent differences prior to the drought. In non-drought years, the Nidever Canyon grid, in lupine scrub habitat, had higher weights than the Airstrip grid (*Isocoma* scrub), and the Willow Canyon grid (grassland) had lower weights. Thus, there may be habitat differences during years of normal or above-normal precipitation, though it appears that during a drought all habitats decline in quality.

Acknowledgments

Deer mouse monitoring in 2013-2015 was conducted by Angela Guglielmino, Robyn Shea, Andrew Abate, Helen Fitting, Danny Black, Nicole LaRoche, Jim Howard, Andrew Yamagiwa, Marie-Eve Jacques, Gabrielle Keeler, Stacy Baker and Natalie Moore. Fieldwork was scheduled and personnel were trained by Angela Guglielmino. I thank Lena Lee, database manager for the National Park Service Mediterranean Coast Network, for her assistance in data management. Rocky Rudolph produced the excellent maps of deer mouse monitoring grid locations.

Most of what is known about deer mouse ecology on the islands is due to the sustained efforts of several individuals over time. Charles Drost, Cathy Schwemm, John Orrock and Rob Klinger have studied island mice extensively (in some cases, for 20-30 years!) and continue to generously lend their interest and expertise to the park's monitoring efforts. For that I am grateful. Additionally, fieldwork by Cathy Schwemm, Charles Drost and Paige Martin kept deer mouse monitoring going during times of inadequate staffing. Thanks to Cathy Schwemm for reviewing a draft version of this report.

Introduction

Like other nearshore island groups, California's Channel Islands have a depauperate vertebrate fauna when compared to that of the nearby mainland. For example, on most of the 8 islands in the archipelago the only rodent is the deer mouse (*Peromyscus maniculatus*), which is recognized as a separate subspecies on each of the islands. Because it is one of only a few vertebrate species occurring on the islands, the deer mouse has considerable ecological influence. Deer mice are a preferred food item for the endemic island fox (*Urocyon littoralis*) (Coonan et al. 2010), and as seed and flower predators they influence the dynamics of both native and non-native vegetation (Schwemm 2008). Deer mice are egg predators for landbirds (Peluc et al. 2008) and for some crevice-nesting seabirds (Schwemm and Martin 2005). Island mice are also important in terms of zoonotic disease. Deer mice on the Channel Islands are a reservoir for the virulent Sin Nombre strain of hantavirus (Graham et al. 1997, Jay et al. 1997, Orrock and Allan 2008), with seroprevalence being higher on islands with greater area, higher precipitation, and fewer predators (Orrock et al. 2011).

Deer mouse population dynamics are well-documented for Santa Barbara Island in Channel Islands National Park (Drost and Fellers 1991). In years of abundant precipitation, deer mice increase to densities considerably higher than those recorded elsewhere, and barn owls (*Tyto alba*) increase in response to the dense prey base. Mice subsequently decline when reproduction declines at high densities, and/or precipitation in following years inevitably declines, and the high barn owl population helps drive down mouse populations to extremely low numbers. Barn owls ultimately decline as well. This results in a multi-year population cycle, in which population highs occur every 3-4 years.

Because of their ecological importance, as well as their status as endemic subspecies, deer mice were chosen for monitoring as part of the park's long-term ecological monitoring program (Fellers et al. 1988). Trapping grids were located in representative stands of island vegetation on Santa Barbara, Anacapa and San Miguel Islands, with capture-mark-recapture sampling occurring twice a year. Despite the vagaries of Federal funding and its effects on staffing, deer mouse data have been collected by park staff and volunteers on a fairly consistent basis since 1992. Data from the early years of the program has previously been reported in a series of annual reports (Schwemm 1995, Austin 1996, Schwemm 1996, Austin 1998) and a trend report (Schwemm and Coonan 2001).

This report presents deer mouse population monitoring data collected from Santa Barbara, Anacapa and San Miguel Islands in 2013-2015. In most cases the data are presented in relation to data collected in previous years.

Methods

Deer mouse monitoring at Channel Islands National Park was established as part of the “vital signs” ecological monitoring program developed at CHIS (Davis et al. 1994) that eventually served as the model for ecological monitoring conducted through the NPS Inventory and Monitoring Program (Davis 2005). CHIS is one of three parks in the Mediterranean Coast Network of the NPS Inventory and Monitoring Program. Development of vertebrate monitoring began in the mid-1980s, and the resulting protocol (Fellers et al. 1988) established 13 deer mouse monitoring grids on Santa Barbara, Anacapa and San Miguel Islands. Due to funding, staffing and logistical constraints, the number of grids that has been consistently surveyed over time is limited to 2 on Santa Barbara Island, 1 on Anacapa, and 3 on San Miguel (Table 1, Figures 1-3), and those were the grids sampled in 2013-2015.

Table 1. Deer mouse monitoring grids sampled at Channel Islands National Park in 2013-2015.

Grid	Habitat Type	Code
<i>Santa Barbara Island</i>		
Terrace Coreopsis	Coreopsis Scrub	TC
Terrace Grassland	Grassland	TG
<i>Anacapa Island</i>		
East Anacapa Island – Inspiration Point	Grassland	EI
<i>San Miguel Island</i>		
Airstrip	Isocoma Scrub	AS
Nidever Canyon	Lupine Scrub	NC
Willow Canyon	Grassland	WC

When the protocol was developed, deer mouse monitoring grids were not randomly located, but instead were placed in representative stands of different habitat types. Habitat characteristics have likely changed to some degree over time on the grids, since vegetation on the islands is generally recovering from decades of grazing by non-native animals. Each grid comprises 100 trap locations in a 10 by 10 configuration, with trap spacing of 7 m. Each grid was trapped twice a year, in the spring and the fall, for three consecutive nights. Monitoring was occasionally conducted in the winter and summer. Box-type live traps (3 x 3.5 x 9 in., H. B. Sherman Traps, Tallahassee, Florida) were baited with rolled oats and checked once a day, in the morning. Captured mice were weighed, sexed and aged (adult, subadult or juvenile), reproductive condition was recorded, and mice were marked with numbered Monel eartags (National Band and Tag Co., Newport, Kentucky).

