EFFECTS OF MILITARY OPERATIONS ON BEHAVIOR AND HEARING OF ENDANGERED SONORAN PRONGHORN

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Abstract: Our objectives in this study were to determine whether military activities (e.g., overflight noise, noise from ordnance delivery, ground-based human activity) on the Barry M. Goldwater Range (BMGR) affect the behavior and hearing of Sonoran pronghorn (*Antilocapra americana sonoriensis*). We contrasted the behavior of pronghorn on BMGR with the closest population of pronghorn in the United States that was not subjected to routine military activity (i.e., on the Buenos Aires National Wildlife Refuge [BANWR], Arizona). Forty percent of the landscape used by the endangered Sonoran pronghorn in the United States is within the 5,739 km^2 BMGR, a bombing and gunnery facility in southwestern Arizona. The range of Sonoran pronghorn covers about 88% of BMGR. The 179 Sonoran pronghorn that lived in the United States in December 1992 declined to 99 by December 2000. The Sonoran pronghorn has been listed as endangered for >30 years, but population limiting factors are unknown. Because Sonoran pronghorn use BMGR, land and wildlife managers raised concerns about the potential effects of military activities on the population. Possible indirect effects of military activities on Sonoran pronghorn, aside from direct mortality or injury, from ordnance delivery, chaff, flares, live ammunition, aircraft mishaps, interference from ground vehicles and personnel, include alteration of behavior or physiology.

We conducted the study on the North and South Tactical Ranges (NTAC and STAC), BMGR, from February 1998 to June 2000. Hearing exams were conducted in Camp Verde, Arizona, the University of Arizona, and on the East Tactical Range (ETAC), BMGR. Interactions between pronghorn and military activity were restricted to 4 observation points that provided viewing areas from which pronghorn and military activity could be observed from ≤10 km. We systematically located pronghorn with spotting scopes and telemetry. When located, we described their behavior and military activity using scan sampling. We tested hearing using auditory brainstem responses (ABR). We could not test the hearing of Sonoran pronghorn because of their endangered status, so we contrasted hearing of pronghorn near Camp Verde, Arizona, and desert mule deer (*Odocoileus hemionus eremicus*) that were and were not exposed to sound pressure levels from military activity. We recorded behavior observations of Sonoran pronghorn on 172 days (44,375 observation events [i.e., 1 observation/30 second]) over 373 hours. These data were compared with 93 days of behavioral data (24,297 observation events) over 202 hours for pronghorn not regularly influenced by military aircraft. Overall, we did not detect behavioral differences (i.e., time spent bedding, standing, foraging, traveling) between males and females. Pronghorn exposed to military activity, and those that were not, bedded the same amount of time. Pronghorn at BMGR foraged less and stood and traveled more than pronghorn not exposed to military activity. These trends were the same with and without anthropogenic activity. Only 7.3% of behavioral events occurred with identi-

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fiable stimuli. Military overflights occurred 363 times (0.8%) and non-military overflights occurred 77 times (<0.2%). Pronghorn rarely responded to military aircraft, but often moved >10 m when ground stimuli were present.

Ambient noise levels ranged up to 123.1 decibels (dB). The average sound pressure level on days with military activity was 65.3 dB compared to 35.0 dB without military activity. Because we obtained hearing tests from deer and pronghorn, we were able to develop an ungulate weighting filter on the noise generated from overflights of A-10 and F-16 aircraft. Desert ungulates do not hear sound pressure levels generated from these aircraft as well as humans do (i.e., 14-19 dB lower).

The military activity we examined had only marginal influence on Sonoran pronghorn. Pronghorn used the ranges shared with the military throughout the year and behavioral patterns of pronghorn were similar with and without the presence of military stimuli. Furthermore, pronghorn behavior exposed to military activity was similar to behaviors of pronghorn not exposed to regular military activity. The auditory characteristics of pronghorn were similar for those that have and have not been exposed to military activity. The population of Sonoran pronghorn in the United States continues to decline and is in serious danger of extirpation. Clearly, additional work needs to be done, but military activity as measured herein is not a limiting factor.

