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Notes from the Editor

We are more than half way through volume 101 of *California Fish and Game*, and issue three has just hit the streets. The year 2014 marked the 100th anniversary of the continuous publication of *California Fish and Game*, a milestone that most other professional journals have yet to match. Publication of volume 100 was a laborious task, and the papers that appeared in that volume had been solicited by the guest editors or the Editor-in-Chief. To those authors who waited patiently while the editorial staff processed the papers comprising Volume 100, thank you. You may rest assured that your contribution was not any less important than those included in the special issues, and they were processed by the editorial staff as received. The majority of papers for which publication was delayed have appeared in the first three issues of volume 101; a few remain in the queue, but will appear in 101(4). Again, thank you for your patience and for submitting the results of your research to be considered for publication in *California Fish and Game*.

Vernon C. Bleich, Ph.D.
Editor-in-Chief
California Fish and Game

About the Covers

Front.—Water is a resource upon which the people and wildlife of California depend. In the Sonoran Desert, mule deer (*Odocoileus hemionus eremicus*) make use of many wildlife water developments to help meet that need (top). Canals also carry water from the Colorado River to major metropolitan and agricultural areas. Lining of the earthen-sided All American Canal in Imperial County (middle left) with concrete (bottom left) was thought to have the potential to entrap mule deer watering at the canal. Unanticipated, but fortuitous mitigation, occurred because the construction process necessitated inclusion of “sheet pile seams”; these areas of rock and vegetation (bottom right) are used by mule deer to access water in the now concrete-lined canal. See the paper by Melanie Bucci and Paul Krausman in this issue for additional details; photos courtesy of M. Bucci.

Rear.—The coyote (*Canis latrans*) is among the most adaptable and prolific of wild canids, and the species has been the object of intense investigation as well as persecution for many years. In this issue, Kyle Marsh and Reginald Barrett relied on changes in visitation rates to water sources and other indices to suggest that weather-driven environmental factors, rather than lethal removal, is the most likely explanation for a decline in the relative abundance of coyotes on a central California ranch. Photo by S. Thompson, U.S. Fish and Wildlife Service.

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A fortuitous mitigation for desert mule deer along the All-American Canal

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We studied mule deer (*Odocoileus hemionus*) presence associated with the All-American Canal (AAC) before, during, and after the U.S. Bureau of Reclamation and Imperial Irrigation District replaced a 36.8-km section of the earthen canal in Imperial County, California with a concrete-lined canal. The concrete-lined canal had steeper sides and higher water velocities than the unlined canal, increasing the risk of mule deer drowning in the canal. Our objective was to determine if the concrete-lined canal had an effect on the occurrence of mule deer along the AAC based on observations, aerial surveys, track plots, and camera traps. We examined deer presence at the AAC prior to lining (2004–2006), during lining (2007–2009), and post-lining (2010–2014). We monitored 1-m^2 track plots north and south of the AAC from 2004 to 2010. We did not find deer south of the canal and deer were rarely found north of the canal from December to April; thus, during 2011–2014, we monitored areas north of the canal from May to November. We also monitored deer at two mitigation catchments (established based on the first years of the study), one previously established catchment, and a sheet pile seam (i.e., 6-m wide gap or seam where the canal has a piece of sheet metal covered with rip-rap rock and dirt instead of cement) that deer used to access the canal. During the pre-lining phase, only one deer was reported near the canal. During the lining-phase we detected deer in a small area north of and adjacent to the canal. There were occasional observations of deer: three that drowned and two that were rescued from the canal. During the post-lining phase we documented continued deer presence at the canal and mitigation catchments. One deer drowned in the canal and one was rescued. The number of deer tracks at the canal remained consistent from 2008 to 2010 and from 2011 to 2014 as did the number of photos; thus, the mitigation catchments did not reduce deer use of the canal. We recommend that the sheet pile seam deer use to access the canal be maintained and kept free of vegetation. Further, we conclude the development of water catchments for this small population of deer crossing sand dunes to acquire water was not necessary. Deer use of the sheet pile seam was unanticipated and fortuitous for deer attempting to acquire water from the AAC.

Key Words: All-American Canal, California, drowning, mitigation, mule deer, *Odocoileus hemionus,* water catchments

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Population growth and infrastructure development in the western United States depend on the availability of water. Over 12,000 km of canals carry water from rivers and reservoirs to industrial, residential, and agricultural users in California. Unfortunately, animals can drown in canals while attempting to cross or drink from them. During the last survey of mortalities of ungulates in canals in the late 1980s, there were ≥21 canals in nine western states and one Canadian province where ≥10 deer (*Odocoileus* spp.) drowned/year (Rautenstrauch and Krausman 1986). In 1977 and 1978, an average of 259 deer and five elk (*Cervus elaphus*) drowned in 22 U.S. Bureau of Reclamation (USBR) canals. More than 95% of ungulates that drown in USBR canals are deer (Latham and Verzuh 1971, Rautenstrauch and Krausman 1986). Other native ungulates that drowned in canals include pronghorn (*Antilocapra americana*), including endangered Sonoran pronghorn (*A. a. sonoriensis*; Arizona Game and Fish Department 1981), and bighorn sheep (*Ovis canadensis*). Ungulates also drown in concrete-lined canals in Europe (Peris and Morales 2004).

Besides causing additional mortalities, canals interfere with ungulate populations because they disrupt seasonal dispersal or daily movements and are attractive nuisances that can result in death (Busch et al. 1984, Fry 1984, Krausman and Hervert 1984). Deer have been entrapped in canals when dispersing (Menzel 1966, Shult 1968), or moving between agricultural fields (Gatz et al.1984), forage plots (Michny and McKevitt 1982), or to canals for water (Guenther et al. 1979, Michny and McKevitt 1982, Krausman and Hervert 1984).

Deer drown more often in canals during summer (Krausman 1985), although some investigators have reported high mortality rates from canals in November and December (Furlow 1969). Busch et al. (1984) reviewed canal design features and operation procedures that prevent trapped deer escaping from canals. Most canals in which deer drowned had concrete-lined side slopes of 2:1 or greater. Mud and algae on concrete canal walls often make it difficult for deer to escape, even when the water level is high (E. A. Seaman, U.S. Bureau of Reclamation, in litt., 1977). Deer also have trouble escaping from concrete-lined canals when the water velocity is too fast or too slow (Menzel 1966, Guenther at al. 1979, Busch et al. 1984, Fry et al. 1984). Further, water depth influences survival of deer that fall into canals (Boulders and Bailey 1980). Due to mortalities, biologists have worked with irrigation districts to minimize drownings.

There are two ways to prevent deer from drowning in canals: exclude them from the canal or provide a way for them to escape from the canal after entering. Some authors have concluded that excluding deer from entering canals is the most effective way to prevent drowning (Gubser 1960, Shult and Menzel 1969, Krausman 1985), but this is not always possible. Busch et al. (1984) identified three ways to prevent and discourage deer from entering canals: fencing, building crossing structures, and providing alternate water sources. Each of these options presents challenges. Fencing is expensive to construct and maintain, and may prevent deer from crossing canals, thereby disrupting migratory movements. Deer crossings have been constructed at many canals to prevent movements from being disrupted and are often successful (Gubser 1960, Latham and Verzuh 1971, Boulders and Bailey 1980, Krausman 1985). Alternate water sources built adjacent to some canals may also have contributed to decreased losses of deer (Rorabaugh and Garcia 1983).

Where methods used to prevent deer from entering a canal have failed or were impractical to implement, structures (i.e., metal grates, ladders, ramps) have been developed to help deer escape from canals, but with limited success (Gubser 1960, Shult and Menzel 1969, Boulders and Bailey 1980). With few exceptions (Richmond ramps; Fry et al. 1984), all of these examples demonstrate the importance of keeping deer out of canals.

The All-American Canal (AAC) is an important water delivery system for agriculture and power generation in the Imperial and Coachella Valley, California (Schaefer and O'Neill 2001). The AAC was built when the Boulder Canyon Project of 1928 was signed into law. It is owned by the USBR but the Imperial Irrigation District (IID) is responsible for maintenance and operation. To conserve water in the AAC (approximately 83,500,000 m^3/year), the USBR and IID replaced the existing earthen canal with a concrete-lined canal parallel to

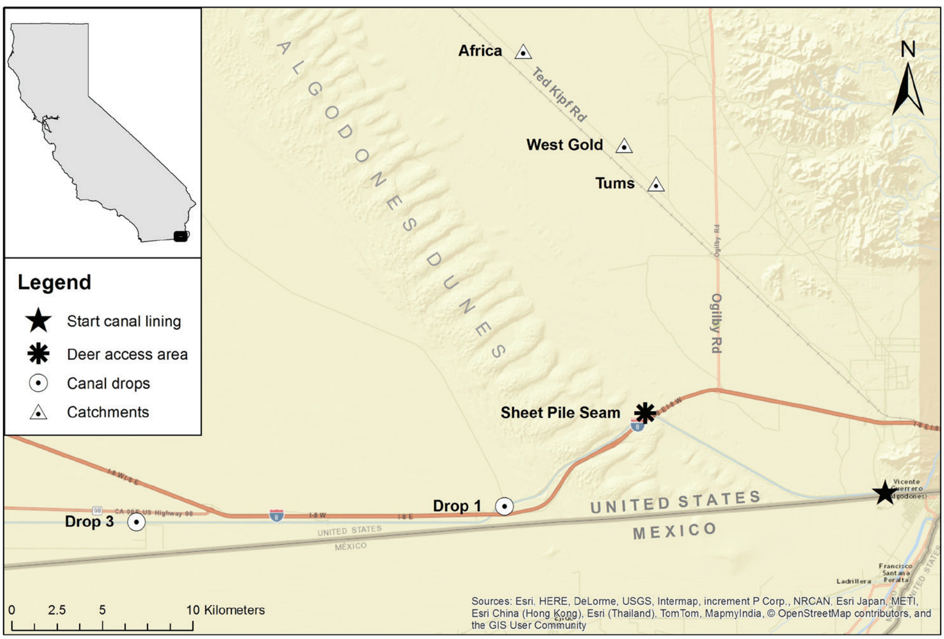

FIGURE 1.—Section of the All-American Canal, Imperial County, California that was concrete-lined from Pilot Knob to Drop 3, including locations of the sheet pile seam (used by deer to access the canal for water), mitigation catchments (Africa and Tums), and West Gold, a previously established catchment.

the existing canal (Figure 1). In June 2004, the IID issued an Environmental Commitment Plan and Addendum to the 1994 Environmental Impact Statement-Environmental Impact Report that included provisions to minimize deer mortality, as required by law.

The new concrete-lined canal has steeper sided slopes and water moves at higher velocities than in the unlined canal. Both conditions could cause higher risk of drowning to mule deer (*Odocoileus hemionus*) that attempt to drink from or attempt to cross the canal (Imperial Irrigation District 2004) and could be problematic because the population of deer in the Sonoran Desert of southeastern California is one of low density and is popular with hunters and recreationists (Thompson and Bleich 1993). Our objectives were to determine the presence of deer in the area where the canal was lined and if mitigation catchments minimized deer approaches to the AAC because of the added sources of water.

Materials and Methods

Study area.—The AAC lining project was in the Sonoran Desert, Imperial County, California, near the international border with Mexico (Figure 1). The AAC was lined for 36.8 km from 1.6 km west of Pilot Knob (32°43'04.6" N, 114°45'15.3" W) to Drop 3 (32°42'19.3"N, 115°07'30.8"W). The AAC originates at Imperial Dam on the Colorado River and flows westward into the Imperial Valley (Bransfield and Rorabaugh 1993). In the nearly 90 years since the canal's construction, deer have likely been in the general area, albeit in small and fluctuating numbers (Marshal et al. 2002, Marshal 2005, Marshal et al. 2006b).

The climate is arid with daytime summer temperatures >45° C and low annual rainfall ($\bar{x}$ = 70 mm in Imperial County, California; Marshal 2006b). Vegetation is typical of the Lower Colorado River Valley Subdivision of Sonoran Desert Scrub (Brown 1994). There are three main vegetation associations: creosote bush (*Larrea tridentata*) scrub, psammophytic scrub, and microphyll woodland. Creosote bush scrub is the most common, and additional typical plant species include brittlebush (*Encelia farinosa*) and burrobush (*Ambrosia dumosa*). Psammophytic scrub occurs in the dune system and the vegetation is adapted to shifting sand. Typical vegetation includes Mormon tea (*Ephedra nevadensis*), buckwheat (*Eriogonum deserticola*), desert twinbugs (*Dicoria canescens*), sandpaper plant (*Petalonyx thurberi*), desert panicgrass (*Panicum urvilleanum*), and fanleaf crinklemat (*Tiquilia plicata*). Microphyll woodland occurs on the alluvial fan along or within drainages from the East Chocolate Mountains and Cargo Muchacho Mountains that are north of the canal. Typical vegetation includes blue palo verde (*Parkinsonia florida*), desert ironwood (*Olneya tesota*), and smoke tree (*Psorothamnus spinosus*; Andrew 1994, RECON Environmental 2009).

Methods.—Our surveys consisted of track and road plot preparation and inspection, aerial surveys, camera traps, and contacts with regular users of the area (e.g., canal maintenance personnel, Border Patrol personnel, California Fish and Game wardens, Bureau of Land Management personnel). Additionally, we examined IID files related to deer in the project area.