Excluder devices (Fig. 4) were used on San Miguel and Anacapa islands to avert trap disturbance by island foxes and western gulls (*Larus occidentalis*), respectively. The excluder device comprises rigid sheet plastic material wrapped around a Sherman trap, and extending beyond each end to prevent other animals from gaining access to the doors of the trap. The device and enclosed trap is anchored to the ground by a surveyor’s chaining pin. The devices have been used on San Miguel in both spring and fall and on Anacapa in the spring since 2009.



Santa Barbara Island Deer Mouse Grids



Figure 1. Location of deer mouse monitoring grids on Santa Barbara Island, Channel Islands National Park.



East Anacapa Island Deer Mouse Grids



0 250 500
Meters

Legend

 Deer Mouse Grid

Location



Produced by Channel Islands GIS Date: 8/31/2012

Figure 2. Location of deer mouse monitoring grid on Anacapa Island, Channel Islands National Park.



San Miguel Island Deer Mouse Grids



Figure 3. Location of deer mouse monitoring grids on San Miguel Island, Channel Islands National Park.



Figure 4. Island foxes inspecting Sherman traps with excluder devices on San Miguel Island. Use of excluder devices on San Miguel and Santa Barbara Islands began in 2009.

In the past, island deer mouse abundance has been reported as density (mice/ha), estimated with the use of program CAPTURE on capture-mark-recapture data from the grids (Schwemm 1995, Austin 1996, Schwemm 1996, Austin 1998, Schwemm and Coonan 2001). Program CAPTURE takes into account detectability and capture probabilities to provide more accurate estimates of abundance than indices of abundance, which do not account for the uncaptured portion of the population. However, in this report we used the number of unique mice caught on a grid during a 3-day grid sampling period as an index of mouse abundance. Such measures are highly correlated with densities estimated via programs CAPTURE, MARK and DENSITY (J. Orrock, University of Wisconsin, unpubl. data), and use of indices is necessary to avoid problems of model selection in cases where captures are too few to use density estimators. We present 2013-2015 values for mouse abundance on the grids alongside abundance values from previous years.

Mouse weight may be a good indicator of individual condition, and hence resource abundance, as influenced by precipitation and habitat type (Zwolak and Foresman 2008). However, there is variability due to sex, age, season and reproductive condition. Males generally weigh more than females, except when females are pregnant, and adults weigh more than juveniles or subadults. Since we were nonetheless interested in looking at mouse weights over time, we controlled for this variability by limiting our longer-term analysis to adult male weights in the spring of each year.

To examine the general influence of precipitation on mice, we used annual precipitation for the water year (July 1 – June 30) on Santa Barbara Island. Because San Miguel Island does not have a longterm weather record, we used precipitation data from neighboring Santa Rosa, located 25 km to the east. The datasets for both islands were compiled and corrected by T. Handley, U.S. Geological Survey.

Results and Discussion

In both spring and fall of all years, relatively few individuals were caught on each grid (compared to previous years with population highs), with the exception of the East Anacapa grid (Table 2). Graphs of abundance over time for each grid indicate that, with the exception of Anacapa, island mouse populations were still relatively low, although mice increased on two San Miguel grids (Figures 5-7).

Table 2. Sampling dates and trapping results for deer mouse monitoring grids surveyed at Channel Islands National Park, 2013 -2015.

Grid	Dates Sampled	Unique individuals	Recaptures
<i>Anacapa Island</i>			
Inspiration Point	4/1/2013 – 4/3/2013	8	6
	9/22/2013 – 9/24/2013	77	50
	10/15/2014 – 10/17/2014	177	84
	2/19/2015 – 2/21/2015	64	32
<i>Santa Barbara Island</i>			
Terrace Coreopsis	3/14/2013 – 3/16/2013	0	
	11/3/2013 – 11/5/2013	7	5
	3/16/2014 – 3/18/2014	0	
	10/14/2014 – 10/16/2014	59	48
	3/11/2015 – 3/11/2015	68	51
Terrace Grassland	3/17/2013 – 3/19/2013	2	0
	10/31/2013 – 11/2/2013	2	0
	3/13/2014 – 3/15/2014	1	1
	10/11/2014 – 10/13/2014	18	14
	3/14/2015 – 3/16/2015	43	52
<i>San Miguel Island</i>			
Airstrip	3/3/2013 – 3/5/2013	17	16
	10/5/2013 – 10/7/2013	27	27
	4/6/2014 – 4/8/2014	21	15
	11/15/2014 – 11/17/2014	30	27
	3/27/2015 – 3/29/2015	18	13
Nidever Canyon	3/15/2013 – 3/17/2013	63	66
	10/17/2013 – 10/19/2013	85	45
	4/3/2014 – 4/5/2014	54	37
	11/19/2014 – 11/21/2014	44	53
	3/15/2015 – 3/17/2015	56	46
Willow Canyon	2/28/2013 – 3/2/2013	7	4
	10/2/2013 – 10/4/2013	17	11
	5/2/2014 – 5/4/2014	15	17
	11/12/2014 – 11/14/2014	8	6
	3/21/2015 – 3/23/2015	8	6

