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Notes from the Editor

Welcome to this somewhat-belated issue of *California Fish and Game*; the delay is the result of expired printing contracts, end-of-year account closures, and shifting of accounts from the previous (2012 – 2013) to the current (2013 – 2014) fiscal year. Budget policies and regulations precluded publication of this issue prior to 1 July.

The Editor-in-Chief has submitted an application to the Library of Congress for an International Standard Serial Number (ISSN) to be assigned to the new electronic version of *California Fish and Game*, and is anxiously awaiting that information. In the future, print and electronic versions each will include ISSNs for both formats. Assignment of a separate ISSN to the electronic format of the journal is necessary, and will enhance the efficacy of literature search services that currently include titles of papers published in *California Fish and Game*. Those international services provide information on the contents of each issue of the journal on a world-wide basis. As a result, papers published in *California Fish and Game* are announced in the same manner and with the type of international notification as papers published in more widely known journals, such as *Ecology* or *Nature*. Thus, material published in *California Fish and Game* is not "buried" in the literature, but is available world-wide to international researchers almost immediately upon publication.

Due to the recent retirement of an Associate Editor, and the potential for another to resign due to the expanding responsibilities of his new position, I am inviting individuals that are interested in serving on the journal staff to contact me. Specifically, I will be seeking individuals whose strengths are in the fields of natural history, botany, plant ecology, or avian ecology. Thank you in advance for considering an opportunity to become part of the editorial staff of California's longest-running professional journal, *California Fish and Game*. Volume 100 will appear in 2014.

Vernon C. Bleich, *Editor-in- Chief*

California Fish and Game 99(2):65-79; 2013

Home range and habitat use by desert mule deer in altered habitats

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Alterations of desert mule deer (*Odocoileus hemionus eremicus*) habitat in Sonora, Mexico include overgrazing by livestock, additions of water sources, and transformation of desert scrub into pastures of exotic buffelgrass (*Cenchrus ciliaris*). No previous research has been conducted to understand how mule deer respond to these alterations. We studied radiocollared mule deer from April 2002-June 2004 to evaluate home range sizes and habitat use of altered habitats in central and western Sonora, Mexico. Sizes of home ranges were larger in the more arid environments of western Sonora (27.3 km^2 ± 2.6 [*SE*]) than in central Sonora (14.5 km^2 ± 2.0 [*SE*]). During summer, mule deer home ranges were smaller than in any other season in western and central Sonora. There was no statistical difference in the size of home ranges of mule deer in areas with buffelgrass when compared to the size of home ranges of deer using native scrub vegetation. Desert mule deer did not use the vegetation associations in proportion to their availability, but selected xeroriparian vegetation and sites closer to water in both areas. Thermal cover was greater at deer sites than random sites in most seasons. Vegetation cover was greater and gravel cover less at mule deer locations on one area in one season. Desert mule deer used altered areas with buffelgrass; however, they selected sites with larger amount of shrubs or trees that supplied thermal cover. Researchers and managers should focus conservation efforts to identify threshold limits of altered habitats, determine differences in mule deer densities, and evaluate productivity and survival rates of desert mule deer in relation to those alterations.

Key words: buffelgrass, *Cenchrus ciliaris*, habitat, Mexico, mule deer, *Odocoileus hemionus*, Sonora, water sources

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Desert mule deer (*Odocoileus hemionus eremicus*) are an important big game species in North America and inhabit parts of the Sonoran and Chihuahuan deserts in the southwestern United States and northwestern Mexico (Heffelfinger 2000, 2006). Population trends, productivity, and performance of mule deer have been well documented in the United States (Kie and Czech 2000, Avey et al. 2003). On the contrary, there is a lack of literature on the status or trend of mule deer populations, and on condition of mule deer habitat in Mexico.

The central and western regions of Sonora, Mexico have distinctive biotic characteristics (Brown 1994). In addition, landscapes in these regions have been altered to enhance cattle management (Camou-Healy 1994). Alterations to the habitat of desert mule deer include transformation of the desert scrub into pasture for exotic buffelgrass (*Cenchrus ciliaris*), overgrazing by livestock, and establishment of artificial sources of water.

Buffelgrass was introduced into the Southwest to stabilize soil against erosion (Martin et al. 1998) and provide additional forage for cattle (Holt 1985). This exotic graminoid dominates indigenous grasses (Ibarra et al. 1995). By the early 1990s, buffelgrass was present in 10% (1,200,000 ha) of Sonoran rangeland (Yetman and Burquez 1994) and there are estimates that buffelgrass occurs on >1,600,000 ha (Burquez-Montijo et al. 2002) of rangeland. In fact, the conditions of desert mule deer habitat in Sonora have been modified to favor cattle production since the 1960s. About 20% of the mule deer range in Sonora has been altered by shrub-removal, and then establishing buffelgrass pastures. There is no primary literature showing the effect of these habitat alterations on mule deer.

The objectives of our study were to (1) determine home range sizes of desert mule deer, and differences among seasons and areas of central and western Sonora that have been altered with plantations of buffelgrass; (2) determine the use of natural and altered components of habitat by desert mule deer; and, (3) identify differences in the characteristics between selected sites and random sites in altered habitat of desert mule deer.

MATERIALS AND METHODS

Study areas.—This study was conducted in 2 areas of the Lower Sonoran Desert in the central and western Sonora, Mexico (Figure 1). The first area included Rancho La Jubaivena and adjacent lands. This area is located 54 km north of Hermosillo in the central region of Sonora (29° 34' and 29° 41' N, 111° 12' and 111° 18' W; CETENAL 1974). Size of the area was 24,155 ha and elevations ranged from 500–650 m. Average annual precipitation was 320 mm (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). Precipitation was bimodally distributed: approximately 60% occurred between July and September, and about 40% occurred between November and March. The remaining months usually were dry. Summer rainfall occurred as thunderstorms that were frequently localized, and were of high intensity. Annual mean temperature was 23°C. Daytime temperatures averaged 34°C, but frequently exceed 40°C in June through August. Night-time temperatures averaged 8°C in winter, and approached 0°C in December, January, and February.

Vegetation was representative of the arbosuffrutescent desert scrub in the Plains of Sonora Subdivision of the Sonoran Desert (Shreve and Wiggins 1964, Brown 1994). We followed Shreve and Wiggins (1964) for scientific nomenclature and United States Department of Agriculture–National Resources Conservation Service PLANTS database, Version 3.5 (http://plants.usda.gov) for common names of plants. Shrubs and small to

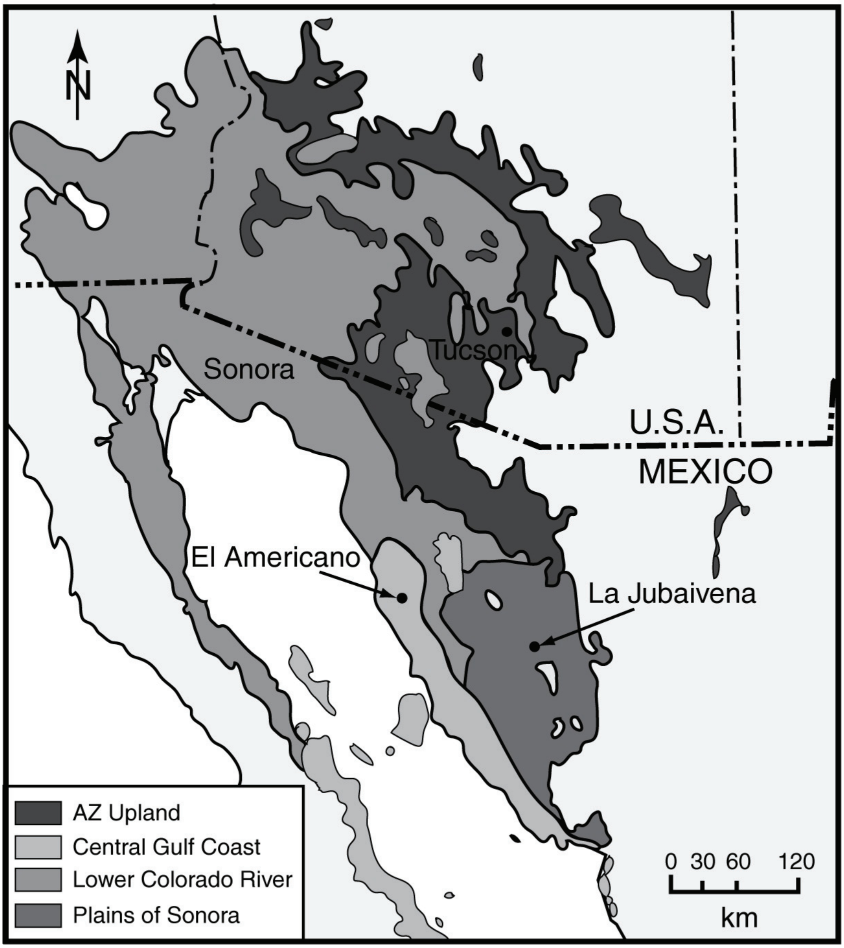

FIGURE 1.—Locations of the study areas for analyses of home range and habitat use in altered habitats by desert mule deer, central and western Sonora, Mexico, 2002–2004.

medium sized trees dominated overstory vegetation. Common species were ironwood (*Olneya tesota*), mesquite (*Prosopis velutina*), paloverde (*Parkinsonia* spp.), bird-of-paradise (*Caesalpinia pumila*), brittle bush (*Encelia farinosa*), snakewood (*Condalia* spp.), and catclaw mimosa (*Mimosa laxiflora*). Understory vegetation was represented by perennial herbaceous species including tidestromia (*Tidestromia lanuginosa*), milkweeds (*Euphorbia* spp.), and grasses including false grama (*Bouteloua diversispicula*), spidergrass (*Aristida ternipes*), sixweeks threeawn (*Aristida adscensionis*), false sideoats (*Bouteloua reflexa*) and bristlegrass (*Setaria macrostachya*). Cacti were present, but sparse. Common cacti were organ pipe cactus (*Stenocereus thurberi*), and chainfruit cholla (*Opuntia fulgida*). The core of the study area comprised 10,500 ha of native arbosuffrutescent scrub surrounded by buffelgrass pastures. Native vegetation has been severely grazed (Holechek and Galt 2000) by cattle. Understory vegetation was scarce and bare ground appeared on extensive areas where erosion was evident. We identified 4 major vegetation associations: mesquite – bird-of-paradise – xeroriparian, ironwood – brittle bush – plains, elephant tree (*Pachycormus discolor*) – catclaw mimosa – foothills, and buffelgrass pastures in the study area (Figure 2).

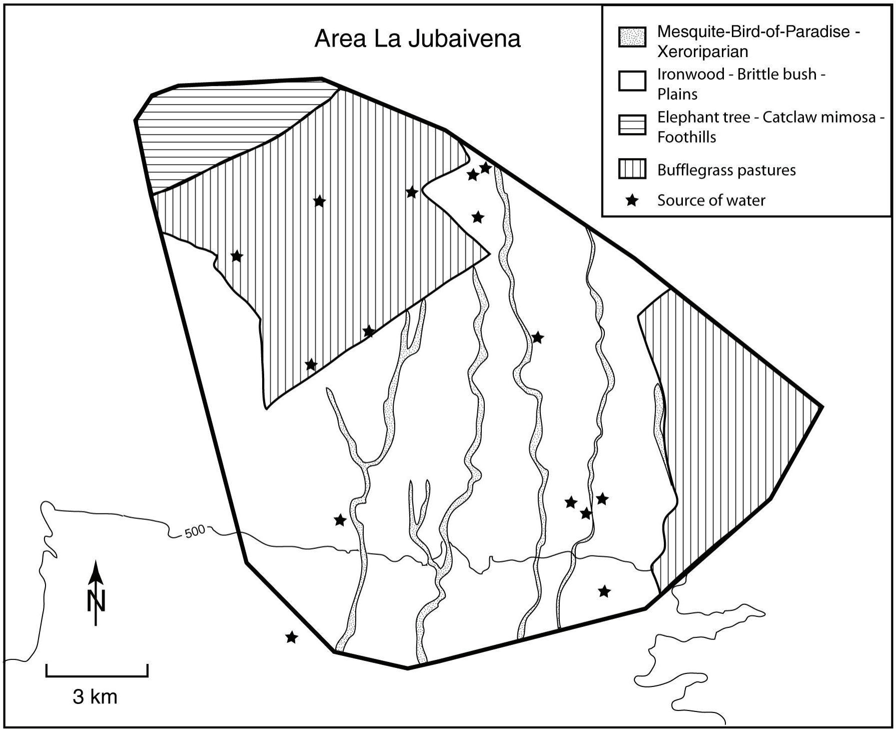

FIGURE 2.—Vegetation associations and location of water sources available to desert mule deer in the La Jubaivena study area, central Sonora, Mexico, 2002–2004.