The study was conducted in three phases: pre-lining (November 2004 through 2006), lining (2007–2009), and post-lining (2010–November 2014). The post-lining phase began when lining was complete and water had been transferred to the lined canal. During the pre-lining and lining phases, we surveyed the project area weekly for deer using road surveys and track plot surveys, and monthly aerial surveys from a Cessna 172 (Krausman and Etchberger 1993). We surveyed the project area weekly using 1-m^2 track plots (Popowski and Krausman 2002) set ≤3 km north and south of the AAC that were randomly selected but adjacent to roads (i.e., all roads were numbered and then selected from a random number generator). We checked for any tracks or pellets present, and cleared the plots by raking. We conducted observations of the landscape from the top of Pilot Knob (267 m; the highest elevated peak in the study area) to detect deer. We conducted road surveys by driving <25 km/hr along >56 km of roads (all of which had sandy substrate suitable for detecting tracks) to detect deer or deer sign (i.e., tracks or pellets). The roads were also dragged with tires by the Border Patrol to detect illegal border crossing activity in the area; dragged roads were also useful for detecting animal tracks.

Aerial surveys were conducted with a pilot and two observers flying 150 m above ground level at 130 knots. The area surveyed by air included Pilot Knob along the AAC west to Drop 3 as the southern boundary, then west along the Algodones Dunes, north to the railroad tracks north of the AAC that run parallel to Ted Kipf Road, and east to Ogilby Road (Figure 1). Deer tracks could easily be observed on sand dunes in the morning; thus, we also looked for deer and deer tracks when flying over the dunes.

There was a patch of vegetation (1 km × 0.5 km in size; hereafter referred to as the deer use area [DUA]) north of the AAC and west of the Interstate Highway 8 (I-8) bridge (32°44'59.9" N, 114°52'09.8" W) crossing the AAC. We surveyed the DUA because it became clear in the first few years of study that deer only crossed at this small patch when travelling from the north to the canal.

We established a road survey immediately adjacent to the AAC 0.64 km east of the I-8 bridge and continuing for 0.96 km west of the bridge on the road above the canal. This embankment above the canal was not as disturbed as the road immediately adjacent to the canal, which was used by canal workers on a near daily basis. We also searched for deer tracks along the canal to Test Hill, 3.0 km west of the bridge, by driving <25 km/hour with an observer verifying and counting the number of times tracks crossed the road. We used the number of tracks as an index of deer presence across years.

We could not maintain the same track plots and road surveys throughout the study because of AAC construction activity, illegal border crossing activity, recreationists (i.e., off-road vehicles), and we obtained a better understanding of areas used by deer as the project progressed. Thus, we ceased observations from Pilot Knob and weekly track plot inspections in April 2010 during the post-lining phase when many plots could not be maintained or it had been determined that they were in areas not used by deer. We also ceased monthly aerial surveys in April 2010 because of our increased knowledge of deer use of the project area.

During the post-lining phase, we changed our methods to detect mule deer use of the canal due to information obtained during the previous stages. Because evidence of deer was not observed south of the AAC during the pre-lining or lining phases we concentrated our searches north of the canal during the post-lining phase. We continued monitoring the road survey route near the I-8 bridge crossing that had been established in September 2007 after identifying deer tracks in the area from track plot surveys, and maintained those surveys throughout the duration of the study. We used ANOVA to compare the number tracks detected from 2008 to 2010 and from 2011 to 2014.

We also created track plots at two water catchments constructed during summer 2010, Tums (32°50'47.5"N, 114°52'04.0"W) and Africa (32°54'06.3"N, 114°56'01.4"W) in response to concerns regarding deer presence at the AAC. Those catchments were established in an effort to reduce movement of deer to the AAC by providing alternate sources of water. We also monitored another catchment constructed in 2000, West Gold (32°51’45.0”N, 114°53’01.2”W), which was between the two newly installed water catchments (Figure 1). We created track plots by raking the substrate around water catchments that deer would have to move through when going to water.

In addition to counting tracks on roads and determining deer presence at the catchments, we set up camera traps (DV-7SS, Leaf River Outdoor Products, Taylorsville, MS; Stealth Cam STC-AD3, Stealth Cam, Bedford, TX; Bushnell XLT Model 119456, Bushnell Outdoor Products, Overland Park, KS; Reconyx Hyperfire PC850, Recoynx, Holmen, WI) at the mitigation catchments and a sheet pile seam (i.e., a 6-m wide gap or seam where the canal has a piece of sheet metal covered with rip-rap rock and dirt instead of concrete; 32°45’03.2”N, 114°52’23.6”W) along the AAC. Cameras were set up 10 m from the water sources and were programed to take 1–3 photos each time a deer approached water; we could not distinguish between individual deer except on two occasions. We used the number of deer counted in photos as an index to compare across sites and time. We used ANOVA to compare deer presence based on photos between years at water sources (i.e., the AAC and catchments) and between water sources.

We continued weekly track surveys the first year of post-construction until 31 December 2010. We documented most deer presence from May to November from 2007 to 2010; beginning in 2011 we reduced weekly surveys to biweekly surveys from May to November that continued until the end of the project in November 2014.

Results

During the pre-lining phase (November 2004 to December 2006), only one deer was observed in the study area. A deer was photographed by IID personnel on the AAC roadway at Drop 1 (32° 42’ 43.0” N, 114° 56’ 34.9” W) in July 2006. This was the first documentation of deer near the canal during this study. We observed no other deer from the air or ground. We found no tracks or pellets present in our track plots or during road surveys, and we did not receive any reports of deer from other individuals working in the study area.

We first detected deer near the AAC on track plots north of the AAC and I-8 in the DUA beginning in June 2007 (during the lining phase). From June 2007 through 2008, we observed deer or deer tracks and sign in the DUA with the exception of December 2007 to May 2008 (Table 1). In 2009 we first documented deer tracks in February but, overall, we did not find deer or deer sign in the area until May. More deer tracks were observed from August to November than other months, with the most recorded in November 2009 (n = 533). We did not detect an annual difference in the number of tracks counted from 2008 to 2010 ($F_{2,33} = 0.78$, $SE = 118.43$, $P = 0.47$). We included 2010 because that was the last year of weekly monitoring throughout the year; thence, monitoring was performed twice each month from May to November.

Deer observations during the lining period were rare. We observed deer only four times in 2007, and one time each in 2008 and 2009. Deer were also occasionally seen near the mitigation catchments, and there were four other incidents involving deer that the AAC reported to us during the lining phase (P. R. Krausman and M. E. Bucci, Imperial Irrigation District, in litt., 2014).

Table 1.—Mule deer tracks and number of deer photographed located north of the All-American Canal (AAC), Imperial County, California at the junction of the canal and Interstate Highway 8 bridge. Tracks were counted 0.64 km east of the I-8 bridge along the canal, and 0.96 km to the west on the embankment above the canal. Photographs were taken at a sheet pile seam (32° 45' 03.2" N, 114° 52' 23.6" W).

	Lining phase			Post-lining phase								
Month	2007	2008	2009	2010	2011 Tracks	2011 Deer	2012 Tracks	2012 Deer	2013 Tracks	2013 Deer	2014 Tracks	2014 Deer
January		0	0	56								
February		0	4	0								
March		0	0	0								
April		0	0	0								
May		25	30	0	0		6	9	7	14	6	0
June	N/A[a]	83	45	0	0		32	37	0	2	66	31
July	N/A	227	149	129	2		45	52	21	22	43	56
August	N/A	332	159	291	218	28[b]	0	0	152	189	4	19
September	13	150	110	13	89	80	0	0	11	4	0	1
October	74	144	27	0	13	42	2	3	1	3	38	58
November	99	151	533	0	0		2	0	12	6	0	6
December	0	10	51	0								

[a]Deer tracks and pellets first observed north of I-8 where the canal goes under the freeway the first time west of Pilot Knob. There was no standardized method for counting tracks adjacent to the canal until September 2007.
[b]Start of camera monitoring.

Table 2.—Track observations (T; Y = deer tracks present, N = no deer tracks present) and number of deer (D) photographed at the Tums (Tu; 32° 50' 47.5" N, 114° 52' 04.0" W) and Africa (Af; 32° 54' 06.3" N, 114° 56' 01.4" W) water catchments north of the All-American Canal, Imperial County, California, 2010–2014.

	2010		2011				2012				2013				2014			
Month	T Tu	T Af	T Tu	D Tu	T Af	D Af	T Tu	D Tu	T Af	D Af	T Tu	D Tu	T Af	D Af	T Tu	D Tu	T Af	D Af
January																		
February																		
March																		
April																		
May			N		N		Y	7	Y		Y	10	Y	6	Y	45	Y	12
June	N[a]	N[a]	Y		Y		Y	17	Y		Y	13	Y	4	Y	75	Y	35
July[c]	N	N	Y	3[b]	Y		Y	3	N		Y	3	Y	31	Y	15	Y	34
August	N	Y	Y	1	Y	5[b]	N	0	Y	2	Y	0	Y	168	Y	25	Y	33
September	N	Y	N	1	Y	76	N	0	N	2	Y	9	Y	8	Y	22	Y	16
October	N	Y	N	0	Y	78	N	0	Y	36	Y	9	Y	35	Y	26	Y	209
November	N	Y	Y		Y		Y	0	Y		Y	0	Y	13	Y	126	Y	161
December	Y	Y																

[a]First track observations made.
[b]Start of camera trap monitoring.
[c]Africa catchment was broken and empty 11 July-26 July 2010.

Deer presence generally started off slow, gradually increased until August and then decreased until November. We found no annual difference in the number of tracks counted from 2011 to 2014 ($F_{3,24}$ = 0.52, *SE* = 52.01, *P* = 0.68). We obtained a similar result with the number of deer photos captured at the AAC from 2012 to 2014 ($F_{2,18}$ = 0.36, *SE* = 43.86, *P* = 0.70).

Based on the number of photos from the Tums catchment, deer presence increased in 2014 from 2012 and 2013 ($F_{2,18}$ = 7.65, *SE* = 23.58, *P* = 0.004; Table 2). Deer presence remained consistent in 2013 and 2014 at the Africa catchment ($F_{1,12}$ = 0.81, *SE* = 69.77, *P* = 0.39; Table 2). Deer presence was similar between Tums catchment and the AAC in 2012 ($F_{1,12}$ = 1.60, *SE* = 15.68, *P* = 0.23) and also between Tums and Africa catchments and the AAC in 2013 ($F_{2,18}$ = 2.03, *SE* = 60.63, *P* = 0.16).

We suspected that the West Gold catchment received more use than the mitigation catchments because we observed more tracks surrounding West Gold than the newer Tums or Africa catchments. We observed tracks at West Gold from April 2009 (when we began to monitor the West Gold catchment) to January 2010 and again beginning in June 2010 through the end of the year. From 2011 to 2014, we observed tracks during every month that we monitored except May 2011. In 2014 we documented 1,267 deer from photos ranging from 109 (September) to 294 (November). We also photographed more deer at West Gold than at the other two catchments and the AAC ($F_{3,24}$ = 7.71, *SE* = 63.56, *P* = 0.001) in 2014.

The cameras also took photos of one uniquely marked deer at the catchments and at the canal, demonstrating that some deer continued to use the both the canal and catchments as water sources. Furthermore, a collared female was photographed at the Africa catchment in September and October of 2011. The only known investigator that collared deer in the area was Marshal (2005) and deer using the AAC and mitigation catchments were likely from the same population.

Discussion

During the first two years of the study, only one deer was observed along the canal that was to be lined. This was not unusual as the canal traversed sand dunes that are not considered deer habitat. Mule deer occupy washes (Krausman et al. 1985) in desert habitats and bajadas east of the Algodones Dunes and occupy mountain ranges and riparian zones along the Colorado River (Marshal et al. 2006a). However, in a recent study of mule deer in the Sonoran Desert of southeastern California (33° 00' N, 114° 45' W) none of the >34 deer that were captured and radio-collared in the East Chocolate and Cargo Muchacho mountains north of the AAC ever approached closer than 5 km of the ACC (Marshal 2005, Marshal et al. 2002, Marshal et al. 2006b). Deer in the project area likely come from the mountains north of the AAC as we occasionally obtained photographs of collared deer from studies by Marshal (2005) and Marshal et al. (2002, 2006a, 2006 b). Deer use of the study area is likely minimal because, in general, it does not contain the habitat components required by mule deer.

Deer eventually were documented at the AAC at a single site that offered access to the canal from which to drink, the sheet pile seam. Deer in deserts often have home ranges >90 km^2 (Krausman and Etchberger 1993, 1995) that include numerous sources of water and other resources (McNab 1963, Krausman 1985, Rautenstrauch and Krausman 1989, Hayes and Krausman 1993); deer using the AAC surely used other sources of water, and the area is likely used for short periods to obtain water from the AAC. We did not collect any data on the movements of deer or of their use of surrounding parts of the landscape, so our conclusions are based only on evidence of deer presence at the DUA, sheet pile seam, the mitigation catchments, and the West Gold Catchment. The West Gold catchment, established in 2000, was probably more familiar to deer than either of the mitigation catchments (Tums and Africa), which did not reduce deer use of the canal from 2011 to 2014. We were able to determine presence of deer near the AAC and the mitigation catchments, but could not measure the importance of those catchments to the deer using them. Based on photographs and tracks, we concluded the mitigation catchments were not effective in reducing deer use of the canal.