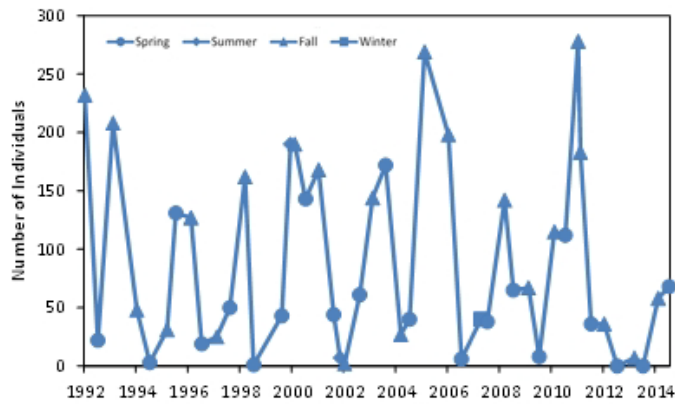
Santa Barbara Island

On Santa Barbara Island, the Terrace Grassland grid had lower population highs over time than did the Terrace Coreopsis grid, suggesting that the grassland habitat was lower quality than the coreopsis scrub. Because those grids were established in the 1980s, it is possible that vegetation composition may have changed since then, as the island gradually recovers from historic grazing. It is possible that the Terrace Coreopsis Grid is more open and contains less closed canopy coreopsis scrub than when first established (C. Drost, U.S. Geological Survey, pers. comm.). However, evaluation of vegetation composition on the grids via recent (2012) aerial photography showed the Terrace Grassland grid to still be 100% grassland, while the Terrace Coreopsis grid comprised 76% dense coreopsis, 12% scattered coreopsis, and 12% grassland (D. Rodriguez, National Park Service, unpublished data).

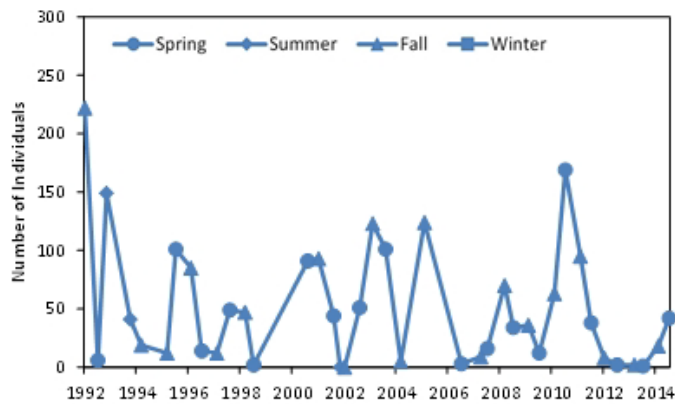
Mouse populations on Santa Barbara Island have been low since the current drought began in 2011, but both grids saw increases in fall 2014 and spring 2015, suggesting that the nadir of a population cycle has passed, and that the population may be in a build-up phase. Since monitoring began in 1992, Santa Barbara mice have exhibited a multi-year cycle, with highs occurring once every 2-4 years. It is interesting that populations may be beginning to increase, even though the drought has not yet broken (Figure 5c).

Annual precipitation on Santa Barbara Island averaged 21.1 cm from 1992-2014 and was variable (Figure 5c). Mouse abundance did not appear to be determined solely by precipitation (although no statistical tests were conducted at this time). Peak mouse years on the grids did not always correspond to peak precipitation years, especially for the Terrace Grassland grid, which exhibited fairly consistent peaks. On the Terrace Coreopsis grid, a fall 2005 population high of >260 mice was associated with previous (July 1, 2004 – June 30, 2005) precipitation of >50 cm.

a)



b)



c)

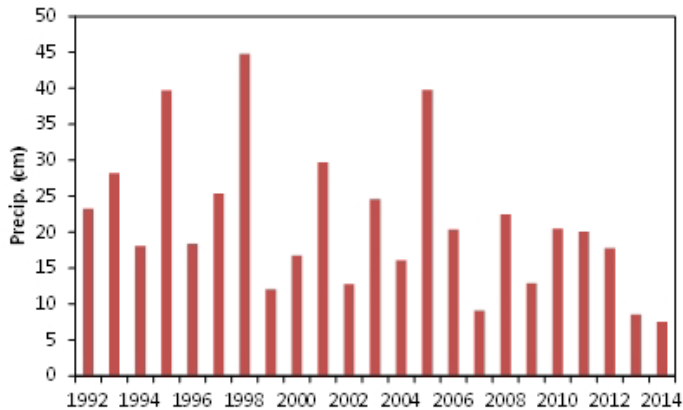


Figure 5. Deer mouse abundance (number of unique individuals) on a) the Terrace Coreopsis grid, and b) the Terrace Grassland grid, Santa Barbara Island, 1992 – 2015, along with c) annual precipitation on Santa Barbara Island for the water year (July 1 – June 30).

Anacapa Island

Mice on the East Anacapa Inspiration Point grid have exhibited seasonal variability since monitoring was reinstated in 2010 following several years of personnel shortages and implementation of the rat eradication project (Figure 6). Fall numbers have been higher than spring numbers, but numbers have generally increased since 2010, despite lower than average precipitation. Mice on East Anacapa increased dramatically in 2003, 2 years after removal of rats (*Rattus rattus*) in 2001 (Howald et al. 2005, Gellerman 2007; those data are not from NPS monitoring grids).