The second area included Rancho El Americano and adjacent lands. This ranch was located 25 km north of Puerto Libertad in Pitiquito, Sonora, (30° 00' and 30° 17' N, 112° 17' and 112° 43' W). This area encompassed 83,000 ha where physiognomic and vegetation characteristics represent 2 of the subdivisions of the Sonoran Desert. The southern and western portions of the area of study were coastal plains inclined to the sea that were part of the Central Gulf Coast Subdivision of the Sonoran Desert (Shreve and Wiggins 1964, Brown 1994). The central and northern portions of Rancho El Americano were coastal plains that merged into rough terrain and northern plains characteristic of the Lower Colorado River Valley Subdivision (Shreve and Wiggins 1964, Brown 1994). Elevation ranged from 150-500 m in coastal plains and from 500–750 m in desert mountain ranges (i.e., Sierra Aguirre and Sierra Picu). Precipitation was bimodal, with 70% occurring in summer months. Average annual precipitation was 180 mm. Annual mean temperature was 23°C.

Vegetation in coastal plains was characteristic of the sarcocaulescent desert scrub and vegetation in foothills and northern plains was microphyllous desert scrub (Shreve and Wiggins 1964, Brown 1994). Common plants in the sarcocaulescent desert scrub included elephant tree, bursera (*Bursera hindsiana*), limberbush (*Jatropha cuneata*, *J. cinerea*), creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), and brittle bush, and the cacti etcho (*Pachycereus pringlei*), chainfruit cholla and teddy bear cholla (*Opuntia bigelovii*).

Microphyllous desert scrub in foothills and northern plains included creosote bush, ocotillo (*Fouquieria splendens*), paloverde (*Parkinsonia florida*, and *P. microphylla*), triangleleaf bursage (*Ambrosia deltoidea*), burrobush, brittle bush, and limberbush. Common cacti were organ pipe cactus, saguaro (*Carnegia gigantea*), barrel cactus (*Ferocactus acanthodes*) and teddy bear cholla. Small and localized areas converted to buffelgrass represented 1% of the study area. Performance and natural dispersion of buffelgrass was limited in the area because of lower precipitation. We identified 6 major vegetation associations in this area: mesquite – ironwood – xeroriparian, elephant tree – limberbush – northern foothills, creosote bush – paloverde – hills, creosote bush – bursage – plains, creosote bush – etcho – coastal plains, and buffelgrass pastures (Figure 3).

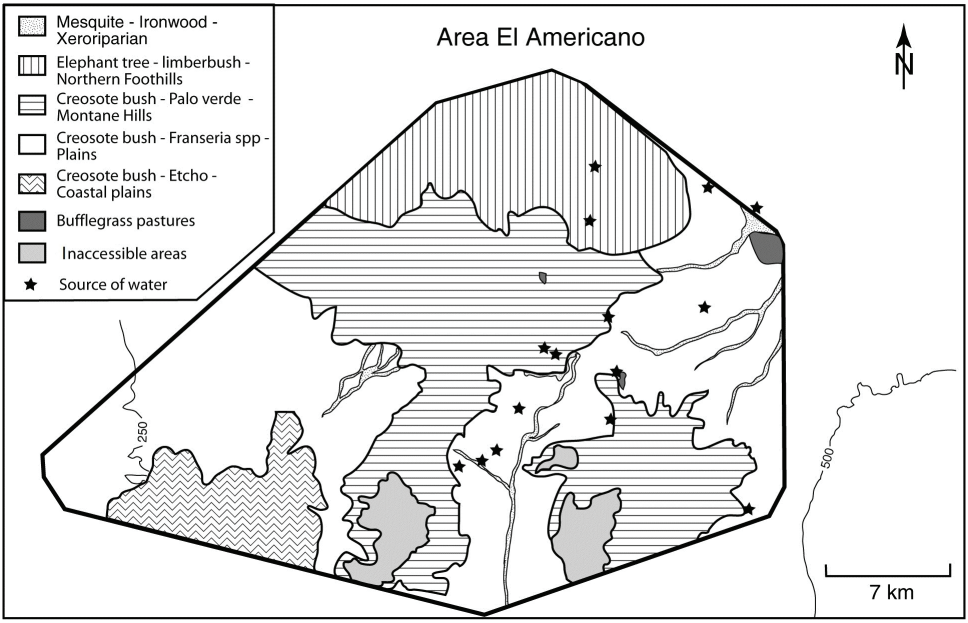

FIGURE 3.—Vegetation associations and location of water sources available to desert mule deer in the El Americano study area, western Sonora, Mexico, 2002–2004.

Cattle grazing was a common practice year-round in both areas, but stocking rates were lower in El Americano, where rangeland offered a comparatively reduced amount of forage for livestock. Free standing water (15 sources in each area) was available for desert mule deer. Large- and medium-sized mammals other than mule deer and cattle present in both areas included Coues white-tailed deer (*Odocoileus virginianus couesi*), collared peccary (*Pecari tajacu*), mountain lion (*Puma concolor*), coyote (*Canis latrans*), antelope jackrabbit (*Lepus alleni*), and desert cottontail (*Sylvilagus audubonii*). Feral burros (*Equus asinus*) and black-tailed jackrabbits (*Lepus californicus*) were also present in El Americano.

We determined seasons for our study areas from bimodal precipitation and temperature regimes (Krausman 1985). The seasons were cold-wet (winter: January–March), hot-dry (spring: April–June), hot-wet (summer: July–September), and cold-dry (autumn: October–December).

Methods.—We captured adult female mule deer in April 2002 with a net-gun fired from a helicopter (Krausman et al. 1985). We attached VHF radiocollars (MOD-500) with mortality sensors (S6A, 4 h; Telonics, Mesa, Arizona) to the neck of each animal. We monitored marked deer from April 2002–June 2004. Ground locations involved visual contact of radiocollared mule deer and were made ≥4 times each month (i.e., we attempted to locate each deer once a week) using a Model TR-2 receiver and hand-held H-antennas (model RA-1AK, Telonics, Mesa, Arizona). We made aerial locations 1 time/month from a Cessna 182 aircraft equipped with a Model TR-2 receiver, an antenna switch selector, and directional H-antennas (model RA-2AK, Telonics, Mesa, Arizona) mounted on each wing strut. We assumed aerial location error of 200 m and followed recommendations in aerial tracking according to Krausman et al. (1984). We determined geographic coordinates of all locations of mule deer with a Geographic Position System (eTrex, Garmin, Olathe, Kansas, USA) and plotted each one on cartographic images using ArcView 3.2 (Environmental Systems Research Institute 1996). When mule deer were located from the ground, we recorded information on the vegetation association. For ≥20% of locations in every season we evaluated plant composition, thermal cover (i.e., vegetation ≥75 cm high that provided shade for a deer), and ground cover (i.e., percent of ground covered by organic litter), gravel (i.e., rocks <25 mm in diameter), and stones (i.e., rocks ≥25 mm in diameter). Locations for vegetation measurements represented the proportional amount of time deer spent in each vegetation association (i.e., if an association made up 25% of the area, 25% of vegetation measurements were obtained in that area). We used the point intercept method (Heady et al. 1959) and measured vegetation along a 40-m line centered at mule deer locations. We determined the direction of the line randomly. For comparison, we randomly selected a paired location 100 m from the selected location and collected data in the same manner. We used logistic regression to compare site characteristics between selected and random locations. We discriminated site characteristics with $P > 0.10$, and conducted comparisons using Wilcoxon tests.

We calculated home range of desert mule deer during each season in both study areas. We used the minimum convex polygon (MCP) through the MCP extension in ArcView 3.2. We followed established procedures (Mares et al. 1980) to obtain an adequate number of locations and minimize bias. We compared home range sizes among seasons and study areas using Wilcoxon and Kruskal-Wallis tests.

The area of every vegetation association was calculated with ArcView 3.2. We used chi-square contingency table analyses to test the null hypothesis that mule deer used vegetation associations in proportion to their availability (Neu et al. 1974, Byers et al. 1984) by comparing the total number of observations of deer in each study area with the total area of each vegetation association. When we found a difference ($P \leq 0.05$) between expected and observed use, we calculated Bonferroni confidence intervals to determine whether percentage use of each vegetation association was significantly greater or less than its percentage availability (Neu et al. 1974, Byers et al. 1984). We plotted individual selection variability (Thomas and Taylor 1990) for each vegetation association in both study areas.

We used ArcView 3.2 to calculate distance of every deer location to the nearest source of water. We generated the same number of random locations and determined if deer locations were closer to water sources than random points. We used analysis of variance with Tukey-Kramer (Honestly Significant Difference) tests ($P < 0.05$) for comparisons between areas and among seasons.

RESULTS

We captured and collared 19 female mule deer in La Jubaivena and 14 female mule deer in El Americano. We obtained 1,175 locations of radiocollared mule deer in La Jubaivena and 829 locations of radiocollared mule deer in El Americano. We calculated seasonal home ranges for each deer that had ≥14 locations/season. Access to both areas was restricted during winter due to hunting, and we did not have enough data to calculate home ranges in winter for La Jubaivena. Overall, sizes of annual home ranges were larger in El Americano (27.3 km^2 ± 2.6 [*SE*]) than La Jubaivena (14.5 km^2 ± 2.0 [*SE*]) (Kruskal-Wallis $\chi^2_6 = 17.98$, $P = 0.006$). During summer, mule deer home ranges were smaller ($P < 0.05$) than any other season in both areas (Table 1). There was no difference ($P > 0.05$) in sizes of mule deer home ranges between spring (6.0 km^2) and autumn (7.6 km^2) in La Jubaivena. Conversely, home range sizes in winter (12.3 km^2) and spring (10.1 km^2) were larger ($P < 0.05$) than summer (5.1 km^2) and autumn (6.9 km^2) in El Americano (Table 1).

TABLE 1.—Seasonal home ranges (km^2) of desert mule deer in central and western Sonora, Mexico, 2002–2004.

	Study areas							
	La Jubaivena, Sonora, Mexico [a]				El Americano, Sonora, Mexico			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Mean	---	6.04	4.45 [b]	7.63	12.31	10.08	5.06[b]	6.92
SE	---	0.75	0.55	0.85	3.02	2.41	0.48	2.07
Range	---	1.3 - 11.2	1.3 - 8.7	2.4 - 15.2	1.3 - 36.6	3.6 - 32.3	3.1 - 9.1	2.1 - 14.3
No. animals	---	18	18	17	11	11	13	6
No. locations	---	334	286	321	172	236	262	84

[a] Home range sizes were different between areas (Kruskal-Wallis $\chi^2 = 17.98$, 6 *df*, $P = 0.006$).

[b] Statistically different ($P < 0.05$) among seasons in the same area.

During capture operations in La Jubaivena, 4 of 19 deer were captured inside buffelgrass pastures. These animals were subsequently located 235 times. All but 2 locations were inside the perimeters of the buffelgrass plantations. Therefore, we compared the home ranges of the deer inside buffelgrass areas to the rest of the collared mule deer in La Jubaivena. There was no difference (Kruskal-Wallis, $\chi^2_1 = 0.28$, $P = 0.60$) in the size of home ranges of mule deer from inside buffelgrass areas (5.16 km^2 ± 0.95 [*SE*]) when compared with the size of home ranges of the other collared deer (6.16 km^2 ± 0.51[*SE*]) in La Jubaivena.

We determined the boundaries of each study area by connecting all the outermost locations of collared deer and adding a zone of half the mean traveled distance registered between individual locations, and used that information to examine habitat use. We defined 24,155 ha for La Jubaivena (Figure 2) and 83,036 ha for El Americano (Figure 3). Buffelgrass made up 32 and 1% of the study areas in La Jubaivena and El Americano, respectively (Table 2 Table 3).

Table 2.—Utilization-availability of vegetation associations used by desert mule deer in the La Jubaivena study area, western Sonora, Mexico, 2002–2004.

Vegetation association	Total area (ha)	Relative area (%)	Expected usage	Observed usage	$(\text{Obs-Exp})^2 \div \text{Exp}$	Bonferroni 95% C.I.		Degree of selection
						lower	upper	
Prju-Capu [a]	884	4	43.00	196	544.3667	0.1396	0.1940	(++) S [e]
Olte-Enfa [b]	14,382	60	699.60	698	0.0037	0.5583	0.6298	(-+)
Busp-Mila [c]	1,199	5	58.32	2	54.3929	0.0000	0.0047	(--) A
Buffelgrass [d]	7,690	32	374.07	279	24.1637	0.2064	0.2685	(--) A
Total	24,155	100	1,175	1,175				

[a] Mesquite – bird-of-paradise – Xeroriparian; [b] Ironwood - brittlebush - Plains; [c] Elephant tree - catclaw mimosa - Foothills; [d] Buffelgrass pastures; [e] (++) S = used > expected, (--) A = used < expected, (-+) = used as expected.

Table 3.—Utilization-availability of vegetation associations used by desert mule deer in the El Americano study area, central Sonora, Mexico, 2002–2004.

Vegetation association	Total area (ha)	Relative area (%)	Expected usage	Observed usage	$(\text{Obs-Exp})^2 \div \text{Exp}$	Bonferroni 95% CI		Degree of selection
						lower	upper	
Prju-Capu [a]	1,050	1	10.48	63	263.1029	0.0517	0.1003	(++) S [g]
Busp-Jacu [b]	12,679	15	126.58	64	30.9407	0.0527	0.1017	(--) A
Latr-Cemi [c]	26,350	32	263.07	200	15.1201	0.2021	0.2805	(--) A
Latr-Frsp [d]	36,535	44	364.75	493	45.0941	0.5497	0.6397	(++) S
Latr-Papr [e]	5,915	7	59.05	5	49.4765	0.0000	0.0131	(--) A
Buffelgrass [f]	507	1	5.06	4	0.2227	0.0000	0.0112	(-+)
Total	83,036	100	829	829				

[a] Mesquite - ironwood - Xeroriparian; [b] Elephant tree - limber bush - Northern foothills; [c] Creosote bush - paloverde - Hills; [d] Creosote bush - *Franseria* spp. - Plains; [e] Creosote bush - etcho - Coastal plains; [f] Buffelgrass pastures; [g] (++) S = used > expected, (--) A = used < expected, (-+) = used as expected.