We collected data in the same manner in the lining and post-lining phases. Some plots had to be moved due to safety concerns associated with illegal border activity, but were replaced with others. During the lining phase, however, heavy equipment precluded systematic data collection because plots were often destroyed by construction activity and, thus, were relocated to different areas. Deer crossing the canal came from the north and, to our knowledge, are the only deer that have been reported south of the AAC during this study. It is unlikely deer entered the study area from the south because of the fence along the international border between the United States and Mexico that parallels the ACC in the study area.

The study began in 2004, but deer were not detected until 2007. Although we have no information to suggest why deer apparently did not use the area, we suggest they were never abundant even if present. Presence of deer was, however, detected later in the lining phase as well as during the post-lining phase of the study. During 2008, no evidence was recorded until May; use peaked in August and remained consistent from September through November, but declined again in December. More tracks were detected in November 2009 than in any other month. Our track results in 2009 paralleled the number of drowning deaths reported by Furlow (1969) in the Mohawk Canal, Arizona but were not consistent with our later results. Overall, more deer visited the canal from July to November than in other months.

There was very little rainfall in 2009 compared to other years. For example, there were approximately 7, 2, and 8 cm of rain in 2008, 2009, and 2010, respectively (National Climatic Data Center; http://www.necd.noaa.gov/). The high number of tracks recorded likely reflects increased movement to the canal for water by ≥1 group of deer, but not necessarily by additional deer. There was also intense construction activity at this time that may have caused increased rates of movement to and away from the AAC.

Why we began to detect deer near the AAC during the lining phase is unknown. One possibility was the limited scope of the study. We were interested only in deer that were present in areas adjacent to the canal. Because we did not know how many deer were in the area, where the population obtained water, the availability of water for deer outside of this limited study area, or the home ranges of deer using the AAC, we did not have the information necessary to make broader inferences.

Mortality from deer falling in the canal and drowning was not a major issue during this study. During 10 years of monitoring, four deer drowned and three were rescued from the canal. The mitigation waters were used, but some deer that used those catchments also used the canal. Photographs of naturally marked deer at the canal and at the catchments supported our conclusion that the mitigation catchments did not "short-stop" deer movements to the AAC during this study.

Marshal et al. (2006b) estimated that population densities from 1999 to 2004 ranged from 0.05–0.13 deer/km^2. Ungulate populations in deserts are generally small and additional mortality (e.g., from drowning) is usually additive (Krausman 1985, Krausman and Leopold 1986). Nevertheless, creating additional water sources to mitigate for the loss of the AAC as a water source was not supported by our data. Deer used the mitigation catchments but continued to use the AAC as well. Because biologists do not want deer to use the area adjacent to the AAC, establishing water catchments near or adjacent to the canal was not recommended (Krausman 2009, Imperial Irrigation District Interim Report, in litt. 2009). The creation of the mitigation water sources between the AAC and the mountains to the north likely did not serve the intended purpose of precluding deer from travelling to the AAC, as several existing water sources that were used by deer already were available. Indeed, some deer continued to use the AAC and use of the canal did not decrease significantly once the two new water catchments were constructed.

In summary, deer use the AAC north of I-8 and some have died accessing the canal, albeit only a few. To eliminate mortality from the canal, the canal would have to be fenced from Test Hill to Ogilby Road (Figure 1). We do not think this is a reasonable management approach if managers are willing to accept mortalities from time to time as documented herein. It is important, however, to maintain the design feature (referred to as the sheet pile seam) that deer use to access the AAC.

The sheet pile seam is the only section of the canal where we documented any use during this investigation. Although it was not planned to offer deer safe passage to the cement-lined AAC, it has been a design element that has minimized deer drownings and may be useful in other canals. Because the sheet pile seam is not concrete-lined, however, vegetation that grows through the rip-rap must be continually trimmed to offer safe access to the AAC. Finally, and in the interest of conserving limited dollars for conservation, our results suggest that mitigation to offset impacts to deer be considered in the context of population-level impacts rather than out of concern for the loss of individual animals.

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Literature Cited

Andrew, N. G. 1994. Demography and habitat use of desert-dwelling mountain sheep in the East Chocolate Mountains, Imperial County, California. M.S. Thesis, University of Rhode Island, Kingston, USA.

Arizona Game and Fish Department. 1981. The Sonoran pronghorn. Special Report No. 10. Arizona Game and Fish Department, Phoenix, USA.

Boulders, J., and J. Bailey. 1980. Big game loss monitoring study: Navajo Indian Irrigation Project. Final Report contract number 7-07-50-VO959. U.S. Bureau of Reclamation, Amarillo, Texas, USA.

Bransfield, R., and J. Rorabaugh. 1993. Final Fish and Wildlife Coordination Act Report, All-American Canal lining project, Imperial County, California. U.S. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada, USA.

Brown, D. E. (editor). 1994. Biotic communities: southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City, USA.

Busch, D. E., J. C. Rorabaugh, and K. R. Rautenstrauch. 1984. Deer entrapment in canals of the western United States: a review of the problem and attempted solution. Pages 95-100 *in* P. R. Krausman and N. S. Smith, editors. Deer in the southwest: a symposium. School of Renewable Natural Resources, University of Arizona, Tucson, USA.

Fry, E. M., V. L. Wyman, and E. H. Yoeman. 1984. A method for evaluating the effectiveness of a deer protection system on a concrete-lined canal with comments on planning these systems. Pages 647-658 *in* A. F. Crabtree, editor. Third international symposium on environmental concerns in rights-of-way management. Mississippi State University, Mississippi State, USA.

Furlow, B. 1969. The Wellton-Mohawk Canal incident. Arizona Wildlife Views 12(2):22-25.

Gatz, T., G. Brucker, W. Otto, S. Rothe, and D. Orthmeyer. 1984. Wildlife use of an irrigation canal rights-of-way in the prairie pothole region of North Dakota. Pages 630-639 *in* A. F. Crabtree, editor. Third international symposium on environmental concerns in rights-of-way management. Mississippi State University, Mississippi State, USA.

Gubser, C. E. 1960. An inquiry into the effects of reservoirs and canals on big-game migrations. Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissioners 40:42-52.

Guenther, H. R., F. P. Sharpe, and P. Strauss. 1979. Mule deer losses—Mohawk Canal, Arizona: a problem identified—a solution sought. Pages 642-644 *in* G. A. Swanson, editor. The mitigation symposium: a national workshop on mitigating losses of fish and wildlife habitats. General Technical Report RM-65. U.S. Forest Service, Fort Collins, Colorado, USA.

Hayes, C. L., and P. R. Krausman. 1993. Nocturnal activity of female desert mule deer. Journal of Wildlife Management 70:197-201.

Imperial Irrigation District. 2004. Environmental commitment plan and addendum to the All-American Canal Lining Project EIS-EIR. California State Clearinghouse Number SCH90010472. Imperial Irrigation District, Imperial, California, USA.

Krausman, P. R. 1985. Impacts of the Central Arizona Project on desert mule deer and desert bighorn sheep. Contract Number 9-07-30-X069. U.S. Bureau of Reclamation, Phoenix, Arizona, USA.

Krausman, P. R., and R. C. Etchberger. 1993. Effectiveness of mitigation features for desert ungulates along the Central Arizona Project. Final Report 9-C5-32-00350. U.S. Bureau of Reclamation, Phoenix, Arizona, USA.

Krausman, P. R., and R. C. Etchberger. 1995. Response of desert ungulates to a water project in Arizona. Journal of Wildlife Management 59:292-300

Krausman, P. R., and J. J. Hervert. 1984. Impacts of the Granite Reef Aqueduct on desert ungulates. Pages 640-646 *in* A. F. Crabtree, editor. Third international symposium on environmental concerns in rights-of-way management. Mississippi State University, Mississippi State, USA.

Krausman, P. R., and B. D. Leopold. 1986. The importance of small populations of desert bighorn sheep. Transactions of the North American Wildlife and Natural Resources Conference 51:52-61.

Krausman, P. R., K. R. Rautenstrauch, and B. D. Leopold. 1985. Xeroriparian systems used by desert mule deer in Texas and Arizona. Pages 144-149 *in* R. R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre, editors. Riparian ecosystems and their management: reconciling conflicting uses. General Technical Report RM-120. U.S. Forest Service, Fort Collins, Colorado, USA.

Latham, H. S., and J. M. Verzuh. 1971. Reducing hazards to people and animals on Reclamation canals. Engineering and Research Center Report Number REC-ERC-71-36. U.S. Bureau of Reclamation, Denver, Colorado, USA.

Marshal, J. P. 2005. Interactions of mule deer, vegetation, and water in the Sonoran Desert. Ph.D. Dissertation, University of Arizona, Tucson, USA,

Marshal, J. P., V. C. Bleich, P. R. Krausman, M. L. Reed, and N. G. Andrew. 2006a. Factors affecting habitat use and distribution of desert mule deer in an arid environment. Wildlife Society Bulletin 34:609-619.

Marshal, J. P, P. R. Krausman, V. C. Bleich, W. A. Ballard, and J. S. McKeever. 2002. Rainfall, El Niño, and dynamics of mule deer in the Sonoran Desert, California. Journal of Wildlife Management 66:1283-1289.

Marshal, J. P., L. M. Lesicka, V. C. Bleich, P. R. Krausman, G. P. Mulcahy, and N. G. Andrew. 2006b. Demography of desert mule deer in southeastern California. California Fish and Game 92:55-66.

McNab, B. K. 1963. Bioenergetics and the determination of home range size. American Naturalist 97:133-140.

Menzel, K. 1966. Deer and the Ainsworth Canal. Nebraska Game and Parks Commission, Bassett, USA.

Michny, F., and J. J. McKevitt. 1982. Tehama-Colusa Canal deer study. Final report. U.S. Bureau of Reclamation, Mid-Pacific Regional Office, Sacramento, California, USA.

Peris, S., and J. Morales. 2004. Use of passages across a canal by wild mammals and related mortality. European Journal of Wildlife Research 50:67-72.

Popowski, R. J., and P. R. Krausman. 2002. Use of crossings over the Tucson Aqueduct by selected mammals. The Southwestern Naturalist 47:363-371.

Rautenstrauch, K. R., and P. R. Krausman. 1989. Influence of water availability and rainfall on movements of desert mule deer. Journal of Mammalogy 70:197-201.

Rautenstrauch, K. R., and P. R. Krausman. 1986. Preventing desert mule deer drownings in the Mohawk Canal, Arizona. Contract Report 9-07-30-X0069. U.S. Bureau of Reclamation, Boulder City, Nevada, USA.

RECON Environmental, Inc. 2009. Biological Assessment for the Imperial Sand Dunes Draft. Recreation Area Management Plan-Draft Environmental Impact Statement. Prepared for U.S. Department of the Interior. San Diego, California, USA.

Rorabaugh, J., and J. R. Garcia. 1983. An evaluation of wildlife response to windmill wells at the Coachella Canal and Algodones Sand Dunes, Imperial County, California. California Department of Fish and Game and U.S. Bureau of Reclamation, Long Beach, California, USA.

Schaefer, J., and C. O'Neill. 2001. The All-American Canal: an historic properties inventory and evaluation. ASM Affiliates, Encinitas, California, USA.

Shult, M. J. 1968. Incidence of deer in the Nebraska concrete-lined Ainsworth Irrigation Canal. M.S. Thesis, Iowa State University, Ames, USA.

Shult, M. J., and K. E. Menzel. 1969. Some observed deer behavior in relation to an irrigation canal in Nebraska. Iowa State Journal of Science 43:335-340.

Thompson, J. R., and V. C. Bleich. 1993. A comparison of mule deer survey techniques in the Sonoran Desert of California. California Fish and Game 79:70-75.

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Length-weight and length-length relationships, condition index, and trophic level of *Sphyraena idiastes* Heller and Snodgrass, 1903 (Teleostei: Sphyraenidae)

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The pelican barracuda (*Sphyraena idiastes* Heller and Snodgrass, 1903) is a schooling pelagic species inhabiting waters as deep as ~100 m and is common throughout the southeastern Pacific and present at least occasionally along the western coast of the Baja California peninsula and in the Gulf of California (Merlen 1988, Sommer 1995, Grove and Lavenberg 1997, Robertson et al. 2010, Gonzalez-Acosta et al. 2013). This species is caught commercially in the southeastern Pacific using gill-net and hook-and-line fishing techniques (Jimenez-Prado and Bearez 2004); however, despite its commercial value in artisanal fisheries, its biology is poorly known (e.g., Froese and Pauly 2015). In this study we provide the first appraisals of its length-weight (L-W) and length-length (L-L) relationships, Fulton's condition index, and data on its trophic ecology based on specimens caught in the northernmost range of its distribution.

This study is based on specimens from different localities on the outer coast of the Baja California peninsula and in the Gulf of California (see Gonzalez-Acosta et al. 2013 for locality coordinates). Specimens were caught with gill nets of 7.5 cm and 15 cm mesh size (n = 7), trolling with artificial lures (n = 13), and with spear gun while scuba diving (n = 1). All specimens were identified using pertinent literature (Heller and Snodgrass 1903, Sommer 1995, Bearez 2008), measured to the nearest 0.1 cm (SL and TL), weighed (g), and sex was determined by macroscopic examination of gonads. Some food items were determined by inspection of a few stomachs.