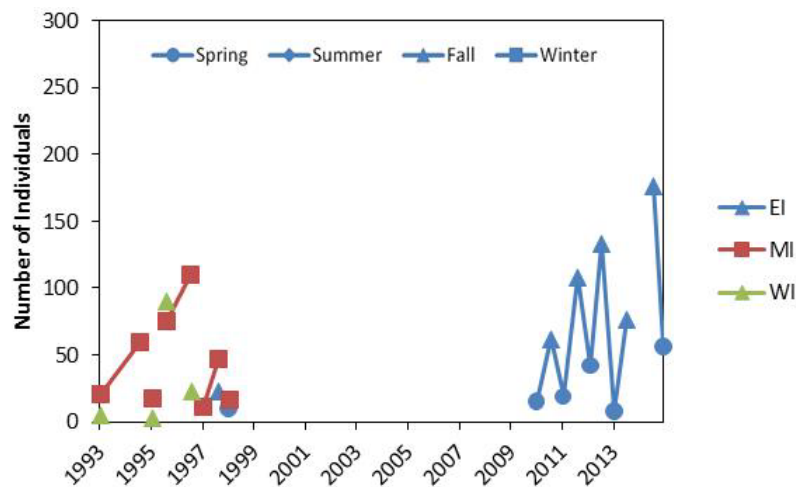


Figure 6. Deer mouse abundance (number of unique individuals) caught on deer mouse monitoring grids on Anacapa Island, 1992-2015. EI = East Anacapa Inspiration Point, MI = Middle Anacapa, WI = West Anacapa Island.

San Miguel Island

Mice on San Miguel appeared to exhibit annual cycles (spring minima and fall maxima) until 2006, when multi-year cycles, as observed on Santa Barbara Island, seemed to begin (Figure 7). The annual cycles occurred when island foxes were in the final stages of a massive population decline (1995-1999), were subsequently in captivity and absent from the wild (1999-2004), and were at relatively low, recovering, population levels (2004-2006). However, trap saturation at high densities may be masking true population highs, and density estimates derived from program CAPTURE suggest that multi-annual cycles began when foxes entered captivity (C. Drost, U.S. Geological Survey, unpubl. data). The current population pattern on San Miguel, with generally low numbers and little seasonal variation, has not been observed before in island mice.

The change in population cycling was more pronounced on the Nidever Canyon and Willow Canyon grids, where mice increased in an annual cycle of spring minima and fall maxima until 2005, when decrease and a multi-annual cycle began.

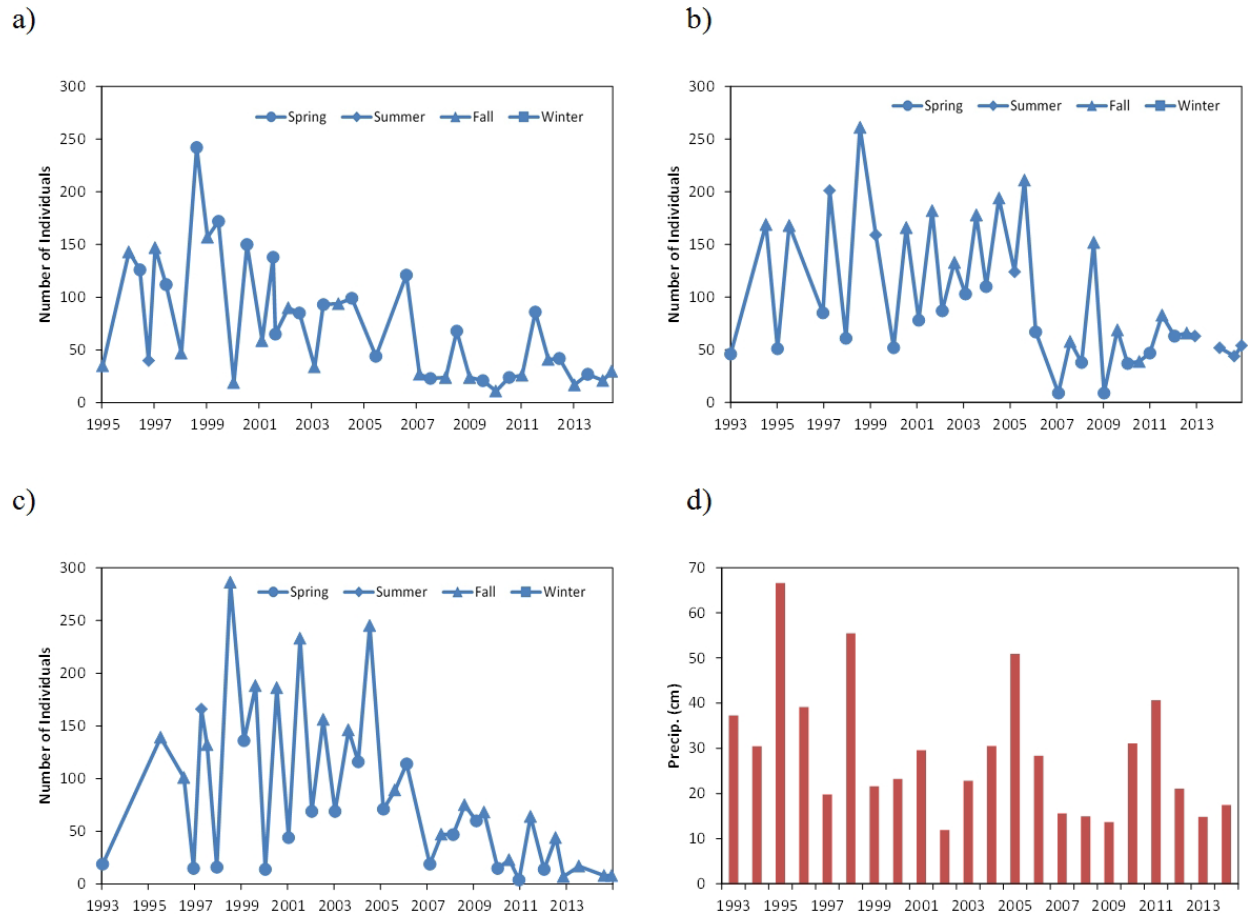


Figure 7. Deer mouse abundance (number of unique individuals) on a) the Airstrip grid, b) the Nidever Canyon grid, and c) the Willow Canyon grid, San Miguel Island, 1993-2015, along with d) annual precipitation for the water year (July 1 – June 30), Santa Rosa Island.