Desert mule deer did not use the vegetation associations in proportion to their availability in either study area ($P < 0.001$; Table 2, $\chi^2_3 = 622.9$; Table 3, $\chi^2_5 = 404.0$). In general, desert mule deer selected xeroriparian vegetation in both areas throughout the study (Table 2, Table 3). Vegetation association in plains next to xeroriparian areas was also selected in El Americano (Table 3), and used in proportion to availability in La Jubaivena (Table 2). The buffelgrass area was avoided in La Jubaivena, and used in proportion to availability in El Americano.

The mesquite – bird-of-paradise – xeroriparian association was selected during all seasons in La Jubaivena (Table 4; $\chi^2_3 = 11.1$). The elephant tree – catclaw mimosa – foothills association was consistently avoided. The ironwood – brittlebush – plains association was used in proportion to availability in all seasons. Buffelgrass areas were avoided in most seasons except on summer, when they were used in proportion to availability (Table 4).

In El Americano, the mesquite – ironwood – xeroriparian association was also selected during all seasons (Table 5). The creosote bush – bursage – plains association was selected in spring and summer, and was used in proportion to availability during autumn and winter. The creosote bush – etcho – coastal plains association was consistently avoided during all seasons. The elephant tree – limberbush – northern foothills association was avoided during spring and summer, but was used in proportion to availability during autumn

Table 4.—Selection (S) and avoidance (A) of vegetation associations by desert mule deer in the La Jubaivena study area, western Sonora, Mexico, 2002–2004.

			Vegetation association			
Season	χ^2	No. locations	Prju-Capu [a]	Olte-Enfa [b]	Busp-Mila [c]	Buffelgrass [d]
Winter	30.57	174	S[e]	--	A	A
Spring	51.33	255	S	--	A	A
Summer	50.46	267	S	--	A	--
Autumn	100.18	133	S	--	A	A

[a] Mesquite – bird-of-paradise – Xeroriparian; [b] Ironwood - brittlebush - Plains; [c] Elephant tree - catclaw mimosa - Foothills; [d] Buffelgrass pastures; [e] S = used > expected, A = used < expected, (--) = used as expected.

Table 5.—Selection (S) and avoidance (A) of vegetation associations by desert mule deer in the El Americano study area, central Sonora, Mexico, 2002–2004.

			Vegetation association					
Season	χ^2	No. locations	Prju-Capu [a]	Busp-Jacu [b]	Latr-Cemi [c]	Latr-Frsp [d]	Latr-Papr [e]	Buffelgrass [f]
Winter	74.49	332	S [g]	--	--	--	A	A
Spring	54.75	171	S	A	--	S	A	--
Summer	61.97	361	S	A	A	S	A	--
Autumn	27.78	311	S	--	--	--	A	--

[a] Mesquite - ironwood - Xeroriparian; [b] Elephant tree - limber bush - Northern foothills; [c] Creosote bush - paloverde - Hills; [d] Creosote bush - franseria spp. - Plains; [e] Creosote bush - etcho - Coastal plains; [f] Buffelgrass pastures; [g] S = used > expected, A = used < expected, (--) = used as expected.

and winter. Buffelgrass areas were used in proportion to availability in most seasons, with the exception of winter when these areas were avoided (Table 5). Individual mule deer had access to all associations, and showed a high variation in their preferences for vegetation associations in both study areas (Figure 4, Figure 5).

From the logistic regression analyses, we identified thermal cover (estimate = -0.15 ± 0.049, $\chi^2 = 9.3$, $P = 0.002$), ground cover (estimate = -0.06 ± 0.036, $\chi^2 = 2.4$, $P = 0.09$), and percentage of gravel covering the substrate (estimate = 0.03 ± 0.018, $\chi^2 = 2.93$, $P = 0.08$) as the variables that distinguished ($P < 0.10$) locations selected by desert mule deer when compared to random locations. These habitat characteristics varied between areas and among seasons (Table 6).

Consistently, thermal cover was higher ($P < 0.05$) in locations selected by mule deer when compared to random locations in both areas. Thermal cover inside buffelgrass areas (10.5%) was significantly lower ($P < 0.05$) than in locations outside buffelgrass areas (18.4%). Thermal cover was highest in summer in La Jubaivena and highest in autumn in El Americano (Table 6).

With the exception of winter in La Jubaivena, ground cover was higher at sites selected by mule deer than in random locations during all seasons in both areas of study. However, the only significant difference ($P < 0.05$) in ground cover occurred during winter (26.5%) at El Americano.

Table 6.—Differences in thermal cover (TC), ground cover (GC), and percentage of gravel covering the ground (Gr) between selected and random sites for desert mule deer in central and western Sonora, Mexico, 2002–2004.

	Selected			Random		
Season and area	TC	GC	Gr	TC	GC	Gr
Winter						
La Jubaivena	10.9*	33.6	4.7	7.0	45.0	5.9
El Americano	19.8	26.5*	23.8	11.2	10.9	35.1
Spring						
La Jubaivena	18.5*	24.3	0.0	3.5	21.0	0.0
El Americano	12.9*	19.5	7.8*	4.1	15.9	22.7
Summer						
La Jubaivena	27.9*	31.5	0.0	12.8	27.7	0.0
El Americano	16.4*	22.3	10.3	6.9	20.5	16.9
Autumn						
La Jubaivena	18.9	28.9	0.0	14.6	26.7	0.0
El Americano	23.5*	15.3	9.3	10.9	14.9	13.5

* Indicates difference ($P < 0.05$) between selected and random sites for the same characteristic.

The presence of gravel in La Jubaivena was detected only in random and selected sites during winter. Percentage of gravel for that area and season was not significantly different ($P > 0.05$). Gravel was present at all sites (i.e., both random and selected sites) at El Americano. Percentage of gravel was lower at selected locations than at random locations during all seasons in that area; however, a significant difference ($P < 0.05$) was reported at selected locations (7.8%) when compared to random locations (22.7%) during spring.

We obtained 1,175 and 829 locations of desert mule deer in La Jubaivena and El Americano, respectively to examine the relationships of deer to the distance to water sources. The average distance of desert mule deer to the nearest source of water was closer ($P < 0.05$) in every season throughout the study than were random locations. At La Jubaivena, mean distances of desert mule deer to nearest water were 1.9 ± 0.07, 1.5 ± 0.05, 1.7 ± 0.05, and 2.0 ± 0.05 km in winter, spring, summer, and autumn, respectively. Distances to a nearest source of water were closer ($P < 0.05$) during spring and summer than during other seasons.

In El Americano, mean distances of desert mule deer to the nearest source of water were 3.5 ± 0.22, 2.4 ± 0.19, 2.1 ± 0.18, and 2.6 ± 0.26 km in winter, spring, summer and autumn, respectively. Mean distance to the nearest water source was less during summer than during any other season, not significantly different ($P > 0.05$) from spring or autumn. During winter, the mean distance to the nearest source of water was larger ($P < 0.05$) than during any other season.

DISCUSSION

Home range size and movements of desert mule deer are influenced by season, habitat, and other factors inherent to the species (Mackie et al. 1982, Anderson and Wallmo 1984, Heffelfinger 2006). Home range size increases as the distance between necessary resources increases. Mackie et al. (1982) reported home ranges in semi-desert ranges as large as 21 km^2. However, in arid environments home ranges are as large as 8 times that reported by Mackie et al. (1982). Studies in southern Arizona have reported home ranges for desert mule deer ranging from 121 to 172 km^2 (Krausman 1985, Rautenstrauch and Krausman 1989).

Overall in our study, sizes of home ranges were larger in El Americano than in La Jubaivena. El Americano in western Sonora receives lower precipitation and has scarce vegetation when compared to La Jubaivena in central Sonora. Our findings agree with the statements that in more arid environments the mule deer exhibit larger home ranges to obtain their necessary resources (Fox and Krausman 1994, Krausman and Etchberger 1995). During summer, desert mule deer home ranges were smaller than during any other season in both of our study areas. Similar results were obtained by Fox and Krausman (1994), and Krausman and Etchberger (1995) for female mule deer from western Arizona. There were no differences in sizes of home ranges between spring and autumn at La Jubaivena. Conversely, home range sizes in winter and spring were larger than summer and autumn in El Americano. Our results were consistent with the sizes of home ranges reported for mule deer in the Belmont and Big Horn mountains, Arizona (Fox and Krausman 1994).

Buffelgrass areas comprised >30% of the study area at La Jubaivena. Mule deer inhabit those areas all year. There was no difference in the size of home ranges of mule deer inside buffelgrass areas when compared to the size of home ranges of the other collared mule deer. No previous documentation is available with which to compare our results. Plantations of buffelgrass have been present since the 1980s. Although most shrubs and trees were removed in preparation for seeding buffelgrass, a combination of trees and shrubs is present that provides enough resources for some mule deer to stay in those areas.

Desert mule deer selected xeroriparian vegetation and the adjacent plains were selected or used in proportion to availability during spring and summer (warmer seasons) in both areas throughout the study. Tree and shrub cover in those selected areas provide thermal shelter for desert mule deer, especially for pregnant or lactating females. Similar observations were made by Fox and Krausman (1994), who reported that females selected areas with vegetation to protect their fawns from predators and temperature extremes. Tull et al. (2001) also reported that desert mule deer selected bed sites in areas of relatively high thermal cover in all seasons.

Our data indicated that buffelgrass areas were avoided or used in proportion to availability, but were never selected. However, individual variability in proportion of habitat use minus proportion of availability suggests that mule deer selected home ranges with no regard to the availability of buffelgrass pastures. We suggest that the level of reduction in thermal cover and browse in buffelgrass areas does not constrain use of these areas by female mule deer. Four of the 19 collared deer in central Sonora exhibited annual home ranges completely inside buffelgrass areas, even though they had access to the other associations. The home ranges of four other collared deer, which were captured outside buffelgrass areas, included the same buffelgrass areas; one of those was located 48% of the time inside buffelgrass pastures.

Our data also indicate that desert mule deer selected sites closer to water sources than were random locations. Free-standing water was probably the reason that some mule deer stayed in buffelgrass areas. Water has been considered an important limiting factor for desert mule deer (Leopold and Krausman 1991). The amount and distribution of water sources affect the distribution of mule deer in arid environments (Marshal et al 2006). In the southwestern United States, mule deer are usually found within 2.4 km of free water (Hanson and McCulloch 1955, Swank 1958, Boroski and Mossman 1996). Some studies in the desert areas of southwestern Arizona and California reported similar observations where mule deer were significantly closer to water sources during summer (Hervert and Krausman 1986, Ordway and Krausman 1986, Krausman et al. 1989, Rautenstrauch and Krausman 1989, Krausman and Etchberger 1995, Marshal et al. 2005). Ranching has been the main activity in the rangelands of Sonora, Mexico since 1950. Thus, water sources for cattle have been established throughout areas occupied by desert mule deer. Additionally, recent interest by ranchers in managing wildlife populations has added more water sources to mule deer habitat.

We could not conclude that desert mule deer use areas altered with buffelgrass differed from areas without buffelgrass. Our data suggest that desert mule deer used altered areas with buffelgrass, but selected sites with higher thermal cover and that were closer to water sources.

Conditions for desert mule deer in the rangelands of Sonora are different than conditions in other regions of their distribution. Cattle grazing, removal of scrub vegetation, introduction of exotic forages, and the number of artificial water sources have obviously altered natural interactions among mule deer and their habitat. Undoubtedly, the reduction of cover and forage in arid environments represent a major concern for conservation of desert mule deer. Managers should recognize that even in altered habitats, mule deer use areas having cover and forage provided by trees and shrubs. Thus, it is very important to minimize extensive transformation of new areas into open grasslands. Another major concern should be the potential risk of wild fires when increasing buffelgrass stands. Areas where buffelgrass is not grazed may accumulate large loads of dry fuel that cause fires of high intensity. These fires destroy cacti, shrubs, and trees that provide important food and cover for mule deer. It also is important to continue with more research to quantify the level of those alterations, and to further evaluate the performance of mule deer inhabiting the Sonoran Desert. Research and adaptive management should focus on identifying threshold limits of altered habitats, determining differences in mule deer densities, and evaluating the productivity and survival rates of desert mule deer in relation to those alterations.

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An ectoparasitic snail (*Evalea tenuisculpta*) infects red abalone (*Haliotis rufescens*) in northern California

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We document the presence of the ectoparasitic fine-sculptured odostome snail (*Evalea tenuisculpta*) on red abalone (*Haliotis rufescens*) in northern California. Red abalone form the basis for an important recreational fishery north of San Francisco. We found that 82% of the red abalone examined from three sites (*n*=73) in Sonoma County had these small snail parasites. We document that the parasitic snails also infects northern abalone (*H. kamtschatkana*). Infected red abalone had an average of 12 parasitic snails, averaging 4.8mm in length (range 1.0 to 8.8 mm) on their shell. In the laboratory, starved parasitic snails presented with live abalone elongated their proboscis to feed. Over three days, parasitic snails (85%) laid at least one egg mass, with larger snails laying more egg masses (containing more eggs) than smaller snails. Egg masses averaged 360 eggs per mass. More work is needed on the biology of this parasitic snail to determine its impacts on abalone, abalone populations, and the abalone fishery.