The length-weight regression [LWR] (Ricker 1975) was calculated from 15 freshly collected specimens using the equation: log W = log ***a*** + ***b*** log L, where W is the weight (g) and L is the standard length (mm). The "***b***" value was derived by Student's *t*-test. The SL-TL relationship was calculated by simple linear regression. The condition index of Fulton (K) was estimated using the equation $K = [100*W/L^3]$.

The trophic-level of the pelican barracuda was based on the trophic determination of the difference between the isotope composition of the consumer and its food source, appraised through analysis of stable isotopes (SIA) of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) (see Aurioles-Gamboa et al. 2013). Additionally, we estimated the isotopic contribution as a percentage of potential prey items in the diet through a multi-source SIA in R [SIAR] model, a Bayesian mixture model that allows incorporation of several sources and the estimation of the uncertainty associated with isotopic values from prey in relation to those of the predator (Parnell et al. 2008, 2010).

A total of 20 individuals of the pelican barracuda was examined (Table 1): three males (277–560 mm SL, 315–640 mm TL, and 319–961 g), six females (353–541 mm SL, 412–598 mm TL, and 278.2–860 g), and eleven immature (57–455 mm SL, 64–515 mm TL, and 0.5–440 g). Immature fish were the most abundant group in this study, comprising 57.1% of the total sample, their predominance perhaps a consequence of the sampling methods employed. A previous record of total length (910 mm) reported for an "unsexed fish" from the Galapagos Islands (Merlen 1988, Froese and Pauly 2015) contrasts with the maximum total length of one of our male specimens (640 mm) from Punta Diablo (Table 1).

Table 1.—Biometry and meristics from 6 females (F), 3 males (M) and 11 immature (I) specimens of pelican barracuda from the outer coast of the Baja California peninsula and Gulf of California (see Gonzalez-Acosta et al. 2013). Values in parentheses are proportion of the standard length and values in brackets expressed as proportion of head length; *n* = number of individuals.

Measurements (mm) & meristics	Location										
	Bahia Asuncion		Punta Diablo		Guaymas area			Puerto San Carlos	Guerrero Negro	Isla San Esteban	
	F	M	F	M	I	F	M	I	F	I	F
Standard length	353.0-376.0	363.0	470.0	560.0	57.0-365.0	397.0	277.0	359.8	541.1	390.0-455.0	423.3
Total length	412.0-440.0	428.0	545.0	640.0	64.0-433.0	466.0	315.0	379.4	598.3	470.0-515.0	495.6
Weight (g)	278.2-349.5	319.4	860.0	891.0	0.5-286.0	396.0	96.1	271.0	779.0	300.0-440.0	487.0
Head length	112.0-116.0 (30.8-31.7)	111.0 (30.6)	143.0 (30.4)	170.0 (30.3)	22.2-112.1 (30.7-38.6)	117.6 (25.2)	87.1 (31.4)	108.9 (30.3)	154.8 (28.6)	113.4-128.0 (27.0-29.8)	123.9 (29.3)
Body depth	46.0-64.0 (13.0-17.0)	51.0 (14.0)	79.0 (16.8)	64.0 (11.4)	4.5-40.0 (10.9-11.2)	42.3 (10.6)	31.1 (11.2)	44.6 (12.4)	59.4 (10.9)	43.0-54.9 (11.0-13.4)	48.7 (11.5)
Snout length	47.5-48.0 [41.4-42.4]	49.0 [44.1]	69.0 [48.2]	82.0 [48.2]	8.1-49.4 [34.9-44.0]	51.4 [43.7]	35.1 [40.3]	47.5 [43.6]	71.9 [46.4]	51.1-56.4 [44.0-45.3]	59.9 [48.3]
Orbit diameter	13.0-14.0 [11.6-12.1]	14.0 [12.6]	16.5 [11.5]	18.0 [10.6]	3.5-18.1 [13.4-16.8]	19.8 [16.8]	12.5 [14.3]	17.0 [15.6]	15.9 [10.3]	14.8-17.1 [12.9-13.4]	18.7 [15.1]
Postorbital length	43.0-47.0 [38.4-40.5]	46.0 [41.4]	59.5 [41.6]	68.0 [40.0]	7.3-47.9 [31.5-42.7]	48.6 [41.3]	33.2 [38.1]	46.0 [42.3]	62.7 [40.5]	46.2-54.9 [40.7-43.0]	52.3 [42.2]
Pectoral fin length	34.0-38.0 [30.5-32.7]	32.0 [28.8]	43.0 [30.0]	54.0 [31.7]	2.3-34.4 [9.4-30.7]	40.3 [34.2]	26.0 [28.9]	35.2 [30.9]	42.5 [27.4]	35.0-42.3 [30.0-33.6]	37.0 [29.8]
Pelvic fin length	30.0-34.0 [26.8-29.3]	31.0 [27.9]	39.5 [27.6]	48.0 [28.2]	4.6-31.0 [19.8-28.9]	36.3 [30.8]	25.2 [28.9]	31.1 [28.6]	43.8 [28.3]	34.2-42.9 [27.8-36.8]	37.1 [29.9]
Dorsal fin elements	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9	V-I, 9
Anal fin elements	II, 9	II. 9	II, 8	II, 8	II, 8	II, 8	II, 8	II, 8	II, 8	II, 8	II, 8
Pectoral fin rays	14	14	14	13	13	13	13	13	13	13	13
Lateral line scales	133	135	148	146	134-139	136	136	135	135	135-138	141
n	2	1	1	1	6	1	1	1	1	4	1

Length-weight (L-W) and length-length (L-L) relationships calculated from 15 of our specimens using a logarithmic transformation of the linear regression equation, showed good fit for the linear regression for the overall population ($r^2 > 0.911$, $P < 0.001$; Figure 1, Table 2). These data represent the first assessment of LWR and LLR for the species, and may prove useful in future regulation of its artisanal fishery. At this time, this fishery in the southeastern Pacific is currently assessed as not overfished (Jimenez-Prado and Bearez 2004).

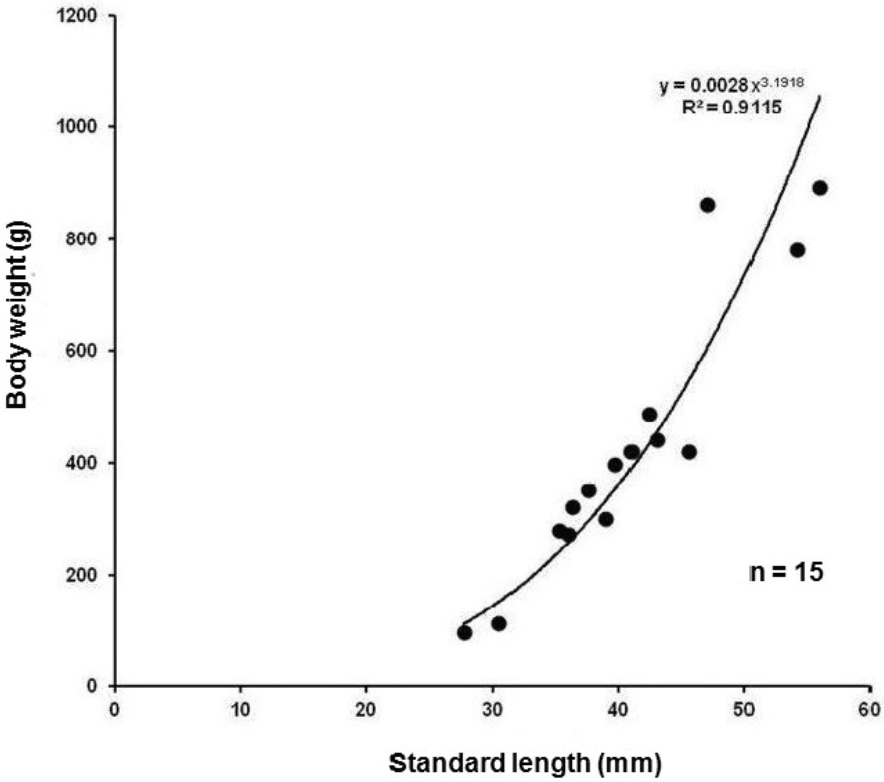

Figure 1.—Length-weight relationships of pelican barracuda (*Sphyraena idiastes*) from the northeastern Pacific Ocean.

Table 2.—Parameters of length-weight (LW) and length-length (L-L) relationships from 15 freshly collected specimens of pelican barracuda from the outer coast of the Baja California peninsula and in the Gulf of California.

Length (mm)				95% CI of *b*		
Min.	Max.	*Log a*	*b*	Min.	Max.	r^2
277	560	-2.556	3.192	2.596	3.787	0.911

Parameters of length-length relationships to convert SL to TL
$a = 3.034$ $b = 1.075$ $r = 0.934$

The determined *b*-value (3.19) (Table 2) is within the range of 2.5 to 3.49 reported for other barracuda species, such as the great barracuda, *S. barracuda* (e.g., Froese and Pauly 2015). The Student's *t*-test indicates isometric growth ($b = 3.19$; $t = 0.695$, $d.f. = 13$, $P < 0.001$) for the pelican barracuda. Isometric growth assumes that body shape and proportions do not change with increase in length (Ricker 1975); alternatively, it may be due to homogeneity in body form and condition of the 15 specimens analyzed herein (e.g., Grupta et al. 2011).

The overall mean of Fulton´s condition index (0.574) for our specimens appears to indicate unsuitable environmental conditions for the pelican barracuda in the northern part of its range, perhaps relating to state of sexual maturity or fitness (e.g., Williams 2000, Froese 2006). Information on the L-W and L-L relationships and Fulton's index of condition has not been reported previously for pelican barracuda (e.g., Froese and Pauly 2015). Thus, our results represent the first appraisal of its population parameters. These should be considered as preliminary and need to be corroborated in future population surveys throughout its wide distributional range.

Stomach contents of nine specimens were examined for food material. However, only three contained food items: two (male 560 mm SL and female 376 mm SL) had semi-digested remains of fishes; the third (female 470 mm SL) contained an individual (~190 mm SL) Pacific sardine (*Sardinops sagax*) identified by means of its urohyal bone morphology (Figure 2; Burnes-Romo 2007). Pacific sardine is a pelagic-neritic species occurring between the surface and ~200 m (Whitehead 1985). This finding corroborates this sardine in the diet reported for pelican barracuda by Grove and Lavenberg (1997) and also suggests a preference of pelican barracuda for pelagic-neritic habitats.

FIGURE 2.—Urohyal bone of Pacific sardine (*Sardinops sagax*) from the stomach contents of a pelican barracuda (*Sphyraena idiastes*; 470 mm SL) from the northeastern Pacific Ocean.

Based on four of our specimens caught off Isla San Esteban in the north-central Gulf of California (see Gonzalez-Acosta et al. 2013), Aurioles-Gamboa et al. (2013) estimated a trophic-level of 4 for pelican barracuda, which falls within values ($\bar{x} = 4.5 \pm 0.8$ [*SE*]) reported for this species (Froese and Pauly 2015) and is similar to other large predatory pelagic fishes such as bonito, swordfish and tunas (Stergiou 2005). The isotopic analyses of 30 specimens considered as potential prey species for pelican barracuda indicate that the highest percentages of contribution (33 ± 13%) to the diet are likely provided by Panama lanternfish (*Benthosema panamense*) and flatiron herring (*Harengula thrissina*) whereas Pacific sardine and the jumbo squid (*Dosidicus gigas*) contribute with lower percentages (21 ± 12%). The isotopic signature of the pelican barracuda depicts the contribution of its potential prey species over long periods of time, as well as the complex interaction between them via the assimilation of energy or mass flux through different pathways (Post 2002). Our results stress the importance of further population surveys on pelican barracuda to provide additional data on its life history throughout the tropical eastern Pacific.

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Literature Cited

Aurioles-Gamboa, D., M. Y. Rodriguez-Perez, L. Sanchez-Velasco and M. F. Lavin. 2013. Habitat, trophic level, and residence of marine mammals in the Gulf of California assessed by isotope analysis. Marine Ecology Progress Series 488:275-290.

Bearez, P. 2008. Occurrence of *Sphyraena qenie* (Sphyraenidae) in the tropical eastern Pacific, with a key to species of barracudas occurring in the area. Cybium 32:95-96.

Burnes-Romo, L. A. 2007. Urohiales de especies selectas de peces del Pacifico oriental. Bachelor of Science Thesis, Universidad Autonoma de Baja California Sur, La Paz, Mexico.

Froese, R. 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22:241-253.

Froese, R., and D. Pauly (editors.). 2015. Fishbase [Internet]. World Wide Web publication [version 02/2015]. Available from: www.fishbase.org

Gonzalez-Acosta, A. F., L. T. Findley, G. Ruiz-Campos, L. A. Burnes-Romo, and H. Espinosa Perez. 2013. Extreme northern range extension of the Pelican barracuda *Sphyraena idiastes* (Perciformes: Sphyraenidae) in the eastern Pacific. Journal of Applied Ichthyology 29:655-657.

Grove, J. S., and R. J. Lavenberg. 1997. The fishes of the Galapagos Islands. Stanford University Press, Stanford, California, USA.