San Miguel mice were perhaps more influenced by precipitation than were mice on Santa Barbara Island. Average precipitation on Santa Rosa Island from 1992-2014 (29.4 cm) was greater than that on Santa Barbara Island. Mice maxima in fall 1998 were associated with the second-highest annual precipitation value during the time period (Figure 7d) and with a wild fox population of <20 individuals. Also, the change in cycle from annual to multi-annual occurred simultaneously with a 4-year decrease in precipitation. Although an increase in precipitation followed (in 2010-2011), mice did not increase, perhaps because of the influence of predation; island fox densities were high by that time.

Overall, the sex ratio of mice in 2013-2015 favored males slightly (513 males:449 females) (Table 3). Sex ratios were consistently skewed toward males on San Miguel Island, and there was an exceptional bias toward males on Anacapa in spring 2015. Very few juveniles were caught in 2013-2015, though the presence of some subadults indicated a modicum of recruitment on Anacapa and Santa Barbara.

Table 3. Number of deer mice captured by age class and by sex on Santa Barbara, Anacapa and San Miguel Islands, 2013-2015.

Year	Season and Island	Adults	Subadults	Juveniles	Males	Females	Sex Ratio
2013	<i>Spring</i>						
	Santa Barbara	2			1	1	1.00
	Anacapa	8			3	5	0.60
	San Miguel	77	9		49	37	1.32
	<i>Fall</i>						
	Santa Barbara	8	1		6	3	2.00
	Anacapa	38	38	1	35	42	0.83
	San Miguel	126	3		67	62	1.08
2014	<i>Spring</i>						
	Santa Barbara	1			1		
	Anacapa	(no data)					
	San Miguel	87	2		49	40	1.23
	<i>Fall</i>						
	Santa Barbara	47	27	2	36	40	0.90
	Anacapa	161	11	5	87	90	0.97
	San Miguel	74	6	1	48	33	1.45
2015	<i>Spring</i>						
	Santa Barbara	63	20	27	57	53	1.08
	Anacapa	47	2		31	6	5.17
	San Miguel	73	2	5	43	37	1.16

Average weights of mice varied by age, sex, and island (Appendix A). When spring 2015 weights of adult males were compared, Anacapa and San Miguel weights were similar, while Santa Barbara weights were lower than both (Figure 8). This may indicate lower habitat quality on Santa Barbara, at the tail end of the drought. Over time, Santa Barbara weights were generally lower than those on San Miguel (with a few exceptions), perhaps reflecting the lower annual precipitation, and perhaps lower productivity, on Santa Barbara Island.

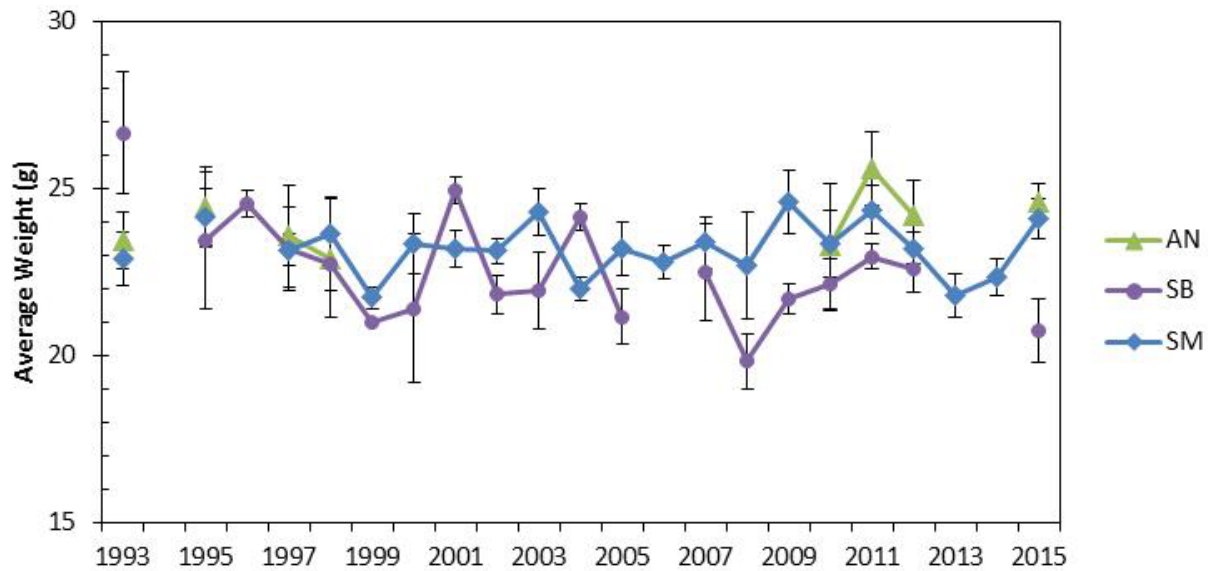


Figure 8. Average weights of adult male deer mice in springtime, for Anacapa (AN), Santa Barbara (SB) and San Miguel (SM) islands, Channel Islands National Park, 1993-2015.