Key words: California, ectoparasite, *Evalea tenuisculpta*, *Haliotis rufescens*, *Haliotis kamtschatkana,* Odostomidae, Pyramidellidae

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There is growing evidence that parasitic gastropods in the family Pyramidellidae can have significant effects on mollusk fisheries (Wilson et al. 1988) and aquaculture (Cumming 1988), but little is known about the prevalence of pyramidellids on their hosts. These snails are small marine ectoparasites that feed on mollusc and polychaete hosts (McLean 2007). Economically important bivalves such as the American oyster (*Crassostrea virginica*) and the giant clam (*Tridacna gigas*) have experienced shell malformation, lower growth rates, increased mortality, and increased transmission of bacterial disease in response to pyramidellid infestation (Boglio and Lucas 1997, Wilson et al. 1988). Pyramidellids derive nutrients from their host by piercing the body wall with an acrembolic proboscis and sucking blood or tissue by means of a buccal pump (radula is lacking) (Fretter and Graham 1949). These small snails (commonly <5 mm in length) are cross-fertilizing, simultaneous hermaphrodites (Mclean 2007, Robertson 2012). This method of reproduction eliminates the necessity of finding a mate of the opposite sex for fertilization and can increase the reproductive potential of the parasites. While a few species of pyramidellids from California have been identified, literature on their biology and host associations is scarce.

The fine-sculptured odostome snail (*Evalea tenuisculpta*; Carpenter 1864) in the subfamily Odostomiinae has been observed in intertidal and shallow subtidal habitats from Alaska to Baja California (Abbott 1974). It has been described as a parasite on scallops, chitons, clams, mussels, and abalone (Harbo et al. 2012), but little is known about its distribution, behavior, or life history. The systematics of the fine sculptured odostome snail is poorly understood. Formerly known as *Odostomia tenuisculpita,* this snail has had more than 15 different synonyms (Abbott 1974). More study is needed on living pyramidellid snails to understand their relationship with host mollusks.

The red abalone (*Haliotis rufescen*s) forms the basis for an important recreational fishery in northern California. On average 260,000 red abalone are fished each year by 36,000 fishermen, who support the local coastal economy (Kalvass and Geibel 2006). Little work has been done examining parasites of red abalone, but some information exists on shell-boring organisms. Common shell parasites include boring bivalves, polydorid worms, and boring sponges (Cox 1962, Stefaniak et al. 2005). Shell-boring organisms create crevices and reduce shell strength of the host. These weaknesses facilitate predation and mortality of abalone, causing shell breakage during heavy wave action or human harvest (Shepherd 1973, Pedren-Caballero et. al. 2010). A single host abalone may support a diverse assemblage of parasites, and multiple parasite loads may work in concert to influence host growth, shell bio-erosion, and health and survival of the host.

We observed parasitic snails on red abalone taken by recreational fishermen in northern California during summer 2012. We identified the snails as the fine sculptured odostome (*E. tenuisculpta*) belonging to the family Pyramidellidae. Here we examine populations of the fine-sculptured odostome and their relationship with abalone at three sites in northern California. Using field surveys and laboratory observations, we examined: (1) prevalence of the snail on red abalone at three sites in Sonoma County; (2) infestation characteristics of the parasites; (3) feeding behavior; and (4) reproductive capacity of the snails.

Materials and Methods

Field sites.—Our study sites were located at Sea Ranch (38° 42' N, 123° 26' W), Jenner (38° 45' N, 123° 11' W), and Horseshoe Cove (38°18' N 123° 04' W) along the coast of Sonoma County, California. All sites are dominated by rocky reef ecosystems. These sites support diverse kelp forest ecosystems with abundant red abalone and sparse Northern abalone populations. One of the sites, Horseshoe Cove, is located within the Bodega State Marine Reserve where no fishing is permitted.

We sampled abalone in Sea Ranch for the presence of the fine sculptured odostome in October 2012. We performed four dive surveys for the snails to depths of 18 m. Based on a visual assessment, red and northern abalone were categorized as infested (with snails) or not infested (without snails). A subsample of eight red abalone was brought to the surface to confirm the identity of the snails and examine characteristics of the infestations. In Jenner, we examined nine red abalone caught by recreational fishermen in November 2012.

Abalone were taken from depths of 3–9 m. A total of 18 red abalone were collected from Horseshoe Cove in November 2012 and maintained in the Bodega Marine Lab (BML) until examination during March 2013. At all three sites we quantified the number of the snails on each abalone, the location of the parasites, and egg mass cover on the abalone shell. Parasitic snail surveys were not conducted on other mollusk species or on rocky substrates during our field surveys.

Laboratory.—Live parasitic snails (*n*=254) were transported to BML for measurements and to observe feeding and reproductive behaviors during fall, 2012. Length was determined by measuring the shell of the snail from the longest leading edge of the anterior (siphonal) canal to the apex of the shell spire. Parasitic snails (*n*=15) were separated from their host and starved for 10 days to facilitate examination of feeding preferences. The snails were then allowed to feed on live adult red abalone, live juveniles (>15 mm shell length), or freshly dissected red abalone tissue. Red abalone used in these trials were collected from Sea Ranch.

The reproductive characteristics of the snails were examined using 20 pairs of snails during December 2012. We placed two snails in 50 ml conical vials filled with sea water and floated the vials in an ambient temperature seawater bath (12–13 °C). The number of egg masses laid was recorded daily, and the water in the vials was changed regularly.

All statistical analyses were performed using JMP software (Version 10). A linear model was used to describe the relationship between the number of snails on the abalone and the snail egg mass coverage on the shell. Similarly, we used a linear model to describe the relationship between snail length and the number of egg masses laid and eggs per mass. We used one-way ANOVA to determine if there were differences in shell size of parasitic snails among sites, and Tukey's multiple comparisons test to determine if snail sizes differed between sites. A distribution of infection densities was used to identify aggregation characteristics.

RESULTS

Parasite prevalence.—We sampled 73 adult red abalone (100–250 mm in length) at Sea Ranch, Jenner, and Horseshoe cove. We found 46 red abalone and 1 northern abalone during 4 swim surveys at Sea Ranch in October 2012 (Table 1). On swim survey number four (Table 1) we sampled a northern abalone, 95 mm in shell length, which was infested with 16 parasitic snails.

TABLE 1.—Number of red abalone, *Haliotis rufescens*, infested with the fine sculptured odostome snail (*Evalea tenuisculpta*). Sea Ranch, Sonoma County, California, November 2012.

Swim Survey	Depth (m)	Abalone with parasitic snail present	Percent
1	3-5	11/13	84
2	4-6	9/11	81
3	4-5	12/21	57
4	15-18	1/1	100
Total		33/46	72

Table 2.—Quantitative descriptions of the fine sculptured odostome snail (*Evalea tenuisculpta*) infecting red abalone (*Haliotis rufescens*). Sonoma County, California, October 2012 – March 2013.

	Location			
	Sea Ranch	Jenner	Horseshoe Cove	Summary
Infection Rate (*n*)	72% (46)	100% (9)	83% (18)	82% (73)
Snails per abalone	0 to 32	2 to 57	0 to 31	0 to 57
Avg per abalone (*n*)	13 (8)	18 (9)	6 (18)	12 (35)
Snail size (mm)	2.4-8.8	1.0-5.0	2.0-8.2	1.0-8.8
Avg snail size (*n*)	6 (70)	2.9 (74)	5.4 (110)	4.8 (254)

The prevalence of the snails infecting red abalone was high (>50%) at all three sites though infection rates varied at each site (Table 2). The number of snails per abalone ranged from 0 to 57 (Table 2). The majority of abalone (70%) were lightly infected (<10 parasitic snails) while 30% percent of abalone had >10 parasitic snails (Figure 1). The number of snails per abalone may be an underestimate as snails could have been lost during collection and transport.

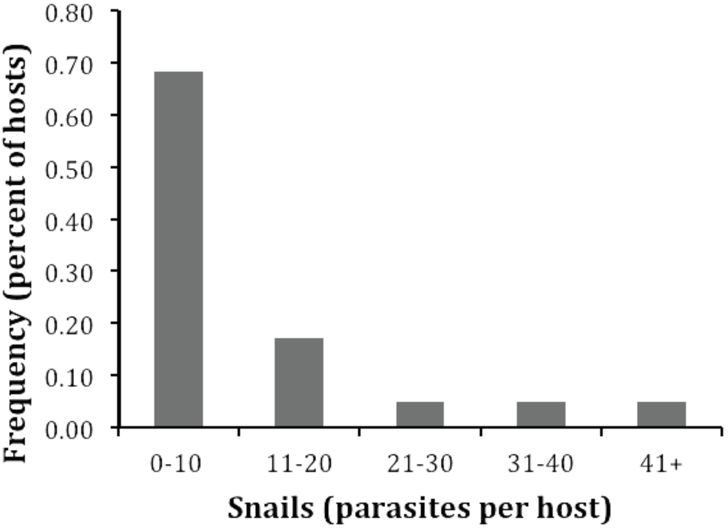

Figure 1.—Distribution of the fine sculptured odostome snail (*Evalea tenuisculpta*) on red abalone (*Haliotis rufescens*) October 2012 – March 2013 in Sonoma County, California.

Parasite size.— Snail sizes were significantly different between all sites, with the largest snails at Sea Ranch and smallest at Jenner (Figure 2). The largest snail found was 8.8 mm. Snail sizes at two sites were normally distributed, while at Jenner they had a bimodal distribution. Snail shell length was significantly different between sites ($F_{2,\,254}$ =127.2, P<0.001). Model residuals were distributed normally.

Figure 2. —Shells of eight fine sculptured odostome snails (*Evalea tenuisculpta*) ranging in size from 1.6 to 8.8 mm. Top row: snails collected from red abalone at Sea Ranch, Sonoma County, California in October 2012 (LACM 178561). Bottom row: snails collected from red abalone at Jenner, Sonoma County, California on 11 November 2012 (LACM 178560). Photo credit P. Lafollette.

Infestation characteristics.—Parasitic snails were found on the abalone shell, but not the foot tissue. Snails were mostly located near the respiratory pores of the abalone, tucked within pits bored out by bivalves, or in eroded areas near the ventral margin of the shell. Groups of snails were often surrounded by or coated in a gelatinous matrix. This matrix contained snail eggs and acted as an attachment to the abalone shell. This gelatinous matrix and egg mass also captured extraneous particles of bio-debris making the parasitic snails hard to detect. We observed four abalone with parasitic snails that had completely merged the respiratory pores at Sea Ranch.

Behavior.—All the snails (*n*=5) presented with a live, intact adult abalone, elongated their proboscis when they came in contact with the abalone and prodded the abalone foot tissue, indicative of feeding (Figure 3). Of the snails (*n*=5) presented with a juvenile abalone, four of the five elongated their proboscis and prodded the foot tissue, again indicative of feeding. Snails fed near crevices in the ventral margin of the shell, through the reparatory pores, or from the base of the abalone foot. The elongated proboscis of the parasites often exceeded the length of the snail. Snails (*n*=5) presented with freshly dissected abalone tentacle tissue did not show any interest in feeding or extending their proboscis.

Figure 3.—Fine sculptured odostome snail (*Evalea tenuisculpta*; length 7mm) collected at Sea Ranch, Sonoma County, California in October 2012, probing adult abalone (182 mm) foot tissue, under laboratory conditions, with its proboscis.

Reproduction.—Egg masses were present on all abalone with >1 parasitic snail, at all sites, from October 2012–March 2013; egg masses were not seen on abalone that lacked the parasites. Masses were irregular in shape and appeared as a thin, opaque, gelatinous layer. One abalone (with over 50 snails) had 65% of its shell covered in eggs. Percent cover of parasitic snail egg masses on the host abalone shell increased with an increase in the number of fine sculptured odostome snails on the red abalone, (r^2= 0.91 n=33, P<0.001; Figure 4). A goodness of fit test suggested the residuals from this linear model were not distributed normally. Egg laying was common in the snail, with 85% of the snail pairs laying egg masses within 3 days of isolation. On average, each snail pair laid two egg masses per vial (i.e., one egg mass per snail), and each egg mass (n=24) contained an average of 360 eggs (SD=230; range 105–840). There was a positive correlation (r^2= 0.59, n=20, P<0.001) between snail size and number of egg masses laid (Figure 5). Furthermore, the larger snails produced egg masses with more than the average number of eggs per mass (r^2= 0.29, n=24, P<0.001; m=93, b=0).