Grupta, B. K., U. K. Sarkar, S. K. Bhardwaj, and A. Pal. 2011. Condition factor, length-weight and length-length relationships of an endangered fish *Ompok pabda* (Hamilton 1822) (Siluriformes: Siluridae) from the River Gomti, a tributary of the River Ganga, India. Journal of Applied Ichthyology 27:962-964.

Heller, E., and R. E. Snodgrass. 1903. Papers from the Hopkins Stanford Galapagos Expedition, 1898-1899. XV, New fishes. Proceedings of the Washington Academy of Science 5:189-229.

Jimenez-Prado, P., and P. Bearez. 2004. Peces marinos del Ecuador continental. SIMBIOE/NAZCA/IFEA, Quito, Peru.

Merlen, G. 1988. A field guide to the fishes of Galapagos. Wilmot Books, London, United Kingdom.

Parnell, A., R. Inger, S. Bearshop, and A. L.Jackson. 2008. SIAR: stable isotope analysis in R. Available at http://cran.rproject.org/web/packages/siar/index.html

Parnell A. C., R. Inger, S. Bearshop, and A. L. Jackson. 2010. Source partitioning using stable isotopes: coping with too much variation. PLoS ONE 5:e9672.

Post, D. M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. Ecology 83:703-718

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Department of Environment, Fisheries and Marine Service, Ottawa, Ontario, Canada.

Robertson, R., B. Collette, H. Molina, A. G. Guzman-Mora, and E. Salas. 2010. *Saphyraena idiastes*, *in* IUCN 2013 [Internet]. IUCN Red List of Threatened Species; Version 2013.2 [Accessed 22 June 2015]. Available at: www.iucnredlist.org

Sommer, C. 1995. Sphyraenidae. Barracudas, picudas. Pages 1618-1621 *in* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter and V. Niem, editors. Guia FAO para identificacion de especies para los fines de la pesca. Pacífico Centro-Oriental, Vol. 3. FAO, Rome, Italy.

Stergiou, K. I. 2005. Fisheries impact on trophic levels: long-term trends in Hellenic waters. Pages 326-329 *in* E. Papathanassiou and A. Zenetos, editors. State of the Hellenic marine environment. Hellenic Centre for Marine Research, Athens, Greece.

Whitehead, P. J. P. 1985. FAO Species Catalogue. Vol. 7. Clupeoid fishes of the world (suborder Clupeioidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part 1. Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis 125:1-303. FAO, Rome, Italy.

Williams, J. E. 2000. The coefficient of condition of fish. Pages 1-2 *in* J. C. Schneider, editor. Manual of fisheries survey methods II: with periodic updates. Fisheries Special Report 25. Michigan Department of Natural Resources, Ann Arbor, USA.

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Abundance, size, and occurrence of *Arbacia stellata* in Orange County, California

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Key words: *Arbacia stellata*, El Niño, *Arbacia incisa*, kelp restoration, Laguna Beach, marine protected area, MPA, recruitment, sea urchin

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The geographic range of the sea urchin *Arbacia stellata* extends along the Pacific coast of North, Central and South America from southern California to Peru, and also includes the Galapagos Islands and the mainland and peninsular coasts of the Gulf of California (Mortensen 1935, Clark 1948, Brusca 1980, Houston 2006). *Arbacia stellata*, thought to be rare in southern California, is found in small numbers and often as single individuals (Morris et al. 1980, Carlton 2007). Given the scarcity of observations and data on density, size, or distribution, this paper presents some new insights on abundance, size, and occurence of the species. Our observations show that *A. stellata* are locally more common at Laguna Beach, California than *Centrostephanus coronatus*, and the data suggest that *A. stellata* are not successfully reproducing in the area; instead, specimens of *A. stellata* are likely survivors from a previous recruitment event.

Sea urchins were collected in Orange County, California from 2007 to 2012 as part of a giant kelp (*Macrocystis pyrifera*) restoration project (Caruso 2007). One of the techniques employed was to reduce the number of sea urchins in a restoration area in order to lower grazing pressure on newly outplanted kelp. Working at depths ranging from 5 to 14 m, all sea urchins were removed from the restoration areas except those individuals that were tightly wedged in crevices and, thereby, difficult to collect. The collected urchins were tallied by species and relocated off-site in accordance with state permits.

Urchins were collected at six different restoration sites totaling 20,500 m^2 at Laguna Beach, California during the project, and those restoration sites are now within the boundaries of the Laguna Beach State Marine Reserve. *Arbacia stellata* was found at all the resotration sites. Among the four most commonly known sea urchin populations (*Strongylocentrotus fransiscanus, Strongylocentrotus purpuratus, Centrostephanus coronatus, Lytechinus anamesus*), *A. stellata* was the third most abundant species at Laguna Beach (Table 1). At least one specimen was found in 56 of the 78 sea urchin collection events.

Table 1.—Densities, total numbers, and size ranges of five species of sea urchins collected at Laguna Beach, California, 2007–2012.

Species	Density (#/m²)	Total Number Collected	Size Range mm (*n*)
S. purpuratus	6	117,659	2 – 66 (1,909)
S. franciscanus	1	27,246	5 – 109 (1,461)
A. stellata	.01	291	29 – 72 (253)
C. coronatus	.002	38	54 – 65 (6)
L. anamesus	.0001	3	11 – 12 (2)
Total	7	145,237	

At Laguna Beach, *Arbacia stellata* were relatively large (29–72 mm) for the species. *A. stellata* is described as a small sea urchin with the majority of individuals in a population measuring ≤30 mm in test diameter (Clark 1948, Brusca 1980, Morris et al. 1980, Olguín 2004). However, 99.2% of the specimens collected at Laguna Beach were larger than 30 mm (Figure 1). Test diameters of *A. stellata* from Laguna Beach were compared to those from Baja California (Olguin 2004; as *A. inscisa*), the only comparable data available (Figure 1). The mean test diameter of *A. stellata* from Laguna Beach (52 mm) was significantly larger than the mean test diameters of Baja California populations (25 mm) (one-tailed *t*-test, $P < 0.01$, $t_{336} = 58.79$), and the size of the individuals collected at Laguna Beach did not change over time (Figure 2). During the observation period, we consistently found mean test diameters greater than 40 mm.

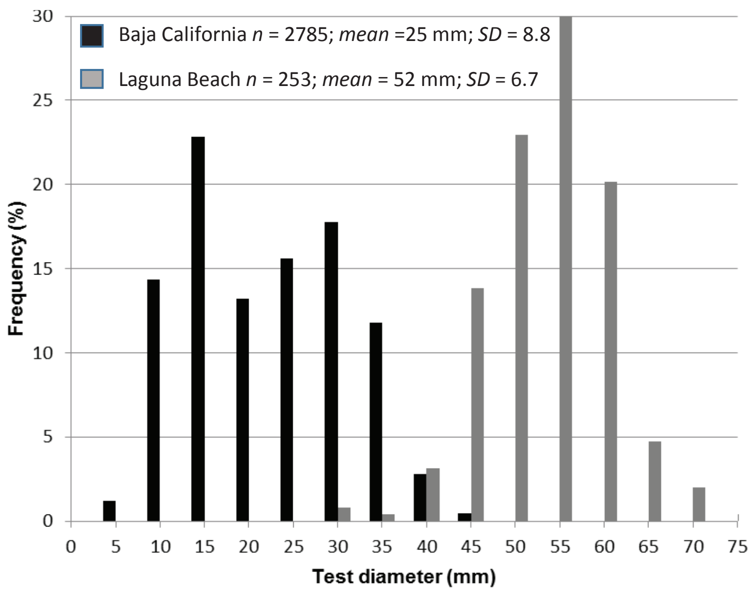

Figure 1.—Comparison of test diameters of *Arbacia stellata* populations from Baja California, Mexico and Laguna Beach, California. Baja California test diameters are from Gulf of California and Pacific Ocean populations May 1993, 1995, 1997 (Olguin 2004).

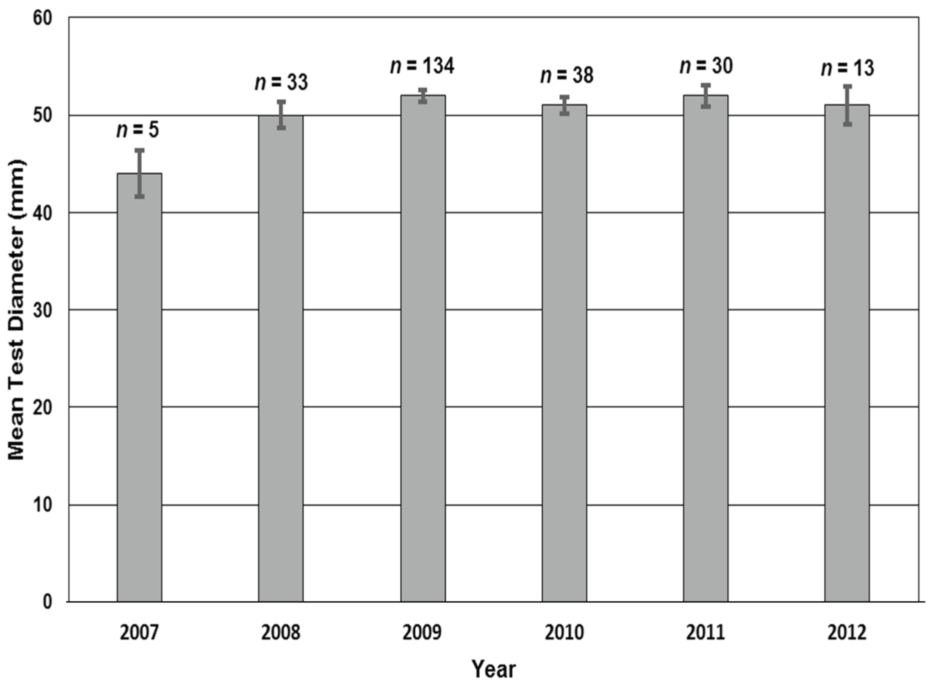

Figure 2.—Diameter ($\bar{x} \pm SE$) of *Arbacia* stellata tests collected at Laguna Beach, California, 2007–2012.

In 2005, Lessios suggested that there are few *A. stellata* in Panama because the larvae may be traveling from "far away" places and settling out along the Panamanian coast. Emlet (1995) reported that the larvae can take up to 22 days to settle in the laboratory. Engle and Richards (2001) reported the occurrence of *A. stellata* in the Channel Islands and concluded that, based on the timing of the species' occurrence and size, larvae of individuals were most likely brought to these areas by warmer waters of the 1997–1998 El Niño.

The absence of juveniles and the existence of only larger sized individuals in the Laguna Beach populations of *A. stellata* suggest that the animals are older and possibly from previous warm water recruitment events. Our results further substantiate the findings of Engle and Richards (2001), who suggested that *A. stellata* may not be successfully reproducing in southern California but their presence may be the result of a recruitment event from warmer waters.

Acknowledgments

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Literature Cited

Brusca, R. C. 1980. Common intertidal invertebrates of the Gulf of California. Second edition. University of Arizona Press, Tucson, USA.

Clark, H. L. 1948. A report on the echini of the warmer eastern Pacific, based on the collections of the Vellero III. Allan Hancock Pacific Expeditions 8:225-352.

Carlton, R. T. 2007. The Light and Smith manual: intertidal invertebrates from central California to Oregon. University of California Press, Berkeley, USA.

Caruso, N. L. 2007. Community-based giant kelp restoration and monitoring in Orange County, California. Bulletin of the Southern California Academy of Sciences 106:116.

Emlet, R. B. 1995. Developmental mode and species geographic range in regular sea urchins (Echinodermata: Echinoidea). Evolution 49:476-489.

Engle, J. M. and D. V. Richards. 2001. New and unusual marine invertebrates discovered at the California channel islands during the 1997-1998 El Niño. Bulletin of the Southern California Academy of Sciences 100:186-198.

Houston, R. S. 2006. Natural history guide to the northwestern Gulf of California and adjacent desert. Xlibris, Bloomington, Indiana, USA.

Lessios, H. A. 2005. Echinoids of the Pacific waters of Panama: status of knowledge and new records. Revista Biologia Tropical 53:147-170.

Mortensen, T. 1935. A monograph of the Echinoidea, Vol. II. C. A. Reitzel, Copenhagen, Denmark.

Morris, R. H., D. P. Abbott, and E. C. Haderlie. 1980. Intertidal invertebrates of California. Stanford University Press, Redwood City, California, USA.

Olguin, I. 2004. Speciation in marine systems: the case study of the sea urchin *Arbacia incisa* (Agassiz 1863). Ph.D. Dissertation, University of California, Davis, USA.

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First case of abnormality in the chilhuil sea catfish (*Bagre panamensis*) from Mexican waters

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The sea catfishes (Family Ariidae) include about 150 species occurring in warm-temperate to tropical continental shelves around the world. These species mainly inhabit marine and brackish waters but some are confined to freshwater (Betancur-R et al. 2007). Ten species have been recognized in the Mexican Pacific, with the chilhuil sea catfish (*Bagre panamensis*) being one of the most frequently caught species in the artisanal fishery that operates in the Gulf of California, Mexico (Saucedo-Barron and Ramirez-Rodriguez 1994). Overall, sea catfish are highly appreciated in the local market for their white meat, high protein content, and palatability. In Mexico, sea catfish rank 35th in terms of production (landed weight), and 27th in terms of economic revenue (total value of national fish production) out of the 58 registered marine fisheries in Mexico according to the National Commission for Fisheries and Aquaculture (Sagarpa-Conapesca 2011, Muro and Amezcua 2011).