Comparison of spring male weights over time on each island revealed differences among grids. On Santa Barbara Island, weights on both grids tracked closely until 2009 (Figure 9). Weights were greater on the Terrace Coreopsis grid in 2009 and 2010 and greater on the Terrace Grassland grid in 2011 and 2012. At the tail end of the current drought, in spring 2015, weights were similar on both grids.

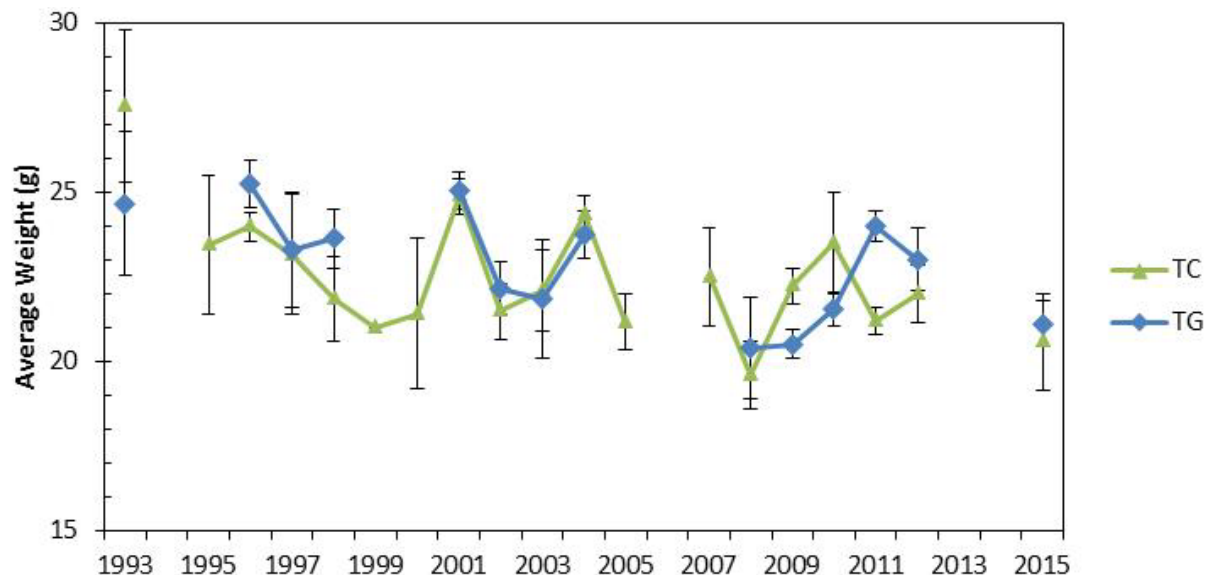


Figure 9. Average weights of adult male deer mice in springtime, on Santa Barbara Island, for the Terrace Coreopsis (TC) and the Terrace Grassland (TG) grids, 1993-2015.

On San Miguel, there was no difference in spring male weights among the three grids in 2010-2013 (Figure 10). Prior to that, weights were higher on the Nidever Canyon grid and lower on the Willow Canyon grid, with weights on the Airstrip grid falling between the two. In the latter part of the drought, weights were lower on the Airstrip grid than on the other two grids. It is interesting that habitat quality was apparently higher on the lupine scrub grid (Nidever Canyon) and lower on the grassland grid (Willow Canyon) until the recent drought, when weights on the three grids generally converged.

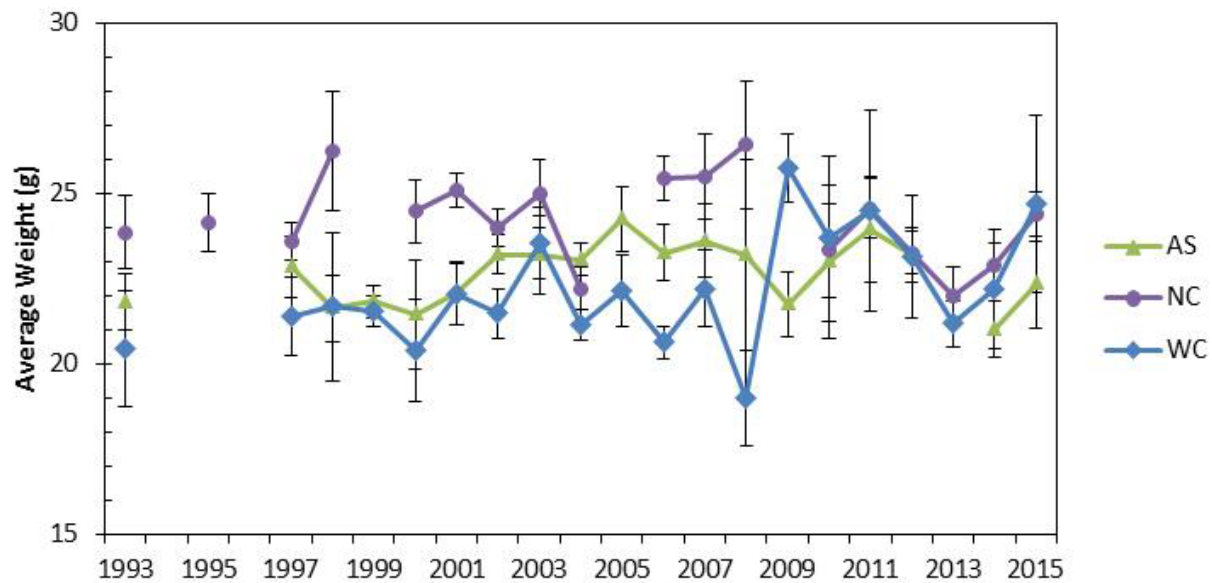


Figure 10. Average weights of adult male deer mice in springtime, on San Miguel Island, for the Airstrip (AS), Nidever Canyon (NC) and Willow Canyon (WC) grids 1993-2015.