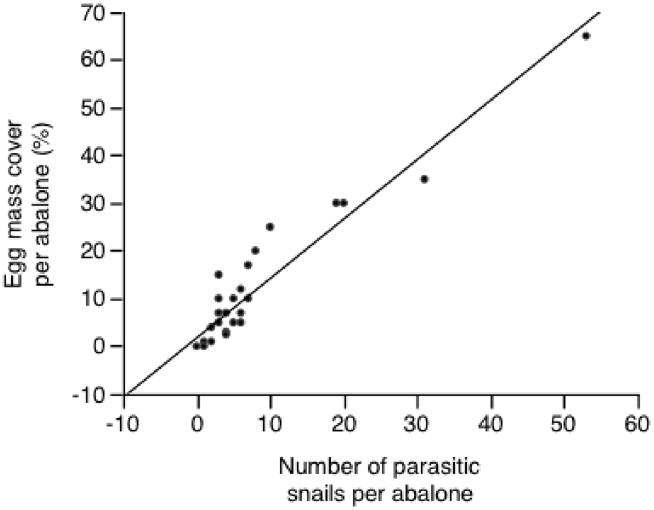

Figure 4.—Relationship between the number of fine sculptured odostome snails (*Evalea tenuisculpta*) and the percent cover of parasitic snail egg masses on the host red abalone shell. The linear relationship is percent cover of parasitic snail egg masses = 1.25 × number of parasitic snails per abalone. Sonoma County, California, December 2012.

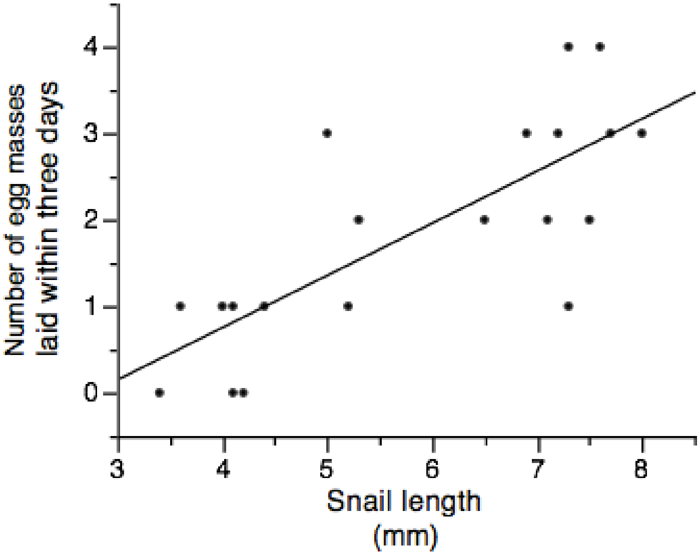

Figure 5.—Relationship between shell length of the fine sculptured odostome snail (*Evalea tenuisculpta*) and the number of egg masses laid. The linear relationship is egg mass number = (0.6 × shell length) + 1.7. Snails were collected from Sea Ranch, California and observed egg laying in the laboratory during December 2012.

DISCUSSION

Snail abundance.—Red abalone are known to be parasitized by snails in the family Pyramidellidae; however, until now the prevalence of these snails has not been quantified. Our study demonstrated that the fine-sculptured odostome snail commonly (82%) infests red abalone at Sea Ranch, Jenner, and Horseshoe Cove, Sonoma County, California (Table 2). Furthermore, our research documents the first known account of the fine sculptured odostome snail infecting northern abalone, a species of concern. We suggest other sites in Sonoma County may also have high infection rates, and that more study is needed to better understand this parasite-host relationship.

Parasitic snails occurred in aggregations on their hosts. We found that many abalone were lightly infested with snails, while a few abalone were heavily infested. Aggregated distributions such as this are typical of macroparasites, and tend to be most harmful to heavily infested hosts (Crofton 1971). As many as 57 snails and as few as 0 snails were found on a single abalone (Table 2). Other investigators have documented up to 100 pyramidellid snails (*Boonea impressa*) on a single oyster (*Crassostrea virginica*) (White et al. 1985). It is likely that higher densities of parasites could be found on red abalone with more sampling. Heavy infestations of snails may have negative consequences for the health of red abalone. The impact of large aggregations on red abalone warrants further investigation.

It was remarkable that egg masses were found on most abalone with more than one parasitic snail and that reproduction did not taper off with high densities of snails (at the densities observed; Figure 4). This relationship was not influenced by the size of the abalone shell. Up to 65% of an abalone's shell was covered by snail egg masses. We have portrayed the relationship between snail number and egg mass coverage as linear, but with a larger sample size this relationship may not hold. The reproductive output of these snails may be enhanced in aquaculture facilities, where abalone are often kept at high densities in recirculating sea water systems.

Snail size.—The fine sculptured odostome snail ranged in size from 1 to 8.8 mm. Prior to our study, the maximum recorded length of this snail was 6 mm (Abbott 1974). We found the largest snails at Sea Ranch (Figure 2). Site differences may be a result of variation in host population, habitat, or lack of synchrony in parasite reproduction. White et. al (1985) reported that the size of preferred hosts changes with pyramidellid size. Additional investigations, such as underwater surveys or sampling of recreational catch, should be undertaken to better understand the relationship between host and snail characteristics.

Knowing that the fine sculptured odostome snail is a relatively large pyramidellid, it is important to understand how the size of a parasite might influence reproduction. In the laboratory, larger snails produced more egg masses (Figure 5). The larger snails not only produced more egg masses, but the masses they produced had more than the average (360) number of eggs. We suggest the fine sculptured odostome may have the highest reproductive output at sites with large snails and large aggregations. Although we know of no literature defining the larval production of the fine sculptured odostome, other species of pyramidellid populations can grow quickly, and may have enhanced reproduction. For example, Cumming (1988) reported that an initial population of six adults can give rise to an average of more than 1,700 individuals in just 4 months. In order to quantify fecundity in this parasite more research on its larval biology and development is needed.

Snail behavior.—Snails were distributed in groups on the shell and were observed feeding on abalone in the lab. Vacant pits and areas of shell damage appeared to act as a place of refuge for the fine sculptured odostome. Snails were found feeding along the respiratory pores and near the edge of the shell of the host. The parasitic snail fed on adult and juvenile abalone in the lab, indicating that abalone not only provide habitat, but also act as a food source. It is important to note, however, that snails did not feed on dissected tissue. We suggest that snails prefer live abalone and may feed exclusively on abalone hemolymph, rather than tissue (Figure 3). The impact of snail parasites on abalone reproduction, growth or health is unknown, although heavy infestation rates could have negative impacts.

In conclusion, we have determined that the fine sculptured odostome snail is commonly found on red abalone in Sonoma County, California. We have learned more about the abundance, behavior, and reproductive capacity of the snail. Many questions remain about the development, distribution, and transmissibility of this parasite, and additional work is needed on the ecology and biology of the parasitic snail to assess its impact on red abalone and other potential hosts.

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Translocating endangered kangaroo rats in the San Joaquin Valley of California: recommendations for future efforts

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Since the early 1990s, translocation has been advocated as a means of mitigating impacts to endangered kangaroo rats from development activities in the San Joaquin Valley. The factors affecting translocation are numerous and complex, and failure rates are high. Based on work we have done primarily with Tipton kangaroo rats and on published information on translocations and reintroductions, we provide recommendations for future translocations or reintroductions of kangaroo rats. If the recommended criteria we offer cannot be satisfied, we advocate that translocations not be attempted. Translocation under less than optimal conditions significantly reduces the probability of success and also raises ethical questions.

Key words: *Dipodomys heermanni*, *Dipodomys ingens*, *Dipodomys nitratoides*, reintroduction, San Joaquin Valley, Tipton kangaroo rat, translocation

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Largely due to habitat loss, several species or subspecies of kangaroo rats (*Dipodomys* spp.) endemic to the San Joaquin Valley of California have been listed by the state and federal governments as endangered. These include the giant kangaroo rat (*D. ingens*), and two subspecies of the San Joaquin kangaroo rat (*D. nitratoides)*, both of which occur in the San Joaquin Desert portion of the valley (Germano et al. 2011) and currently persist on only 2–4% of their historic ranges (Williams and Germano 1992). Despite federal and state protections, projects that eliminate occupied habitat continue to be approved. The giant kangaroo rat and the Tipton kangaroo rat (*D. n. nitratoides)*, which is one of three currently recognized subspecies of *D. nitratoides,* have largely been the focus of translocation efforts since the early 1990s because of their protected status. Translocation of these species, as well as other endangered species, has often been proposed by resource agencies as a strategy to save individuals that are impacted by land development activities (O'Farrell 1999, Germano 2001, Edgar et al. 2005, Ashton and Burke 2007, Germano 2010, Germano et al. 2013).

Aside from land development activities, translocation or reintroduction are also conservation strategies for restoring or expanding extirpated populations, and the number of translocations or reintroductions completed annually has grown in the last two decades (Griffith et al. 1989, Wolf et al. 1996, Fischer and Lindenmayer 2000, Morrison 2009, Perez et al. 2012). In some cases, translocation or reintroduction has been successful. For example, successful reintroduction of the Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*) to a portion of its range from which it had been extirpated likely reduced its risk of extinction (Holler et al. 1989). Also, in southern California, the Stephens' kangaroo rat (*Dipodomys stephensi*) was successfully reintroduced to a portion of its range (Shier and Swaisgood 2012). However, in most cases where translocation has been attempted, the outcome either has been unsuccessful or has not been determined (Fischer and Lindenmayer 2000, Armstrong and Seddon 2008). Most translocations have serious design flaws, lack clear necessity, and fail to address basic criteria for translocations established by leading conservation groups, such as the International Union for Conservation of Nature (IUCN; Perez et al. 2012).

Based on work we have done primarily with Tipton kangaroo rats since the early 1990s, and published information on translocations and reintroductions, we provide recommendations for future translocations or reintroductions of Tipton kangaroo rats. These recommendations, with some modifications, also should apply to translocating giant kangaroo rats and other kangaroo rat species in the western United States. We use standard definitions of the IUCN to define the terms translocation and reintroduction. We recognize that there are other definitions, such as introduction, reintroduction, and augmentation, which are widely used in restoration ecology (e.g., Falk et al. 2006, Mills 2007, Morrison 2009); however, we have chosen to follow IUCN definitions in this manuscript. Thus, translocation is the human-mediated movement of wild animals from one part of their range to another, and reintroduction is the movement of individuals to areas within their historic range from which they have been extirpated (IUCN 1998). Our recommendations apply to either situation. We also use conventional criteria for determining success: a translocation or reintroduction is successful if the introduced population is self-sustaining (i.e., there is successful reproduction of progeny; Griffith et al. 1989).

We make these recommendations because no formal set of guidelines has been established by the agencies that are responsible for the recovery of Tipton kangaroo rats — or any other species of kangaroo rat. Typically, if a translocation is deemed necessary in order to salvage kangaroo rats, biologists are not given enough time to implement one or more of the criteria that will improve translocation success. Although based largely on our own experiences, we provide these recommendations for consideration in any management decisions or permits required to translocate kangaroo rats. Our goal is that these recommendations will be factored in well before animals are moved in the San Joaquin Valley or, potentially, in other parts of California.

RECOMMENDATIONS

Absence of Tipton kangaroo rats on the translocation site.—One of the first considerations when choosing a translocation site is to ensure that Tipton kangaroo rats do not currently occupy the site. Because so few sites in the San Joaquin Valley support this subspecies, the first priority should be to protect any site where they are found. While long-term conservation strategies may suggest that moving small, isolated populations to larger, more protected sites will reduce the chances of genetic depression in small populations (e.g., bottlenecks, genetic drift, etc.) and better their changes of long term survival, we suggest that, currently, it is more important to identify and protect any site that is occupied by the Tipton kangaroo rat. Furthermore, we have seen Tipton kangaroo rats survive and, in fact, thrive on small patches of isolated habitat. Before considering any movement between or among populations, it is important to identify as many existing populations as possible, and then determine an appropriate long-term strategy that incorporates objectives for preserving genetic diversity.

Another reason that a translocation site selected should not have extant Tipton kangaroo rats is that kangaroo rats have intricate intraspecific social relationships and it would be difficult to introduce new individuals into an existing population without inciting agonistic behaviors by residents (Tennant 2011, Shier and Swaisgood 2012). It is likely many individuals translocated to an already occupied site will not survive. Even when translocated animals survive, they may displace resident animals, resulting in losses equivalent to the addition of individuals, especially if the resident population is at or near carrying capacity. In either case, no net benefit to the species is likely.

Absence of congeneric competitors.—In previous studies, translocations into areas with a congeneric competitor were less successful than translocations to sites without a resident, or even a potential, competitor (Griffith et al. 1989). For heteromyids, decades of research has demonstrated that competition plays a strong force in community structure and that sympatric desert rodents partition both biotic and abiotic environmental factors due to interference competition (see reviews by Brown and Harney 1993, Randall 1993). Typically, larger heteromyids use aggressive interference to outcompete smaller species (Blaustein and Risser 1976, Frye 1983, Basset 1995, Perri and Randall 1999; but, see Bleich and Price 1996). In the San Joaquin Valley, an exclusion experiment demonstrated that the larger Heermann’s kangaroo rat (*D. heermanni*), which typically occurs sympatrically with Tipton kangaroo rats, can competitively depress populations of the smaller Tipton kangaroo rat through interference competition (Tennant and Germano *in press*).

Thus, we recommend that translocation efforts for Tipton kangaroo rats consider the potential competitive effects of larger, coexisting congeners. In order to mitigate the effects of competition, we suggest that it may be necessary to remove competing species. Since giant kangaroo rats are the largest kangaroo rat (Williams et al. 1993a), less concern about competitors is necessary during translocations because this species is behaviorally dominant over smaller kangaroo rats (author’s personal observations; also see Blaustein and Risser 1976, Frye 1983, Basset 1995, Perri and Randall 1999).