The chilhuil sea catfish is common in many parts of its range (Cooke et al. 2010). This species is endemic to the Eastern Pacific; it is found from southern California and the Gulf of California to northern Peru (Allen and Robertson 1994), and can also occur in the Galapagos Islands (Cooke 1992). This demersal fish is found inshore, usually on muddy bottoms, to depths of 177 m. It also enters estuaries and mangrove areas (Cooke 1992).

Ocular abnormalities have not been previously recorded for the chilhuil sea catfish. The purpose of this paper is to describe the first record of an abnormality in one specimen of the family Ariidae (*Bagre panamensis*) from the Pacific Ocean.

On 20 October 2013, one unusual specimen (compared with the typical characteristics of the species) was caught as by-catch of the shrimp fishery at the fishing camp Celestino Gasca (23° 47’ 20” N, 106° 52’ 40” W), located in Sinaloa, Mexico. The specimen was obtained by artisanal fishermen using a set gillnet (measurements: 6.35 cm mesh size, 3.125 × 130 m). The specimen was donated by the fishermen and carried frozen to the Laboratory of Fisheries at Facultad de Ciencias del Mar-Universidad Autonoma de Sinaloa (FACIMAR-UAS).

The specimen was identified as *Bagre panamensis* (Gill 1863) using the criteria of Kaliola and Bussing (1995). This fish was measured (mm total and standard lengths) and weighed (grams). Stomach contents were analyzed to observe the presence of prey consumed. One normal specimen was obtained from the same fishing camp for comparison. The specimen was photographed at arrival and other photographs were later taken in the laboratory using a bar scale. X-rays were taken at a veterinary clinic. The specimen was preserved frozen in the Laboratory of Fisheries at FACIMAR-UAS.

The abnormal specimen measured 127 mm total length (TL), 97 mm standard length (SL), and weighed 4.6 g, while the normal specimen measured 165 mm TL, 126 cm SL and weighed 30.6 g (Figure 1). The abnormal specimen showed an evident ocular abnormality (Figure 2). The ocular globes were in the buccal cavity, and the ocular cavity was covered with a membrane. It was not possible to determine if the organism was blind. Radiography did not show bone differences between the normal and abnormal specimens (Figure 3). The dissection of the abnormal fish showed a flattened stomach but, contrary to what was expected, the stomach contained food (crustacean remains).

Some abnormalities can cause the death of the organism; however, multiple morphological abnormalities that did not induce death have been observed in living organisms (Escobar-Sanchez et al. 2013). The fishermen who captured and donated the specimens reported that other sea catfish caught along with the abnormal animal did not show any apparent malformations. This information points to factors other than anthropogenic events (i.e. pollution) that affect several living organisms at a time, such as genetic factors that affect only a single individual at a time, as the cause of this abnormal fish.

Saucedo-Barron et al. (1988) mentioned that the occurrence of blind specimens in good physical condition led some authors to suppose that these fish feed by the reinforcement of their other senses, especially their sense of smell. Ariids are easily recognized by the whiskers or barbels around their mouth, which they use for food detection (mainly shrimp, crabs, or mollusks). Therefore, in spite of the absence of eyes in the usual place, the presence of these barbels could help in the search for food. The slight obstruction of the buccal cavity could prevent food ingestion, but this hypothesis was rejected because of the presence of crustacean remains in the stomach. In addition, the presence of dorsal spines as defense against predation may also offset any potential disadvantage of this abnormality.

The only abnormality recorded in Ariids is albinism (Evangelista-Leal et al. 2013; Wakida-Kusunoki and Amador-del-Angel 2013). In Mexican waters, albinism and skeletal deformity are the most common abnormalities reported in bony fishes (Table 1); in Ariid species, only albinism in the gafftopsail catfish (*Bagre marinus*) from southeast Mexico (San Pedro, Tabasco) has been reported by Wakida-Kusunoki and Amador-del-Angel (2013).

Figure 1.—Normal (A) and abnormal (B) specimens of the chilhuil sea catfish (*Bagre panamensis*) caught 20 October 2013 in the Gulf of California near Mazatlan, Sinaloa, Mexico. Photographs by Juan A. Maldonado-Coyac.

Figure 2.—Abnormal eye position in a chilhuil sea catfish (*Bagre panamensis*) caught 20 October 2013 in the Gulf of California near Mazatlan, Sinaloa, Mexico. Photograph by Juan A. Maldonado-Coyac.

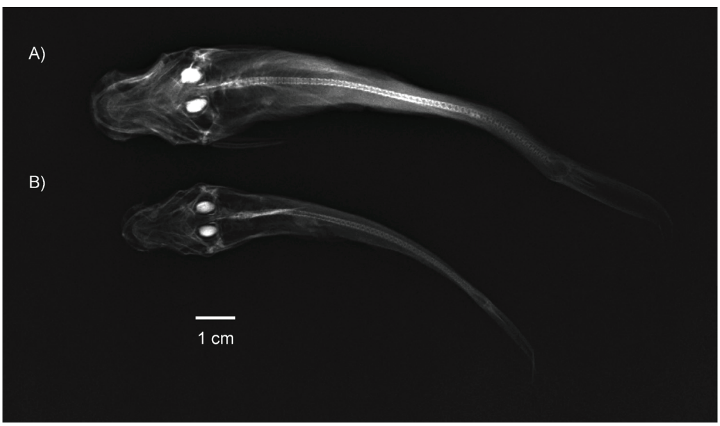

Figure 3.—X-rays of a normal (A) and the abnormal (B) specimen of chilhuil sea catfish (*Bagre panamensis*) caught 20 October 2013 in the Gulf of California near Mazatlan, Sinaloa, Mexico.

Table 1.—Abnormalities in bony fishes recorded in the Baja California Sur region of the Mexican Pacific Ocean. The yellow snapper (Lutjanus argentiventris; marked with an asterisk) was caught off the coast of Sinaloa.

Scientific Name	Common Name	Type of Malformation	Reference
*Lutjanus argentiventris**	Yellow snapper	Malformed pelvic fin	Alvarez-Leon 1980, 1983
Antennarius avalonis	Roughbar frogfish	Ocular malformation	Saucedo-Barron et al. 1988
Sphoeroides annulatus	Bullseye puffer	Ocular malformation	Saucedo-Barron et al. 1988
Diodon holocanthus	Longspined porcupinefish	Ocular malformation	Saucedo-Barron et al. 1988
Atherinops affinis	Topsmelt	Malformed mouth	Rodriguez-Romero et al. 1990
Hoplopagrus guentheri	Green bar snapper	Abnormal vertebral column	Galvan-Magana et al. 1994
Paranthias colonus	Creolefish	Abnormal vertebral column	Rodriguez-Romero et al. 2001
Balistes polylepis	Finescale triggerfish	Skeletal deformity	Escobar-Sanchez et al. 2013

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Literature Cited

Allen, G. R., and D. R. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu, USA.

Alvarez-Leon, R. 1980. A specimen of *Lutjanus argentiventris* (Peters) lacking pelvic fins. Journal of Fish Biology 16:563-564.

Alvarez-Leon, R. 1983. Un caso teratologico en un lutjanido (Pisces: Lutjanidae) del sur de Sinaloa, Mexico. Anales del Instituto de Biologia. Universidad Nacional Autonoma de Mexico 54:229-235.

Betancur-R, R. Acero, A. P. Berminhame, and R. Cooke. 2007. Systematics and biogeography of New World sea catfishes (Siluriformes: Ariidae) as inferred from mitochondrial, nuclear, and morphological evidence. Molecular Phylogenetics and Evolution 45:339-357.

Cooke, R. 1992. Prehistoric nearshore and littoral fishing in the eastern tropical Pacific: an ichthyological evaluation. Journal of World Prehistory 6:1-49.

Cooke, R., A. Acero, R. Betancur, P. Rojas, and A. Cotto. 2010. *Bagre panamensis*. The IUCN red list of threatened species. Accessed 20 August 2014. Available from: www.iucnredlist.org

Escobar-Sanchez, O., X. G. Moreno-Sanchez, and M. Carrera-Fernandez. 2013. Skeletal deformity in *Balistes polylepis* (Balistidae) from the southern Gulf of California, Mexico. Cahiers de Biologie Marine 52:293-295.

Evangelista-Leal, M., U. Horst-Schulz, P. Lehmann-Albornoz, R. Machado, and P. Henrique-Ott. 2013. First record of partial albinism in two catfish species of genidens (Siluriformes: Ariidae) in an estuary of southern Brazil. Brazilian Archives of Biology and Technology 56:237-240.

Galvan-Magana, F., J. Rodriguez-Romero, and L. A. Abitia-Cardenas. 1994. First record of abnormal vertebral column in the green bar snapper *Hoplopagrus guentheri* (Osteichthyes: Litjanidae). Revista de Biologia Tropical 4:388-389.

Kaliola, P. J., and W. A. Bussing. 1995. Ariidae. Pages 860-886 *in* W. Fisher, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. H. Nie, editors. Guia FAO para la identificacion de especies para los fines de la pesca, Pacifico Centro-Oriental Vol II, Vertebrados - Parte 1. FAO, Rome, Italy.

Muro, V., and F. Amezcua. 2011. Observations on the reproductive biology of the chilhuil sea catfish in the southeast Gulf of California: implications for management. American Fisheries Society Symposium 77:325-334.

Rodriguez-Romero, J., L. Cardenas, J. D. Perez-Urbiola, R. Hinohue-Rivera, and M. A. Silva-Hernandez. 2001. A spinal column malformation in the creolefish *Paranthias colonus* (Osteichthyes: Serranidae). Revista de Biologia Tropical 49:1267-1268.

Rodriguez-Romero, J., R. Ramirez-Sevilla, and G. Nunez-Marquez. 1990. Deformacion de la boca de un juvenil de *Atherinops affinis* (Ayres) (Pisces: Atherinidae) desarrollado en laboratorio. Investigaciones Marinas CICIMAR 5:143-146.

Sagarpa-Conapesca. 2011. Anuario Estadistico de Acuicultura y Pesca 2011. Secretaria de Agricultura, Ganaderia y Desarrollo Rural, Pesca y Alimentacion. Comision Nacional de Pesca. Mazatlan. Available from: http://www.conapesca.sagarpa.gob.mx/wb/cona/cona_anuario_estadistico_de_pesca

Saucedo-Barron, C. J., and M. Ramirez-Rodriguez. 1994. Peces de importancia comercial en el sur del estado de Sinaloa, Mexico (Pesca artesanal). Investigaciones Marinas CICIMAR 9:51-54.

Saucedo-Barron, C. J., H. Chavez, and F. Galvan-Magana. 1988. Observacion de ejemplares con defectos oculares de *Antennarius avalonis* Jordan y Starks, *Sphoeroides annulatus* (Jenyns) y *Diodon holocanthus* Linnaeus (Pisces: Antennariidae, Tetraodontidae y Diodontidae), colectados en Baja California Sur. Ciencias Marinas 14:113-124.

Wakida-Kusunoki, A. T., and L. E. Amador-del-Angel. 2013. First record of albinism in gafftopsail catfish *Bagre marinus* (Pisces: Ariidae) from southeast Mexico. Revista de Biologia Marina y Oceanografía 48:203-206.

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Coyote visitation to water sources as evidence of a decline in coyote numbers

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Key words: Coyote, *Canis latrans*, activity patterns, camera trap, blue oak woodland, California

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Patterns of activity in coyotes have been shown to vary with environment. Coyotes in urban environments show a nocturnal activity pattern (McClennen et al. 2001, Riley et al. 2003, Way et al. 2004). Conversely, in natural undisturbed environments coyote activity is more diurnal (Kitchen et al. 2000). Coyotes in a pine-oak forest in Durango, Mexico showed similar distance traveled diurnally versus nocturnally (Servin et al. 2003). It was postulated that habitat type, rather than latitude, influences the amount of distance traveled daily for coyotes (Servin et al. 2003). Despite many studies on coyote activity using radio telemetry (e.g., Gese et al. 2012) there has been little work using camera traps at watering sites to better understand coyote activity patterns or relative abundance. Camera traps at watering sites can document behavioral patterns such as drinking and feeding that radio collars cannot (Atwood et al. 2011, Cove et al. 2012), and camera traps can provide unbiased results when used correctly (Larrucea et al. 2007).

Objectives of this research were to better understand coyote activity at watering sites and find patterns of behavior related to availability of bait, water, air temperature, season, and year. The coyote data were obtained incidental to deer (*Odocoileus hemionus*) and wild pig (*Sus scrofa*) monitoring on typical blue oak rangeland where the primary land use is fee hunting and where coyotes were generally shot on sight. We predicted that coyote activity patterns would be optimized to avoid human exposure, with coyotes being more active at night. We also predicted that coyote water visitation would be affected by physiological need, which should be greatest at high temperatures. We further examined the data to assess the status of coyotes occupying the study area during our investigation.