The similarity of weights on the different grids during the drought suggests that drought is a great equalizer, and habitat quality differences that exist during times of non-drought conditions do not exist during drought.

Summary

Our 20-year dataset shows that deer mice oscillate in consistent 3-4 year population cycles on Santa Barbara, but on San Miguel, cycles changed over time. Annual cycles with spring minima and fall maxima, and overall increasing numbers, predominated through 2004, when island foxes were absent from the wild or at low densities. Multi-year cycles and decreasing numbers occurred from 2005-2015, when island foxes were at increasing to high densities. On San Miguel, deer mice are still at population lows, and they have stayed at low numbers throughout the current drought (2011-2015). High island fox density may be suppressing mouse numbers, preventing them from increasing. In contrast, on Santa Barbara Island, mouse populations have begun to increase from lows in 2012-2014, and if they follow the typical 3-4 year cycle, may be increase to high numbers in 2016. Santa Barbara lacks the generalist island fox, and barn owls (*Tyto alba*), a specialist predator, typically decline as mice decline. Mice on East Anacapa exhibited typical spring lows and fall highs, with little evidence of multi-year cycles.

Literature Cited

- Austin, G. S. 1996. Terrestrial vertebrate monitoring, Channel Islands National Park, 1995 annual report. Channel Islands National Park Technical Report # 96-04. National Park Service, Channel Islands National Park, Ventura, California.
- Austin, G. S. 1998. Terrestrial vertebrate monitoring, Channel Islands National Park, 1996 annual report. Channel Islands National Park Technical Report # 98-03. National Park Service, Channel Islands National Park, Ventura, California.
- Coonan, T. J., C. A. Schwemm, and D. K. Garcelon. 2010. Decline and recovery of the island fox: a case study for population recovery. Cambridge University Press, Cambridge, UK.
- Davis, G. 2005. National Park stewardship and 'vital signs' monitoring: a case study from Channel Islands National Park. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15:71–89.
- Davis, G. E., K. R. Faulkner, and W. L. Halvorson. 1994. Ecological monitoring in Channel Islands National Park, California. Pages 465–482 in W. L. Halvorson and G. J. Maender (eds). *The Fourth California Islands Symposium: Update on the status of resources*. Santa Barbara Museum of Natural History, Santa Barbara, California.
- Drost, C. A., and G. M. Fellers. 1991. Density cycles in an island population of deer mice, *Peromyscus maniculatus* (Wagner). *Oikos* 60:351-364.
- Fellers, G. M., C. A. Drost, and B. A. Arnold. 1988. Terrestrial vertebrates monitoring handbook. National Park Service unpublished report, Channel Islands National Park, Ventura, California.
- Gellerman, H. 2007. Conservation of the Anacapa deer mouse: impact and recovery from an eradication. M.S. thesis. California Polytechnic State University, San Luis Obispo, California.
- Graham, T. B., and B. B. Chomel. 1997. Population dynamics of the deer mouse (*Peromyscus maniculatus*) and Sin Nombre virus, California Channel Islands. *Emerging Infectious Diseases* 3(3):367-370.
- Howald, G. R., K. R. Faulkner, B. Tershy, B. Keitt, H. Gellerman, E. M. Creel, M. Grinnell, S. T. Ortega, and D. A. Croll. 2005. Eradication of black rats from Anacapa Island: biological and social considerations. Pages 299-312 in D. K. Garcelon, and C. A. Schwemm, editors. *Proceedings of the Sixth California Islands Symposium*. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California.
- Jay, M., M. S. Ascher, B. B. Chomel, M. Madon, D. Sesline, B. A. Enge, B. Hjelle, T. G. Ksiazek, P. E. Rollin, P. H. Kass, and K. Reilly. 1997. Seroepidemiologic studies of Hantavirus infection among wild rodents in California. *Emerging Infectious Diseases* 3(2):183-190.
- Orrock, J. L., and B. F. Allan. 2008. Sin Nombre virus infection in deer mice, Channel Islands, California. *Emerging Infectious Diseases* 14(12):1965-1966.

- Orrock, J. L., B. F. Allan, and C. A. Drost. 2011. Biogeographic and ecological regulation of disease: prevalence of Sin Nombre virus in island mice is related to island area, precipitation and predator richness. *The American Naturalist* 177(5): 691-697.
- Peluc, S. I., T. S. Sillett, J. T. Rotenberry and C. K. Gahalambor. 2008. Adaptive phenotypic plasticity in an island songbird exposed to a novel predation risk. *Behavioral Ecology* 19:830-835.
- Schwemm, C. A. 1995. Terrestrial vertebrate monitoring, Channel Islands National Park, 1993 annual report. Channel Islands National Park Technical Report # 94-02. National Park Service, Channel Islands National Park, Ventura, California.
- Schwemm, C. A. 1996. Terrestrial vertebrate monitoring, Channel Islands National Park, 1994 annual report. Channel Islands National Park Technical Report # 96-03. National Park Service, Channel Islands National Park, Ventura, California.
- Schwemm, C. A. 2008. Establishment limitations and population recovery of giant coreopsis (*Coreopsis gigantea*) on the California Channel Islands. Dissertation. University of California, Santa Barbara, California.
- Schwemm, C. A., and T. J. Coonan. 2001. Status and ecology of deer mice (*Peromyscus maniculatus* subsp.) on Anacapa, Santa Barbara and San Miguel Islands, California. Channel Islands National Park Technical report 01-02. National Park Service, Channel Islands National Park, Ventura, California.
- Schwemm, C. A., and P. L. Martin. 2005. Response of nest success of Xantus' murrelet (*Synthliboranthus hypoleucus*) to native predator abundance, Santa Barbara Island, California. Pages 373-384 in D. K. Garcelon, and C. A. Schwemm, editors. Proceedings of the Sixth California Islands Symposium. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California.
- Tercek, M. T., and P. Power. 2014. Mediterranean Coast Network climate of 2012 annual report: Channel Islands National Park. Natural Resource Data Series. NPS/MEDN/NRDS—2014/697. National Park Service. Fort Collins, Colorado.
- Zwolak, R., and K. R. Foresman. 2008. Deer mouse demography in burned and unburned forest: no evidence for source-sink dynamics. *Canadian Journal of Zoology* 86:83-91.