Since the early 1990s, site selection for translocation and reintroduction of Tipton kangaroo rats has been based on the presence or absence of congeneric competitors. However, as is often the case with small mammal communities, populations fluctuate temporally. Thus, despite choosing sites apparently devoid of competitors, competitors may, indeed, be present. This was the case in a 2006 translocation of Tipton kangaroo rats to the Allensworth Ecological Reserve, Tulare County (35° 50' 26.4" N, 119° 20' 26.2" W) where trapping three months before the translocation documented only one Heermann's kangaroo rat, but subsequent monitoring eight months after the translocation showed that numbers of Heermann's kangaroo rats had increased dramatically (Germano et al. 2013) and were excluding Tipton kangaroo rats through interference competition (Tennant and Germano *in press*).

We recommend walking reconnaissance surveys over the entire target translocation site and trapping in areas with burrow systems present to assess species presence or abundance. Thus, we suggest that trapping need not occur over the entirety of the site, but should at least be conducted in portions of the target area where kangaroo rat burrows are located. We recommend that these surveys occur no earlier than one month prior to the translocation date. As an example, two initial trapping surveys during a Tipton kangaroo rat reintroduction effort to Kern National Wildlife Refuge, Kern County, (35° 45' 36.1" N, 119° 34' 50.7" W) indicated that Heermann's kangaroo rat abundance was low (B. Cypher, unpublished data). However, the reintroduction was delayed by almost a year due to inclement weather, site inaccessibility, and other factors. During that time, Heermann's kangaroo rat numbers increased markedly, and likely contributed to the apparent failure of this reintroduction effort (B. Cypher, unpublished data).

Ideal translocation sites are those devoid of congeneric competitors. However, it is extremely difficult to find sites in the San Joaquin Valley that have both suitable habitat and are devoid of either the target species or competitors. We recommend that if more than two individual competitors are captured over a 200 trap-night census, then the population of competitors may be too high. Depending on the size and density of the areas with active burrows, we recommend a minimum 50 traps should be set in areas with kangaroo rat sign. The traps can be set in a grid formation or at active burrow locations. We recommend trapping over at least a four-night census period (equating to a minimum of 200 trap-nights).

If translocation sites for Tipton kangaroo rats cannot be found that have both appropriate habitat and a low number of congeneric competitors, we suggest that competitors be removed before translocating Tipton kangaroo rats. Even if a few competitors remain on site (it is unlikely that trapping will totally eliminate the competitors), the translocated species will have a better chance of becoming established. Additionally, continued trapping to remove congeneric competitors even after the translocation has been completed may be warranted. For example, during a competitor removal study in 2009 at Allensworth Ecological Reserve, Heermann's kangaroo rats were continually removed from the study site over the course of the study period (Tennant and Germano *in press*). Furthermore, patterns of day burrow use suggest that kangaroo rats may prefer to avoid the home ranges of other kangaroo rat species (Perri and Randall 1999). Thus, it is possible that once a Tipton kangaroo rat population is established on a site, abundance and spacing mechanisms may allow them to better compete and coexist with congeneric competitors.

Intraspecific relationships and spacing.—Kangaroo rats have complex neighbor relationships that may help to reduce aggression among conspecifics because of familiarity and relatedness between neighbors (Randall 1989, 1991, 1993). Thus, attention should be given to spacing and neighbor relationships to reduce intraspecific aggression and mortality during translocations. Other translocation research has demonstrated that attention to familial relationships can increase survivorship. For example, research on prairie dogs has shown that keeping familial relationships intact decreases stress and increases survivorship (Shier 2006). Survivorship of translocated Stephens' kangaroo rats (*D. stephensi*) was greatly increased when neighbor relationships where kept intact (Shier and Swaisgood 2012).

We suggest that translocations take into account neighbor relationships on donor sites. Based on our experience, one way to do this is to group individuals on the recipient site in the same spatial arrangement that they were trapped at the source location. Thus, kangaroo rats trapped in adjacent traps on the donor site will be placed in adjacent burrows on the recipient site. This requires advance planning using spatial maps of both the donor and recipient sites so that individuals can be grouped together.

In spacing kangaroo rats on the recipient site, we have generally tried to place individuals close enough so that they will come into contact and find mates, but also far enough apart so as to avoid aggressive interactions. In past translocation efforts, kangaroo rat burrows and cages have been spaced at least 15 m apart. However, Tipton kangaroo rats tend to have larger home ranges than other kangaroo rat species (ca. 1000–3000 m^2; Tennant and Germano *in press*); thus, 15-m spacing may be too close and may promote aggression. More research is needed on kangaroo rat burrow spacing dynamics so that translocations can better incorporate proper spacing parameters. One possible option is to map the burrow locations of each individual at the source location through trapping and night vision technology, and then emulate this spacing on the recipient site (D. Shier, University of California, Los Angeles, personal communication).

Time of year.—We recommend that translocations of kangaroo rats generally be avoided during high or low temperature extremes, or other ambient conditions that would cause excessive stress to individuals. However, because many translocations occur within project development timelines, avoiding temperature extremes often is difficult. For example, a 2006 translocation of Tipton kangaroo rats to Allensworth Ecological Reserve occurred at the beginning of December when low temperatures were barely above freezing because development at the source location was slated to begin (Germano et al. 2013).

Other studies involving translocated dormice (*Muscardinus avellanarius)* found that animals released in early summer (May, June) lost more body mass than those released in late summer (August, September; Bright and Morris 1994). Bright and Morris (1994) also suggested that food scarcity for dormice in early summer may necessitate supplemental feeding. It is unknown to what extent seasonal food shortages affect kangaroo rat populations and how this should be factored into translocation efforts. Food availability may be highest in the late spring, just after annual herbaceous vegetation has matured. Food shortages and population pressure do impact kangaroo rat populations in extreme drought years (Williams et al. 1993b); thus, we suggest that no translocations occur during drought years.

Avoiding the prime reproductive period of kangaroo rats is another factor that is important to consider in translocation efforts. Kangaroo rats primarily breed from February until fall, depending on food availability and other environmental factors (Tappe 1941, Fitch 1948, Eisenberg and Isaac 1963, Jameson and Peeters 1988). Removing endangered kangaroo rats from a source population during the breeding or rearing period may disrupt reproductive success, and also impact the source population. For example, a 2010 reintroduction of Tipton kangaroo rats to an area of Kern National Wildlife Refuge likely failed in part because of the active reproductive status of Tipton kangaroo rats at the source site in late August. Because adult females were still lactating or were pregnant at the source site, we removed and translocated very few adult females in order to lessen the impact to the source population. The majority of the individuals translocated were either adult males or pre-reproductive younger females, and this likely contributed to a failed reintroduction effort (B. Cypher, unpublished data).

Another factor to consider when translocating kangaroo rats is the activity cycles of predators. In the 2010 reintroduction effort to Kern National Wildlife Refuge that took place in late August, northern Pacific rattlesnakes (*Crotalus oreganus oreganus*) killed three reintroduced kangaroo rats (B. Cypher, unpublished data). Several species of snakes are predators of kangaroo rats and, like most reptiles, are active from late spring to early fall. Several species of owls also are predators of kangaroo rats (Grinnell 1932, Hawbecker 1945, Schwartz and Bleich 1985) and, in nearly all translocation efforts we have been involved with, several of the translocated individuals have been preyed upon by owls (Germano 2001, 2010; Germano et al. 2013; Tennant and Germano *in press*). Owls have higher energy requirements during the breeding season when they are rearing young and may take more (or, at least, higher calorie) prey during the spring (Ward et al. 1998). Because high mortality rates are already common when translocating prey species (Germano 2001, Banks et al. 2002, Watland et al. 2007, Germano 2010, Hamilton et al. 2010), we recommend conducting translocations outside of the owl breeding season and when reptile activity is low to reduce the potential for predation.

Given all of these timing factors, we suggest translocations of kangaroo rats in the San Joaquin Valley should be limited to either fall (late September – November) or early spring (March – April), if kangaroo rats do not show signs of being reproductively active or tending young (lactating). During these times, temperatures are moderate, snake activity is usually low, and other avian and mammalian predators are not breeding.

Habitat quality and burrow refugia.—In a review of translocations by Griffith et al. (1989), successful translocations occurred at sites with both high quality habitat and the presence of refugia (which, for kangaroo rats, would be presence of available burrows in which refuge is taken). In fact, without high quality habitat and assurance that active management will occur on the translocation site, there is a low chance of success no matter how many individuals are released (Griffith et al. 1989; Wolf et al. 1996). In the San Joaquin Valley, sites with high quality habitat typically are those that lack dense, non-native grass cover, or that are aggressively managed to reduce dense, non-native grass cover that occurs during years when herbaceous growth is high (Germano et al. 2001, 2012). Dense herbaceous cover negatively affects both Tipton kangaroo rats (Figure 1) and giant kangaroo rats (Figure 2). If sites are not managed for low herbaceous cover, the likelihood of continued survival of translocated kangaroo rats is low. Thus, we recommend that any potential translocation site have a vegetation management and monitoring plan in order to ensure active management continues on the translocation site.

The site to which animals are to be translocated should also have accessible burrows, either in the form of abandoned natural burrows suitable for kangaroo rats, or artificial burrows. In a 2009 translocation of Heermann's kangaroo rats, high survivorship (16.3% at 6 months post-release) was documented on a site with a high abundance of available natural burrows in which individuals could take refuge, which appears to be an important factor for survival of translocated kangaroo rats (Tennant 2011). Studies of translocated prairie dogs (*Cynomys* spp.) in Utah also have shown that at sites where there are pre-existing burrow systems, prairie dogs disperse shorter distances and have higher survival rates than in areas without abandoned burrows (Robinette et al. 1995, Truett et al. 2001). Thus, we recommend that sites with high quality habitat and existing burrows be given higher priority than sites without burrows. If sites do not include ample burrows, artificial burrows should be added (see Germano 2001, Germano et al. 2013), although the extent to which kangaroo rats will use permanent artificial burrows if natural burrows are not available is unknown. The presence and use of artificial burrows may, however, provide enough time for translocated individuals to construct their own burrow systems. Research is needed on the best material for artificial burrows that would provide the temperature and humidity regimes most similar to natural burrows.

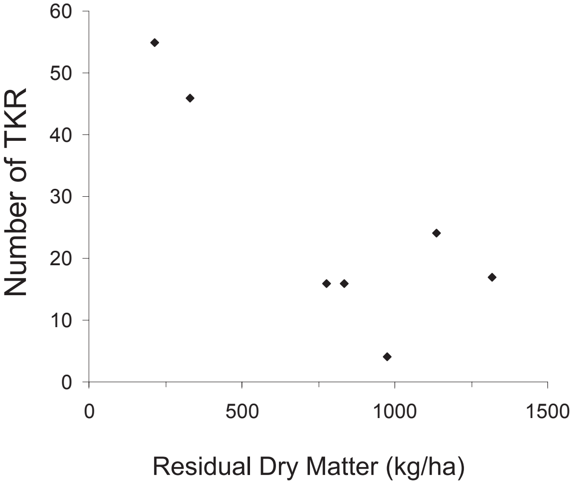

Figure 1.—Correlation between the number of Tipton kangaroo rats (TKR) caught during six-day trapping sessions in the spring and the mean amount of residual dry matter (kg/ha) measured at the Buttonwillow Preserve in Kern County, California. The correlation is significantly negative.

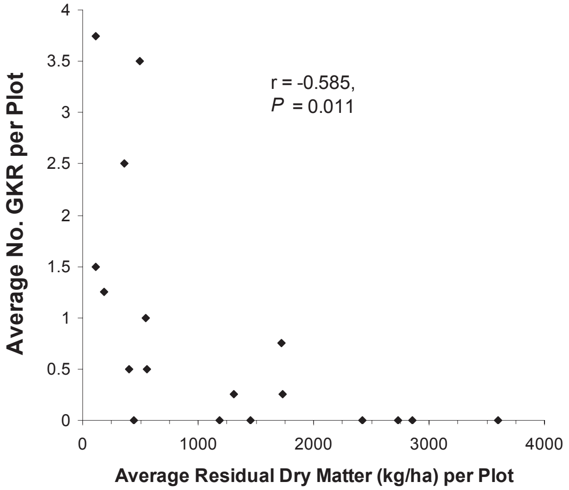

Figure 2.—Correlation between the average number of giant kangaroo rats (GKR) caught during six-day trapping sessions in August on grazed and ungrazed plots and the mean amount of residual dry matter (kg/ha) measured over nine years in Kern County, California. The correlation is significantly negative.

Number of translocated individuals.—Size of translocation and reintroduction efforts for endangered kangaroo rats have ranged from small (15 individuals [Germano 2001, O'Farrell 1999]) to large-scale removals from an entire parcel of occupied habitat (144 individuals [Germano et al. 2013]; 599 individuals [O'Farrell unpublished report {cited in Shier and Swaisgood 2012}]). Also, all past translocation efforts for kangaroo rats have consisted of only one release effort. In an assessment of successful translocations by Griffith et al. (1989), a typical translocation consisted of six releases over a three-year period. Of these releases, the majority consisted of 75 or fewer animals per release (Griffith et al. 1989). Both Griffith et al. (1989) and Fisher and Lindenmayer (2000) reported that success increases when a greater number of animals are initially released. Specifically, Fisher and Lindenmayer (2000) reported that releasing >100 individuals was associated with greater translocation success. Releasing a large number of animals, especially of prey species, serves to satiate predators and provide a buffer effect so that a core population will establish on the site.