The Ventana Ranch in southern San Benito County, California (36° 22' N, 120° 55' W) has an area of 1,136 ha and ranges in elevation from 518 m to 1,097 m. The climate is Mediterranean, and characterized by hot dry summers to cool damp winters. Average annual precipitation for the county during our investigation was 23.95 cm (NOAA 2014), with 90% of annual precipitation occurring between November and March. The quality of the soil on the ranch is poor and it does not hold water well. Deer hunting occurs on the property during August, and pig hunting occurs throughout the year. Habitat types include mixed chaparral, annual and perennial grasslands, and blue oak (*Quercus Douglasii*) woodland.

Camera traps (models RM30, PM35T, and PC 900; RECONYX, Inc. Holmen, Wisconsin 54636) were installed at 17 watering sites on the ranch. Camera traps were placed at a height of about two meters and about four meters away from bait and water. The cameras were set to high sensitivity, no delay, continuous operation, and one photo per trigger, which captured one photo every other second if an animal was in sight and moving. There was a natural or man-made water source provided at or near each site. Bait ("Hog Grower" pellets [16% protein]; Masterfeeds, London, Ontario, Canada]) was replaced approximately monthly when we checked the camera traps.

Camera traps recorded time, date, location, temperature and moon phase for each photo. Data were uploaded to Excel via MAPVIEW (RECONYX, Inc.), and we used Windows Photo Viewer to examine photos individually. We noted if bait was present and if the coyotes fed. We also noted if water was available and if coyotes drank. The duration of each visit was rounded to the nearest minute. A gap of at least six minutes between photos was used as the threshold to define a new visit. If there was only one photo of a coyote representing a visit the duration was recorded as one minute. Coyote activity was expressed as the proportion of total visits detected, or as visits detected per 100 trap-days. We used SYSTAT 13 to calculate mean (±95% CI) visitation rates across the 17 trap locations.

The cameras recorded 1,953 visits by coyotes in 24,530 trap-nights during this investigation (2006–2012). Coyote activity increased at water holes peaking during the middle of the night. At dusk and dawn there was a moderate amount of activity, with minimal activity in the mid-afternoon (Figure 1). Coyotes were most active in October and least active in May. Coyote activity, as recorded by the camera traps, increased in the later months of the year (Figure 2).

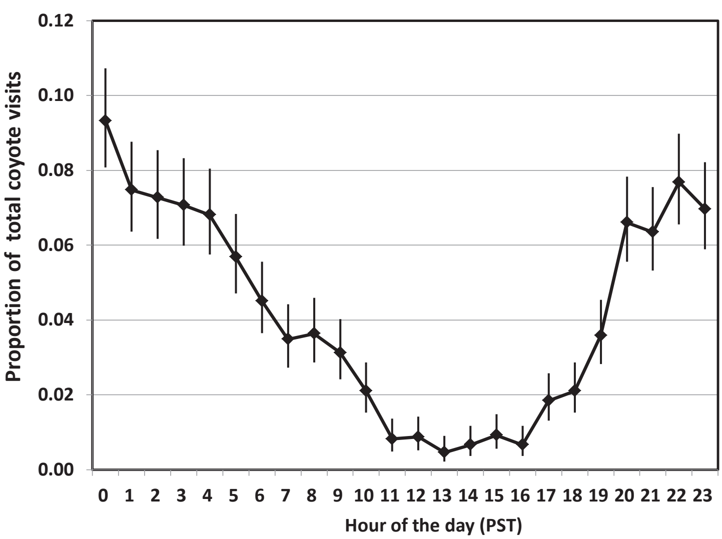

Figure 1.—Diel pattern for coyote visits to water sources at the Ventana Ranch, San Benito County, California, 2006–2012. Camera traps detected 1,953 coyote visits over six years of continuous monitoring. Vertical bars are 95% confidence limits.

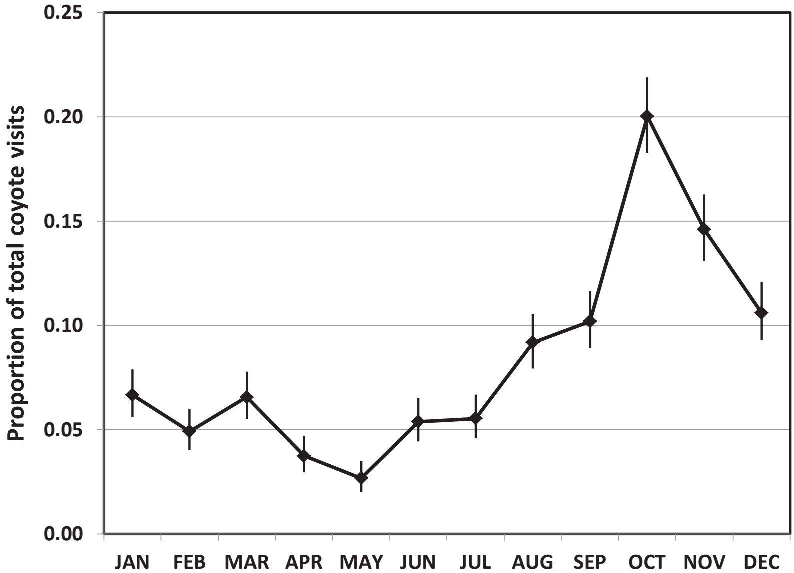

Figure 2.—Seasonal activity pattern for coyotes at the Ventana Ranch, San Benito County, California, 2006–2012. Camera traps detected 1,953 coyote visits to water sources over six years of continuous monitoring. Vertical bars are 95% confidence limits.

Coyotes were recorded drinking available water primarily during the early and late months of the year. Coyotes visited cameras 638 times when water was not available, mainly at two sites where cameras were set on trails leading to water. Of the 1,315 visits when water was in the field of view, coyotes drank ≥218 times (≈17%). Drinking was less frequent in the spring than in the fall. Coyote drinking rate increased as mean monthly temperature increased (Figure 3).

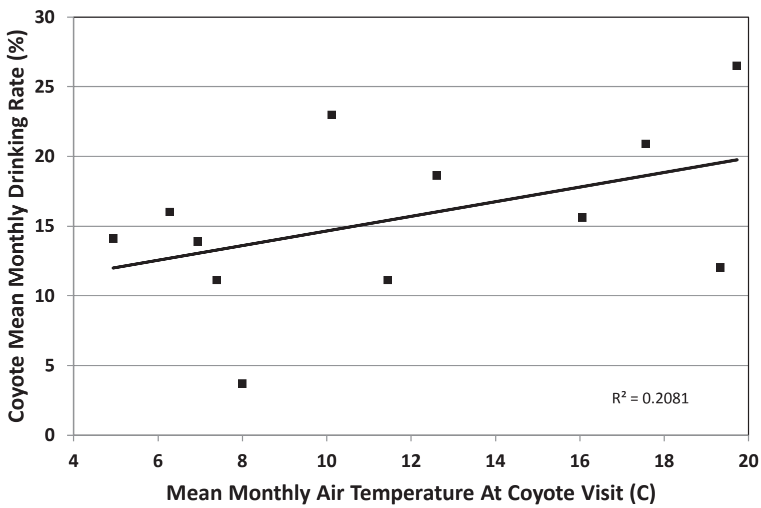

Figure 3.—Coyotes at the Ventana Ranch, San Benito County, California, 2006–2012 tended to drink more often during warmer months; $N = 1,953$ coyote visits over six years of continuous monitoring.

There was a similar pattern with coyotes feeding on bait; feeding activity was least common in the spring and most common in the fall. Coyotes visited camera traps 1,360 times when bait was not available. Of the 593 visits when it was available, coyotes consumed bait ≥261 times (≈44%).

Cameras recorded 1,679 total visits of one minute or less, the most frequent duration of a visit. The longest visit by an individual coyote was 51 minutes. Duration of visits was greatest when bait was present (Figure 4), and length of visits increased in October and November (Figure 5).

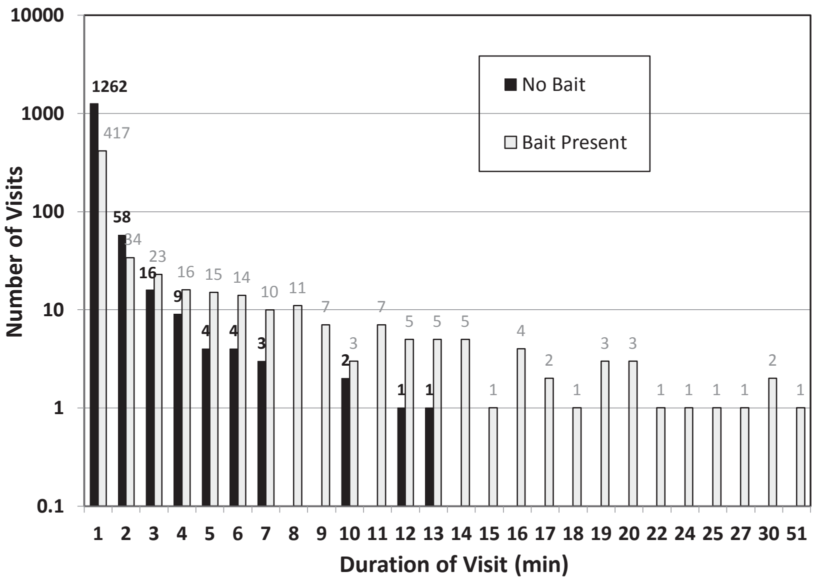

FIGURE 4.—Coyotes at the Ventana Ranch, San Benito County, California, 2006–2012 tended to spend more time at camera trap sites when bait was present. *N* = 1,953 coyote visits over six years of continuous monitoring.

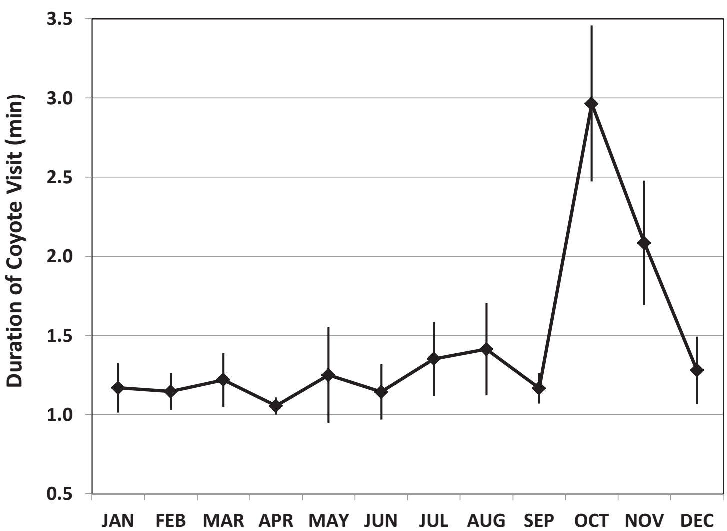

FIGURE 5.—Coyotes at the Ventana Ranch, San Benito County, California, 2006–2012 tended to spend more time at camera trap sites during the fall dispersal period. *N* = 1,953 coyote visits over six years of continuous monitoring. Vertical bars are 95% confidence limits.

There was a decreasing trend of activity in the local coyote population over the six-years of our study. Visits peaked in October of 2007 with 77 visits per 100 camera-trap-nights; during 2012 no more than 10 visits were recorded per 100 camera-trap-nights during any single month (Figure 6).

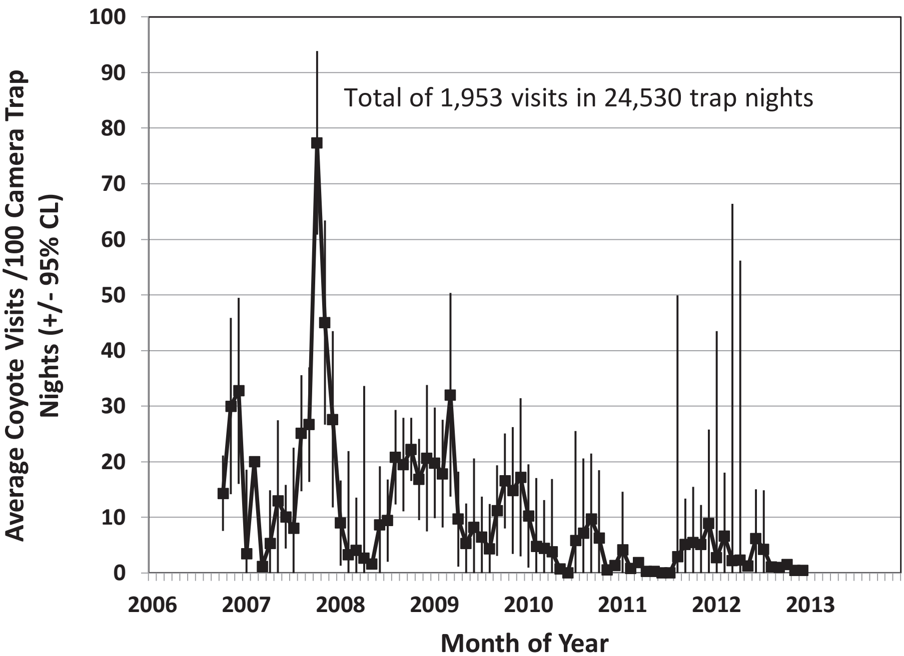

FIGURE 6.— Coyote detections at the Ventana Ranch, San Benito County, California, 2006–2012 tended to decline over six years of monitoring. Vertical bars are 95% confidence limits.