Appendix A. Weights of Deer Mice by Age and Sex

Year	Island	Season	Grid	Age	Sex	Average Weight (g)	N	SE
2013	<i>Anacapa Island</i>	Spring	EI	A	F	26.10	5	1.568
			EI	A	M	26.00	3	2.309
		Fall	EI	A	F	22.13	16	0.573
			EI	A	M	21.84	22	0.320
			EI	J	F	8.00	1	
			EI	S	F	17.59	25	0.402
			EI	S	M	17.31	13	0.576
	<i>Santa Barbara Island</i>	Spring	TG	A	F	28.00	1	
			TG	A	M	22.00	1	
		Fall	TC	A	F	14.67	2	0.333
			TC	A	M	16.87	5	0.564
			TG	A	F	19.00	1	
			TG	S	M	15.00	1	
	<i>San Miguel Island</i>	Spring	AS	A	F	20.18	5	1.215
			AS	A	M	21.38	10	0.735
			AS	S	M	19.00	2	4.500
			NC	A	F	20.62	26	0.617
			NC	A	M	22.01	30	0.427
			NC	S	F	18.13	4	0.375
			NC	S	M	21.78	3	0.969
			WC	A	F	17.88	2	0.625
		Fall	WC	A	M	21.19	4	0.344
			AS	A	F	17.04	16	0.553
			AS	A	M	17.55	11	0.405
			NC	A	F	18.55	40	0.404
			NC	A	M	19.73	44	0.278
			NC	S	F	17.00	1	
			WC	A	F	22.60	5	1.503
			WC	A	M	21.72	10	0.873
			WC	S	M	15.00	2	1.000
2014	<i>Anacapa Island</i>	Spring	EI	A	F	19.87	77	0.431
			EI	A	M	20.67	84	0.259
			EI	J	F	12.25	4	1.010
		Fall	EI	J	M	11.00	1	
			EI	S	F	14.61	9	0.351
			EI	S	M	13.88	2	0.125
	<i>Santa Barbara Island</i>	Spring	TG	A	M	20.50	1	
		Fall	TC	A	F	17.18	18	0.488

Year	Island	Season	Grid	Age	Sex	Average Weight (g)	N	SE
			TC	A	M	18.26	20	0.528
			TC	J	F	9.75	1	
			TC	S	F	14.20	11	0.313
			TC	S	M	15.28	8	0.416
			TG	A	F	21.13	4	0.545
			TG	A	M	18.45	5	1.102
			TG	J	M	11.00	1	
			TG	S	F	13.85	6	0.593
			TG	S	M	15.17	2	0.833
	<i>San Miguel Island</i>	Spring	AS	A	F	19.10	10	0.452
			AS	A	M	21.00	11	0.421
			NC	A	F	21.02	22	0.677
			NC	A	M	22.91	29	0.326
			NC	S	F	15.25	2	1.250
			WC	A	F	23.68	6	1.678
		Fall	WC	A	M	22.19	9	0.894
			AS	A	F	16.61	14	0.623
			AS	A	M	17.38	15	0.581
			AS	S	F	15.00	1	
			NC	A	F	17.23	15	0.615
			NC	A	M	18.16	25	0.424
			NC	S	F	17.00	1	
			NC	S	M	18.00	1	
			WC	A	F	25.00	1	
			WC	A	M	23.06	3	1.396
			WC	J	M	12.00	1	
			WC	S	F	14.75	1	
			WC	S	M	18.25	2	0.750
2015	<i>Anacapa Island</i>	Spring	EI	A	F	25.67	6	0.601
			EI	A	M	24.60	29	0.289
			EI	S	M	21.75	2	1.750
	<i>Santa Barbara Island</i>	Spring	TC	A	F	24.88	15	0.987
			TC	A	M	20.57	23	0.733
			TC	J	F	11.64	11	0.434
			TC	J	M	10.25	5	1.101
			TC	S	F	17.96	7	0.902
			TC	S	M	15.40	7	0.528
			TG	A	F	23.37	12	1.692
			TG	A	M	21.10	13	0.346
			TG	J	F	12.02	5	0.747

Year	Island	Season	Grid	Age	Sex	Average Weight (g)	N	SE
			TG	J	M	12.93	6	0.660
			TG	S	F	14.42	3	1.516
			TG	S	M	14.00	3	0.500
	<i>San Miguel Island</i>	Spring	AS	A	F	24.51	6	1.479
			AS	A	M	22.33	6	0.646
			AS	J	F	12.50	3	0.289
			AS	J	M	12.00	2	1.000
			AS	S	M	19.33	1	
			NC	A	F	23.73	24	0.606
			NC	A	M	24.40	29	0.329
			NC	S	M	16.50	1	
			WC	A	F	22.25	4	1.051
			WC	A	M	24.69	4	1.320

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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