Often in the San Joaquin Valley, development projects occur on a small footprint (e.g., oil wells or well pads, small developments <4 ha) and the number of individuals requiring translocation is small (<30 individuals). Since predation rates on translocated prey species is typically high (Germano 2001, Banks et al. 2002, Watland et al. 2007, Germano 2010, Hamilton et al. 2010) and, therefore, overall survivorship typically is low (8.3% [D. Germano and L. Saslaw unpublished data]; 16.3% [Tennant 2011]; both at six months post translocation), we recommend that translocation efforts not be conducted for kangaroo rats if there are <30 individuals to be translocated. Thus, translocations should be conducted with a founder population of at least 30 individuals. Another reason for this recommendation is that small founder populations are prone to a range of genetic problems, such as inbreeding, bottlenecks and genetic drift (Falk et al. 2006, Morrison 2009).

If there are situations with <30 individuals, we recommend alternatives to translocation be investigated. If a project site is small and habitat is available outside of the project area, one possible solution is to erect exclusion fencing around the project area and move animals outside of the project footprint. However, it is still necessary to address potential interspecific and intraspecific conflicts before any movement of animals occurs. Other alternatives could include using animals for research (e.g. captive breeding or behavioral studies) or in outreach opportunities.

Hard or soft releases.—There are two general types of release methods that are used in faunal translocations: a "hard" release and a "soft" release. A soft release involves a period of confinement in an enclosure on the release site that allows animals to become acclimated (Scott and Carpenter 1987, Thompson et al. 2001, Morrison 2002). Typically, all necessary resources (e.g., food and water) are provided during the acclimation period. A hard release is an immediate and direct release of the animal onto the translocation site.

For kangaroo rat translocations, both hard and soft release methods have been used. In both release scenarios, animals typically are placed into either an artificial burrow constructed of man-made materials, such as cardboard or corrugated pipe, or a rudimentary hole augured into the soil (see Germano [2001] and Germano et al. [2013] for detailed methods). Food is provided inside the burrow in both hard and soft releases. In a hard release, animals are placed into an artificial burrow that is lightly plugged with a piece of paper towel. During a soft release, enclosures are placed around the artificial burrow.

Enclosures have been constructed of hardware cloth and the bottom edge of the hardware cloth is buried to a depth of 20-30 cm to prevent animals from quickly digging out. The enclosures also have hardware cloth or netting as a cover to prevent kangaroo rats from climbing out or prevent other animals from entering. After an acclimation period of several days to a month, the enclosures are removed or openings are created in order for animals to leave the confined area.

The assessments by Griffith et al. (1989) and Wolf et al. (1996) found no consistent association between successful translocations and either hard or soft release methods. In the San Joaquin Valley, results from translocation efforts for Tipton kangaroo rats since the 1990s have shown that mortality from predation for hard-released individuals occurs within the first four to five days (Germano 2001, 2010; Germano et al. 2013). For example, in 2001 four Tipton and seven Heermann's kangaroo rats were removed from a project site, fitted with radio-transmitters to monitor survival, and translocated using a hard release. Only one Heermann's kangaroo rat survived to the end of the study (45 days; Germano 2010). Soft release methods potentially could reduce initial high predation rates. In a 2006 translocation study of Tipton kangaroo rats, more soft-released individuals survived than those that were hard-released, but the differences were not significant (Germano et al. 2013). The reverse was true for a study of translocated Heermann's kangaroo rats, but differences in survivorship again were not significant (Tennant 2011). Additionally, in the Heermann's kangaroo rat study, many of the animals dug out of their cages in one to two days, which made it difficult to assess whether caging increased survivorship. Shier and Swaisgood (2012) successfully translocated Stephens' kangaroo rats using a combination of soft-release methods and maintaining the spatial relationships and, presumably, the social structure of animals from the source location.

Many reintroduction studies have shown success with some form of soft release, especially with avian species, which can easily disperse (Gatti 1981, Ellis et al. 2000, Wanless et al. 2002, Mitchell et al. 2011). Successful use of soft release methods has also been beneficial for some small mammals (Holler et al. 1989, Bright and Morris 1994). However, other reintroduction experiments using soft releases have not improved survival, site fidelity, or body condition (Hardman and Moro 2006). In one study with the marsupial rat-kangaroo (*Bettongia lesueur)*, soft-released individuals injured themselves on fencing and that method was terminated (Short et al. 1992, Christensen and Burrows 1995). It may be that cages are another novel environment that increases chronic stress among reintroduced individuals (Teixeira et al. 2007, Dickens et al. 2010), thereby affecting acclimation to the reintroduction site and survival.

Pending further data on the success of hard and soft release methods, we recommend that decisions be based largely on translocation site conditions. If conditions on the chosen site include high quality habitat, ample burrows, and low levels of competitors, then soft releases, especially the use of cages, may not be necessary to increase survival and site fidelity. Performing soft releases requires substantially more effort and resources, and it may not be worth spending limited resources on such efforts if survival is not significantly improved (also see Hardman and Moro 2006). However, additional testing of the benefits and different parameters that may affect survival of individuals of soft releases, such as length of caging time, size of cage, and spacing of cages, should continue.

Monitoring.—Clear goals and criteria for success or failure and monitoring of translocation outcomes are an integral part of any translocation program. However, most translocations have lacked extensive monitoring and standard criteria for success or failure

(Fisher and Lindenmayer 2000, Armstrong and Seddon 2008, Perez et al. 2012). In the majority of translocations we have been involved with, monitoring of translocation success has been extremely limited. In fact, in only one translocation effort has monitoring extended beyond six months (Germano 2001, 2010; Tennant 2011; Germano et al. 2013; B. Cypher, unpublished data). This often occurs because regulatory agencies require project proponents to fund the translocation effort itself, but fail to include (or may be legally unable to require) funding for follow-up monitoring. In other cases grant funding may be secured for the initial translocation and several months of monitoring, but long-term monitoring is left to the agencies or other entities, and fails to be a priority.

We recommend that post-translocation monitoring be required for at least three years on the translocation site. Three years was established as a baseline in a 2006 translocation to Allensworth Ecological Reserve, and allows for monitoring of at least three generations, which will ensure that reproduction is not only occurring but also is sustaining the translocated population (Germano et al. 2013). In the 2006 Allensworth translocation, study site-wide trapping occurred six months post translocation and then once per year in the fall for three years (Germano et al. 2013), which we suggest is a good model for future efforts. Another reason that at least three years is appropriate is that populations of small mammals typically fluctuate annually and, even though a translocation may appear successful in the first six months, it may fail in subsequent months due to a wide range of factors such as an increase in competitors or predators, or a change in other habitat conditions. Furthermore, monitoring and reporting on the success or failure of translocation efforts is integral to updating and refining recommendations and, ultimately, the future success of translocations of endangered kangaroo rats.

CONCLUSIONS

The Tipton kangaroo rat currently is known to occur at about 10 sites throughout its range, and populations have continued to decline or are unstable (Uptain et al. 1999, USFWS 2010). However, surveys have not been conducted on all remaining habitat parcels, and additional populations could be located in the future. The best option for conserving Tipton kangaroo rats is to protect all remaining parcels on which it occurs. Because this species is found on so few sites, however, recovery may also require that additional land be purchased and restored to native habitat conditions, and animals subsequently reintroduced. Furthermore, development is still occurring on lands inhabited by Tipton kangaroo rats, and mitigation measures may include translocating animals. The situation is similar for other endangered kangaroo rats, such as the giant kangaroo rat. Thus, more research on effective methods for translocating kangaroo rats is needed.

For Tipton kangaroo rats, a particularly pertinent issue is whether there are sites in the southern San Joaquin Valley that (1) have high quality habitat; (2) can be actively managed; (3) contain a high abundance of existing burrows but lack a current population of endangered kangaroo rats; and, (4) have no, or few, competitors. We have found that the lack of available sites has confounded translocation efforts in the past. A current list of potential translocation sites for rare species of kangaroo rats must be developed and maintained so that when translocation is considered, potential recipient sites can be quickly identified.

If our recommended criteria cannot be satisfied, then it is our opinion that translocations should not be attempted. Translocating individuals under less than optimal conditions substantially reduces the probability of success, and also raises ethical questions regarding translocations as a means of protecting the species if, in fact, that is not the case. We suggest it would be better to place individuals in zoos or museums, use them in outreach programs, or use them for research (e.g., captive breeding or behavioral studies), rather than conduct translocations that have a low probability of success.

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Handling adjustments to reduce chemical capture-related mortality in black-tailed deer

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The capture of free-roaming animals is an important foundation of wildlife research and minimizing harm, especially mortality, is a paramount ethical concern (Kilpatrick and Spohr 1999, DelGiudice et al. 2005, Wildlife Investigations Lab 2010, Sikes et al. 2011). However, injuries or mortality are inherent to capture and chemical immobilization, and often necessitate adjustments to accepted techniques (Valkenburg et al. 1983, 1999; Jessup 2001; DelGiudice et al. 2005). In order to limit the potential for harm to study animals the California Department of Fish and Wildlife (CDFW) has formalized training and ethical guidelines for capture and chemical immobilization of wildlife (Wildlife Investigations Lab 2010). Nevertheless, training cannot replace real-time field experience and handling of animals; it is through experience that biologists are able to minimize injuries or mortalities to animals by making proactive adjustments to standardized capture protocols (Jessup 2001; DelGiudice et al. 2001, 2005).

Ungulates are the most common large mammals captured by wildlife biologists, and special care in the capture of *Odocoileus* spp. is needed because of the high potential for injury due to excitability and lengthy handling times (DelGiudice et al. 2005). A capture method that is becoming prevalent is remote delivery of immobilizing agents via free-range darting (Ferris 1990, Kilpatrick and Spohr 1999). Benefits of this approach are low animal capture stress relative to other methods (e.g., net-gunning), ability to select specific individuals, and its utility in dense cover; drawbacks include drug-induced decreases in respiratory and thermoregulatory abilities (Ferris 1990). Of special concern is the capture and immobilization of adult female deer within one month of parturition. Ideally, captures should be executed at other times due to the stressors associated with pregnancy, but circumstances may dictate that captures occur during this period (e.g., migratory animals that are accessible only during a short window on summer range).

During the month prior to parturition, respiration becomes increasingly labored as the size of the fetus increases, thereby reducing the capacity of the thoracic cavity and limiting the expansion of the lungs (Armstrong 1950). Many immobilizing agents (e.g., xylazine) further tax animals through a reduction in respiratory rate and gut motility, thereby resulting in bloat. Thus, chemical capture often results in respiratory distress manifested as low blood oxygen saturation (SpO_2) and reduced respiratory rate (Kreeger et al. 2002). The likelihood of mortality increases dramatically when appropriate adjustments are not made to mitigate respiratory depression, and raises ethical concerns that jeopardize approval or funding for investigations (Peterson et al. 2003). Here we describe adjustments to standard handling approaches (Wildlife Investigations Lab 2010) during the chemical capture of female black-tailed deer (*O. hemionus columbianus*) within one month of parturition in the Mendocino National Forest, California.

Adult female deer (*n* = 18) were captured via free-range darting during April – September 2012. Seven were determined to be in the latter stages of pregnancy using ultrasonography (Stephenson et al. 1995) and known parturition periods for this population (D. Casady et al., CDFW, unpublished data). We used Pneu-Dart® compression rifles (Pneu-Dart Inc., Williamsport, PA) and 1.5 or 2 ml Pneu-Dart® barbed tri-port darts with 3.17 cm needles. We determined distances to deer with a laser rangefinder and darted animals at distances from 5 to 50 m. A combination of Telazol® (tiletamine HCl and zolazepam HCl; Fort Dodge Animal Health, Fort Dodge, IA) and xylazine (Anased®, LLOYD Laboratories, Shenandoah, IA) (DelGiudice et al. 1986) was used to chemically immobilize the animals. Ketamine HCl (Ketaset®, Fort Dodge Animal Health, Fort Dodge, IA) at approximately 4.4 mg/kg was administered as needed to maintain anesthesia and peripheral analgesia.

After injection of the immobilizing agents, we waited 10 minutes before retrieval to minimize stress to the animal during drug induction. Once downed deer were located, their legs were bound front to back on same sides, their eyes were covered, and they were moved to a shaded location. The deer were positioned left side down with head uphill to prevent aspiration of rumen contents, and body temperature and respiratory rate were measured at 10 minute intervals. Blood oxygen saturation was continually monitored using a Nellcor™ pulse oximeter (OxiMax N-65; Nellcor, Mansfield, MA) with a lingual probe attached to the tongue. We fitted each animal with a GPS collar, recorded morphometrics, collected a tissue sample (ear) for biopsy, extracted a canine for age determination (Swift et al. 2002, Bleich et al. 2003), and estimated fetal rates (Stephenson et al. 1995) using an Ibex® portable ultrasound (E.I. Medical Imaging, Loveland, CO) and a CL3.8 abdominal curved linear probe (E.I. Medical Imaging, Loveland, CO). When immobilized deer exhibited signs of recovery (e.g., increased heart and respiratory rates, urination, tail flicking), approximately 60 minutes following the initial injection, we reversed the xylazine with 4.4 mg/kg of tolazoline HCl (Tolazine®, LLOYD Laboratories, Shenandoah, IA).