Our goal was to document coyote activity at watering sites via camera trapping in blue oak woodland habitat. As a result of the small study area, it is likely few coyote territories were sampled. Therefore our results may not, in general, be representative of coyotes occupying blue oak woodlands. Further, our results likely are not representative of non-hunted coyote populations.

Coyote activity primarily was crepuscular. Activity, as recorded by camera traps peaked from September to December, perhaps the result of dispersal of juveniles. Contrary to our predictions, we did not detect a decrease in coyote activity during August and September when deer hunting occurred.

Dispersal of juveniles might explain increased use of bait in the fall and winter; young coyotes becoming independent during those months might be the cause of the increase in feeding on bait designed for pigs. Newly-independent coyotes may be ineffective hunters and visit stationary food sources more often than older animals (Wells and Bekoff 1982). Similarly, newly independent coyotes taking advantage of available water may explain more frequent drinking during fall and winter. Nevertheless, a strong positive relationship existed between drinking rate and mean monthly temperature, thereby confounding this interpretation.

Duration of visits was influenced by the presence or absence of bait at a station. The duration of visits was generally <2 minutes, but visits were longer in the fall and winter months, consistent with the hypothesis that newly independent coyotes might be taking advantage of available bait.

Relative abundance of coyotes at the Ventana Ranch trended strongly downward from 2007 to 2012 as evidenced by annual peaks in visitation rates (Figure 6). That our index to coyote abundance was greatest in 2007, a year following an exceptional acorn crop, was not surprising in that abundant forage may have resulted in an increased prey base and, thereby, had a positive influence on recruitment of pups (Bekoff and Gese 2003). Coyotes were likely having more pups, and a higher proportion of pups were surviving, both of which would increase the number of dispersing juveniles in late summer and early fall of 2007. The following years had poor acorn crops, which could have reduced prey availability and resulted in low pup survival and, thus, fewer visits to camera stations. We speculate that a decline in prey availability, rather than lethal removal, is most likely the reason for the decrease in coyote activity since 2007.

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Literature Cited

Atwood, T. C., T. L. Fry, and B. R. Leland. 2011. Partitioning of anthropogenic watering sites by desert carnivores. Journal of Wildlife Management 75:1609-1615.

Bekoff, M., and E. M. Gese. 2003. Coyote. Pages 467-481 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management and conservation. Second edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Cove, M. V., B. M. Jones, A. J. Bossert, J. D. R. Clever, R. K. Dunwoody, B. C. White, and V. L. Jackson. 2012. Use of camera traps to examine the mesopredator release hypothesis in a fragmented midwestern landscape. American Midland Naturalist 168:456-465.

Gese, E. M., P. S. Morey, and S. D. Gehrt. 2012. Influence of the urban matrix on space use of coyotes in the Chicago metropolitan area. Journal of Ethology 30:413-425.

Kitchen, A. M., E. M. Gese, and E. R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution. Canadian Journal of Zoology 78:853-857.

Larrucea, E. S., P. F. Brussard, M. M. Jaeger, and R. H. Barrett. 2007. Cameras, coyotes, and the assumption of equal detectability. Journal of Wildlife Management 71:1682-1689.

McClennen, N., R. R. Wigglesworth, S. H. Anderson, and D. G. Wachob. 2001. The effect of suburban and agricultural development on the activity patterns of coyotes (*Canis latrans*). American Midland Naturalist 146:27-36.

NOAA (National Oceanic and Atmospheric Administration). 2015. National centers for environmental information [Internet]; [Cited 2015 March 9] Available from: http://ncdc.noaa.gov

Riley, S. P., R. M. Sauvajot, T. K. Fuller, E. C. York, D. A. Kamradt, C. Bromley, and R. K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. Conservation Biology 17:566-576.

Servin, J., V. Sanchez-Cordero, and S. Gallina. 2003. Distances traveled daily by coyotes, *Canis latrans*, in a pine-oak forest in Durango, Mexico. Journal of Mammalogy 84:547-552.

Way, J. G., I. M. Ortega, and E. G. Strauss. 2004. Movement and activity patterns of eastern coyotes in a coastal, suburban environment. Northeastern Naturalist 11:237-254.

Wells, M. C., and M. Bekoff. 1982. Predation by wild coyotes: behavioral and ecological analyses. Journal of Mammalogy 63:118-127.

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Commentary: Wildlife, the public trust, and the modern-day "Tragedy of the Commons"

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In recent years, literature on the North American Model of Wildlife Conservation has included much about wildlife as a public trust resource (Organ et al. 2012). Unfortunately, there has been little connection to the already large and still growing literature surrounding Garret Hardin's classic paper, The Tragedy of the Commons (Hardin 1968). Since public trust resources are the commons of Hardin, the connection is obvious. Readers are referred elsewhere (Wikipedia Contributors 2015a) for a summary of the abundant "commons" literature.

Wildlife and their necessities of public land and water are but a few of very many public trust resources. However, recent and current trends in North American wildlife law and policy have changed the nature of the commons tragedy, at least for wildlife resources. A broad awareness of this change may avert the worst of this modern tragedy of the commons.

Based on writings of an early 19th century economist, Hardin's conclusion was that resources owned and used in common by all the people, such as a public pasture, will suffer overuse through scramble competition initiated and stimulated by the most unsharing persons. In scramble competition, unrestricted individuals initially benefit by taking more than their fair share, stimulating others to likewise compete (Wikipedia Contributors 2015b). Eventually, the public resource is degraded and all users suffer Hardin's tragedy of the commons.

Hardin's thesis is often invoked to promote private ownership, on the assumption that only self-interest can maintain productivity and value of resources. Private ownership of resources results in situations in which interference competition (Wikipedia Contributors 2015b) replaces scramble competition with the result that individuals or groups of individuals control resources to the exclusion of others. For a solution, Hardin concluded that voluntary egalitarian sharing of resources works best, or only, when the population of users is small. Therefore, he recognized—albeit with some disdain—the value of government control in allocating resources among the people. Indeed, in North America, governments are "instituted among men" in large part for this purpose.

North American wildlife conservation has been a history of controlling scramble competition for wildlife and limiting interference competition by retaining some resources in the public domain. Recognizing the different values of public and of private ownership, we have partitioned land, water and wildlife into public and private hands. Private resources are managed mostly with interference competition, sometimes in combination with publicly imposed limits to control external negative impacts such as pollution. In contrast, public resources are managed to control scramble competition and to enhance public benefits. We have established and developed laws, policies, and agencies for allocating, regulating, managing, and enhancing our knowledge of wildlife resources.

The ratio of public to private ownership varies greatly among resources and locations. Also, boundaries between public and private components are not always clear, thereby complicating law, policy, and management. Land boundaries should be clear; yet, self-proclaimed "ownership" of grazing allotments on federal lands is an exception. Water ownerships have become an unsettled maze of law and practice. Wildlife are mostly a public resource, with a few exceptions including falconry. Then there is the paradox of public wildlife occupying privately owned habitat.

Recognizing wildlife as a public trust resource, we have established numerous interacting trustees to oversee management and conservation. Trustees include legislators, commissioners, judges, and agency personnel including wildlife managers—at local, state, and national levels. Some consider agency personnel only as "trust managers"—agents of high-ranking trustees (Organ et al. 2012). I disagree for several reasons: (1) legislators, commissions, and judges relegate some, though varying amounts, of decision space to agencies; (2) agency personnel are usually the primary source of science and experience to ensure good decisions; and (3) agencies should be the preeminent source of reliable public information, whereas public awareness and vigilance are necessary to assure that trust resources are managed to benefit the public trust owners.

The dual obligations of agency personnel are difficult, but also are crucial to the success of public trust doctrine. The role of agency personnel should not be trivialized by formally recognizing responsibilities only to higher-ranking trustees while disregarding obligations directly to the public. Moreover, agency personnel are no less at risk of control by private interests than are any other trustees.

Trustees have managed scramble competition for public wildlife resources fairly well. However, trustee management is being widely subverted for purposes of private gain through interference competition. The modern tragedy of the commons occurs as private interests control trustees to capture and control public resources (Wood 2014). Privatization often occurs with public subsidies and without private burdens of property taxes or maintenance costs. The tragedy is ubiquitous in degrading public values of public resources. It is dealt with in disconnected conflicts in the public arena, but the results are insidiously cumulative. More recognition and response to this broad assault upon a basic North American conviction are needed.

This assault upon the commons takes many forms (Table 1). Much control of the public trustees by private interests has involved the administrative and legislative branches of government. Abundance and success of this strategy is illustrated by the number of natural resource cases reaching the judicial branch. As a result, we should expect increasing attempts to influence the judicial branch of government.

The modern tragedy of the commons seeks to undermine a long and proud history of North American wildlife conservation. The predominant threat to public trust resources is no longer scramble competition. It is the growing threat of interference competition through control of the trustees. Curtailing the tragedy requires greater awareness of its broad reach and changing nature. Young, aspiring, and often idealistic wildlife biologists and managers need be aware of the milieu they are entering. They will have dual, and sometimes conflicting, obligations to superior trustees and to the public beneficiaries. For those involved with local and temporal conservation battles it is useful, but intimidating, to view the larger historical picture. Ultimately, a well-informed public must take action at the ballot box.

Table 1.—Examples of assaults upon public trust resources. Some have been coded in law or regulations. All of these favor private interests at the expense of present and future generations of the public who are owners and beneficiaries of wildlife resources.

Contrived special or exclusive access to the resource.
Use of the resource, especially public land, for an undervalued fee, and with other subsidies.
Coerced use of public funds to restructure the resource for limited, private benefits.
Special permits to degrade or pollute the resource.
Non-reciprocal claims for wildlife impacts while livestock impacts remain acceptable.
Undermining the trustee's ability to manage the resource and regulate users—using budget controls, or transfer of authority to a more "friendly" agency.
Coercion of public agencies, and private companies, to control or eliminate employees who may expose special interests.
Suppression of information and science that is contrary to private interests.
Propaganda to convince the public that their interests are served by activities favorable to private interests.
Electioneering, including funding of private-interest candidates.
Support for public education and research favoring private interests.
The assumption that private property rights exceed public property rights.

While the presence of altruistic genes (Hamilton 1963) is uncertain (but, see Thompson et al. 2010), selfish genes are surely in us (Dawkins 1976). Competition is innate within our species. Aware and discerning minds are needed to overcome the excesses of selfish genes. Recognition of the modern tragedy of the commons is necessary, for the ultimate commons is the whole earth, with a potential ultimate tragedy.

Acknowledgments

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Literature Cited

Dawkins, R. 1976. The selfish gene. Oxford University Press, Oxford, United Kingdom.
Hamilton, W. D. 1973. The evolution of altruistic behavior. American Naturalist 97:354-356.
Hardin, G. 1968. The tragedy of the commons. Science 162:1243-1248.
Organ, J. F., V. Geist, S. P. Mahoney, S. Williams, P. R. Krausman, G. R. Batcheller, T. A. Decker, R. Carmichael, P. Nanjappa, R. Regan, R. A. Medellin, R. Cantu,

R. E. McCabe, S. Craven, G. M. Vecellio, and D. J. Decker. 2012. The North American model of wildlife conservation. Technical Review 12-04. The Wildlife Society, Bethesda, Maryland, USA.

Thompson, G. J., P. L. Hurd, and B. J. Crespi. 2014. Genes underlying altruism. Biology Letters 9:20130395. Available at http://dx.doi.org/10.1098/rsbl.2013.0395

Wikipedia Contributors. 2015a. [Internet]. Wikipedia, The Free Encyclopedia; [cited 2015 June 3]. Available from: http://en.wikipedia.org/wiki/Tragedy_of_the_commons

Wikipedia Contributors. 2015b. [Internet]. Wikipedia, The Free Encyclopedia; [cited 2015 June 3]. Available from: http://en.wikipedia.org/wiki/intraspecific_competition

Wood, M. C. 2014. Nature's trust: environmental law for a new ecological age. Cambridge University Press, New York, USA.

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Books Received and Available for Review

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

Antypowich, L. 2012. A hunting we did go. True mountain adventures. Xlibris LLC, Bloomington, Indiana, USA. 213 pages. $19.95 (soft cover).

Beck, B. H., and E. Peatman (editors). 2015. Mucosal health in aquaculture. Academic Press, San Diego, California, USA. 395 Pages. $180.00 (hard cover)

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

Jorgensen, M. C. 2015. Desert bighorn sheep: wilderness icon. Sunbelt Publications, San Diego, California, USA. 143 pages. $29.95 (soft cover).

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, USA. 208 pages. $24.95 (hard cover).

Sjaastad, E., and K. E. Svensson. 2015. Small ambassadeurs: the legendary light-line fishing reels. Schiffer Publishing, Atlen, Pennsylvania, USA. 256 pages. $ 45.00 (hard cover).

Yang, H., J.-F. Hamel, and A. Mercier (editors). 2015. The sea cucumber *Apostichopus japonicus*: history, biology and aquaculture. Academic Press, San Diego, California, USA. 454 pages. $180.00 (hard cover).

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Literature Cited

Bleich, V. C., N. J. Kogut, and D. Hamilton. 2011. Information for contributors to *California Fish and Game*. California Fish and Game 97:47-57.

CSE (Council of Science Editors). 2006. Scientific style and format: the CSE manual for authors, editors, and publishers. 7th edition. The Rockefeller University Press, New York, USA.

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