The need for adjustment to the standard deer handling procedures (Wildlife Investigations Lab 2010) became apparent when an animal experienced acute respiratory distress that resulted in mortality. We made three adjustments to mitigate the effects of respiratory depression, and none of the subsequent captures resulted in mortality. Due to the nature of the respiratory crisis encountered, some low SPO_2 values were not recorded because personnel were busy attending animals; hence, our results are based on what we observed in the field. We made the adjustments described below and low blood oxygen levels and respiratory rates improved markedly. We believe these adjustments will reduce capture-related mortality in black-tailed deer captured late in gestation.

Our first adjustment was with the amount and ratio of immobilizing agents. We began with 130 mg of Telazol® (*n* = 3; mean = 0.616 [*SE* = 0.030] mg/kg) and 130 mg of xylazine (*n* = 3; mean = 0.616 [*SE* = 0.030] mg/kg) at a 1:1 ratio (Wildlife Investigations Lab 2010). Because of the respiratory depression and bloat caused by the xylazine (Kreeger et al. 2002), we adjusted our mixture to 110 mg Telazol® (*n* = 3; mean = 0.478 [*SE* = 0.013] mg/kg) and 84 mg xylazine (*n* = 3; mean = 0.365 [*SE* = 0.010] mg/kg) at a ratio of 1.3:1. However, these dosages failed to produce unconsciousness in the animals and made handling difficult and unsafe for the subjects and personnel; an additional dosage of 100 mg of ketamine HCl (0.428 mg/kg) was administered to one animal to produce unconsciousness. A further adjustment to a dosage of 120 mg Telazol® (*n* = 5; mean = 0.572 [*SE* = 0.048] mg/kg) and 91 mg xylazine (*n* = 5; mean = 0.434 [*SE* = 0.036] mg/kg) at a 1.3:1 ratio enhanced respiration and produced adequate sedation for safe handling and sample collection. Our final reported dosage of the alpha$_2$-adrenergic drug xylazine is at a higher proportion than the 2:1 ratio of Telazol® to xylazine recommended by Kreeger et al. (2002), but lower than the 1:1 ratio recommended by the CDFW Wildlife Investigations Lab (2010). Further handling adjustments, described below, were necessary to mitigate the adverse effects of alpha$_2$-adrenergic drugs on respiration and cardiac function.

Our second adjustment involved the leg-binding configuration. The recommended method is to bind the front and back legs on the same side (Wildlife Investigations Lab 2010). However, among females in late gestation this configuration greatly increases pressure on the abdomen, thereby inhibiting its ability to expand during respiration. To alleviate abdominal pressure and enhance respiration, we bound the front legs together and the rear legs together, placing a third strap between the bindings to reduce the risk of injury to attending personnel as a result of kicking (Figure1). An alternative, but less safe, method is to leave the legs unbound during handling; this approach is sufficient, however, only for highly sedated animals.

Figure 1. —Suggested configuration for binding legs of chemically immobilized female black-tailed deer within one month of parturition that are experiencing respiratory distress. The front legs are bound together and the back legs are bound together, with a safety strap anchor providing adequate abdominal expansion for respiration and decreasing the potential for injury to personnel.

Our third adjustment involved body positioning. The recommended position for chemically immobilized deer is left-side lateral to minimize abdominal pressure and aspiration of rumen contents (Wildlife Investigations Lab 2010). However, we found that for animals near parturition this position did not allow for adequate abdominal expansion during respiration and inhibited eructation, which counteracts bloat. When SpO_2 readings dropped below 70% during handling, we immediately moved the animals into a sternal position with the legs folded ventrally, thus enhancing respiration by reducing pressure from the rumen and fetus. The head and neck were also held in an upright position to further promote unlabored respiration (Figure 2). After repositioning, an increase in respiratory rate, blood oxygen saturation, and frequency of eructation was noted. It is imperative that respiratory rate and SpO_2 be monitored continuously during handling, and the adjustments described above should be made as soon as the SpO_2 level drops below 70% for more than two minutes (Kreeger et al. 2002).

Figure 2. —Suggested sternal positioning of chemically immobilized female black-tailed deer within one month of parturition experiencing respiratory depression. The head and neck are held in an upright position to facilitate breathing, the body is held in a sternal position with the legs folded ventrally to provide relief from abdominal pressure caused by the rumen and fetal crowding.

We later continued our experimentation with xylazine dosages to minimize negative respiratory side-effects during a subsequent effort to capture black-tailed deer in September. During this session we captured 5 deer, 2 of which showed signs of respiratory distress during handling. On the first animal, SpO_2 fell to 31%, and immediately after adjusting the body position as described above, SpO_2 rose to ~ 45%; after administration of 100mg tolazoline (0.45 mg/kg), it returned to ~ 85%. SpO_2 for a second individual fell to 15%, and the individual actually stopped breathing. We immediately administered 100 mg tolazoline and SpO_2 again increased to ~85%.

We encourage open discussion among wildlife professionals regarding animal handling and safety, including adjustments to established procedures. There is a natural inclination to not share or discuss negative capture experiences (Jessup 2001), but open discussion of capture experiences — both positive and negative — is in the best interest of minimizing injuries or mortalities among study animals.

We do not recommend chemical capture of deer ≤1 month prior to parturition due to the potential for respiratory distress. However, we recognize there are times when captures are warranted during this period; in those cases the adjustments described above can reduce the likelihood of capture-related mortality. It is also crucial that field personnel understand the pharmacology of the chemical agent(s) they are using; this will allow them to develop strategies, on the spot if necessary, to minimize negative effects on study animals and, thereby, decrease risks of injuries or mortalities. Further research is needed on deer handling procedures, especially body positioning, and the optimal dosages of Telazol® and xylazine, to maintain adequate respiration and cardiac function during chemical immobilization.

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Treatment of laboratory waste formalin solutions with Neutralex®

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The California Department of Fish and Wildlife (CDFW) Stockton office has collected several thousand zooplankton, larval fish, fish diets, and other biological samples annually from the San Francisco Estuary that were processed in their laboratories. Most of those samples were fixed and preserved in a 10% formalin (3.7% formaldehyde with 1.0 to 1.5% methanol) solution and many were archived in 5 or 10% formalin solutions. The formalin solutions were often amended with sodium borate to increase the pH or buffered with sodium phosphate monobasic and sodium phosphate dibasic.

The process of rinsing, sorting, processing, and archiving those samples resulted in waste formalin solutions that were successfully treated with Neutralex® (Scigen Scientific, Gardena, CA, USA). An aldehyde neutralization agent, Neutralex® is a noncombustible and stable powder; however, contact with an acid solution of a pH of 4 or less releases sulfur dioxide gas (Scigen 2009). This note documents the procedures used to treat 5 to 10% waste formalin solutions with Neutralex® in the CDFW Stockton laboratories, and the results thereof. Our Neutralex® treatment procedures generally followed the manufacturer's procedures (Sakura 2003, Scigen 2010), adapted for our laboratories and waste formalin solutions.

Each chemical transfer and treatment was conducted in a fume hood. The waste formalin was decanted from the sample through a sieve (43 to 300 microns) to remove debris and organisms, and the waste formalin transferred to a ~10-liter treatment container (American MasterTech, item number FRC-03K). Because the reaction between Neutralex® and formalin was exothermic, treatment containers were frequently inspected and replaced if any evidence of cracking, thinning, or failure was detected. Treatment containers were labeled "Hazardous Waste, Formaldehyde" and stored under the fume hoods located in each of five laboratories until ~7.6 liters of waste formalin had accumulated. There were two treatment containers per laboratory, with one container used for treatment and the other for accumulation.

After ~7.6 liters of waste formalin accumulated in a treatment container, the container was moved to the sink in a fume hood. Using a pH meter (model 85005, Sper

Scientific, Scottsdale, AZ) calibrated daily as necessary, staff tested the pH of the waste formalin. Treatment of solutions with a pH <4.1 did not proceed until the pH was increased to near 7 with sodium borate. The pre-treatment pH of the waste formalin batches ranged from 5.2 to 9.9, with a mean of 7.5 (*n*=706, *SD*=0.78).

For treatment of ~7.6 liters of 5% formalin (1.85% formaldehyde), we used one and a half of the 0.75 kg Neutralex® pouches (1.13 kg), while for treatment of the same quantity of 10% formalin (3.7% formaldehyde), we used two Neutralex® pouches (1.50 kg). After the appropriate amount of Neutralex® was added to the treatment container, the container was capped, shaken to mix thoroughly, and placed in a tray under the sink with a "Neutralex Added" sign. The date, volume and percentage of formalin, pre-treatment pH, and employee's initials were recorded on a treatment log next to each hood.

We let the treatment container stand for 30 to 60 minutes during neutralization, and then moved it back to the fume hood, swirled or otherwise mixed the solution, and tested the pH and residual formaldehyde of the treated solution. We used EM Quant® formaldehyde test strips (product number 10036-1; EMD Millipore, Billerica, MA), which were semi-quantitative with a scale of 0 - 10 - 20 - 40 - 60 - 100 ppm; the test strips and reagent were stored in a refrigerator between use, per the manufacturer's instructions. A 5-ml sample of the treated waste was removed with a pipette and placed in the vial supplied with the formaldehyde test kit. Ten drops of the reagent were added to the vial and the vial gently swirled to mix. A test strip was dipped into the vial for one second, removed, and the long edge placed over a paper towel. After exactly one minute**,** the color on the test strip was matched to the color on the label of the test strip container. If the resultant formaldehyde concentration was >100 ppm, the waste solution was retreated. The resultant pH and formaldehyde concentrations were recorded in a log. The pH of treated batches ranged from 4.1 to 10.5, with a mean of 6.3 (*n*=706, *SD*=0.85). Residual formaldehyde of all treated batches tested at 0 ppm, although actual values potentially were >0 ppm because the lowest values of the test strips were 0 and 10 ppm.

Finding that waste formalin solutions with pre-treatment pH ranging from 5.2 to 9.9 could be successfully treated with Neutralex® is noteworthy, because California Department of Toxic Substances Control (DTSC) field demonstrations of Neutralex® treatment at several health-care facilities used neutral-buffered 10% formalin with a pre-treatment pH near 7 (DTSC 1997). Our post-treatment pH range of 4.1 to 10.5 was also broader than the post-treatment pH range of 5.5 to 7.75 reported from these demonstrations (DTSC 1997), likely because of how we buffered or otherwise adjusted the pH of our formalin solutions, variations in sample to formalin ratio, and variations in preservative age.

DTSC certified Neutralex® as a hazardous waste treatment technology for use by the health-care industry, in part is based on field demonstrations at several health-care facilities. The CDFW process of waste formalin treatment with Neutralex® resulted in formaldehyde concentrations of <10 ppm, consistent with findings from those field demonstrations (DTSC 1997).

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Books Received and Available for Review

The following books have been received, and are available for review. Individuals interested in preparing a review that will be published in *California Fish and Game* should contact the editor (Vern.Bleich@wildlife.ca.gov) with their request to do so.

Gotshall, D. W. 2012. Pacific Coast inshore fishes. Fifth edition. Sea Challengers, Monterey, California, USA. 363 pp. $9.99 (E-Book).

Kirkwood, S., and E. Meyers. 2012. America's national parks: an insider's guide to unforgettable places and experiences. Time Home Entertainment, Inc., New York, New York, USA. 208 pp. $24.95 (hard cover).

Love, M. S. 2011. Certainly more than you want to know about the fishes of the Pacific coast: a postmodern experience. Really Big Press, Santa Barbara, California, USA. 650 pp. $29.95 (soft cover).

Taylor, T. 2013. Fishing the river of time. Greystone Books, Vancouver, British Columbia, Canada. 206 pp. $19.95 (soft cover).

INFORMATION FOR CONTRIBUTORS

California Fish and Game is a peer-reviewed, scientific journal focused on the biology, ecology, and conservation of the flora and fauna of California or the surrounding area, and the northeastern Pacific Ocean. Authors may submit papers for consideration as an article, note, review, or comment. The most recent instructions for authors are published in Volume 97(1) of this journal (Bleich et al. 2011), and are accessible through the California Department of Fish and Wildlife web site (www.dfg.ca.gov/publications).

Planning is in progress to provide an avenue for authors to submit manuscripts directly through the web site, and to enable restricted and confidential access for reviewers. In the meantime, manuscripts should be submitted by e-mail following directions provided by Bleich et al. (2011). The journal standard for style is consistent with the Council of Science Editors (CSE) Style Manual (CSE 2006). Instructions in Bleich et al. (2011) supersede the CSE Style Manual where differences exist between formats.

Authors of manuscripts that are accepted for publication will be invoiced for charges at the rate of $50 per printed page at the time page proofs are distributed. Authors should state acceptance of page charges in their submittal letters. The corresponding author will receive a PDF file of his or her publication without additional fees, and may distribute those copies without restriction. Plans are underway to make the complete series of *California Fish and Game* available as PDF documents on the California Department of Fish and Wildlife web site.

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