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EFECTOS DE OPERACIONES MILITARES EN EL COMPORTAMIENTO Y AUDICION DEL ANTILOCAPRA DE SONORA EN PELIGRO DE EXTINCION.

Resumen: Los objetivos de este estudio fueron determinar si las actividades militares (ruidos por sobrevuelo, de suministro de artillería, y de actividades humanas de la base de tierra) del Campo militar Barry M. Goldwater Range (BMGR) afecta el comportamiento y audición de la cabra Sonorense (*Antilocapra americana sonoriensis*). Comparamos el comportamiento de la cabra de Sonorense en BMGR con la población más cerca de la cabra de Sonorense en los Estados Unidos que no estaba sujeta a la actividad de la rutina militar (en el refugio nacional de vida silvestre Buenos Aires en Arizona [BANWR]). Cuarenta por ciento del territorio usado por la cabra Sonorense en peligro de extinción en los Estados Unidos esta dentro de los 5,739 km^2 del BMGR, que es una facilidad militar de práctica de tiro y bombardeo en el suroeste de Arizona. El territorio de la cabra de Sonorense cubre alrededor del 88% del BMGR. De 179 cabras Sonorenses que se encontraban en los Estados Unidos en Diciembre de 1992 declinaron a 99 para Diciembre del 2000. La cabra Sonorense ha sido enlistado como una especie en peligro de extinción por >30 años, pero los factores limitantes de la población son aun desconocidos.

Debido a que la cabra Sonorense usa el campo militar BMGR, los encargados de vida silvestre y de su manejo tenían preocupación acerca del efecto potencial de las actividades militares en su población. Posibles efectos indirectos de actividades militares en la cabra Sonorense, aparte de la mortalidad o daños por la caída de artillería, material militar abandonado, luces de bengala, uso de municiones, percances de aviones, interferencia con vehículos y personal de tierra querían ser estudiados debido a incluyen alteraciones de comportamiento o de su fisiológicas.

Condujimos el estudio en los terrenos de prácticas Norte y Sur (NTAC y STAC) del campo militar BMGR de Febrero 1998 a Junio 2000. Exámenes de audición fueron conducidos en el Camp Verde, Arizona, la Universidad de Arizona y en el Terreno de Práctica Este (ETAC) del BMGR. Las interacciones de la cabra Sonorense y las actividades militares se estudiaron en 4 puntos de observación que proveyeron áreas en la cual la cabra y las actividades militares podían ser observadas a 10 Km. o menos de distancia. Las cabras Sonorenses se localizaron sistemáticamente con telemetría y con telescopios puntuales. Una vez localizadas se describió su comportamiento y la actividad militar usando muestreos de exploración "scan samplings".

La audición se examino usando respuestas auditivas del tallo cerebral (ABR, auditory brainstream responses). No se pudo examinar la audición de la cabra Sonorense porque es una especie en peligro de extinción, así que la audición se contrasto con audiciones de cabras cerca de Camp Verde, Arizona, y con venado del desierto (*Odocoileus hemionus eremicus*) que fueron no expuestos y expuestos a niveles de presión de ruido provenientes de la actividad militar.

Las observaciones del comportamiento de la cabra sonorense fueron gravadas por 172 días (44,375 eventos observados [1 observación/30 segundos] en 373 horas). Esos datos fueron comparados con 93 días de datos de comportamiento (24,297 eventos observados) con 202 horas para cabras no influenciadas regularmente por vuelos militares. En general no se detecto diferencias de comportamiento [como tiempo usado para dormir, descansar, forrajear, viajar] entre hembras y machos. Las cabras expuestas a la actividad militar, y esas que no lo estuvieron durmieron la misma cantidad de tiempo. Las cabras en el BMGR forrajearon menos y estuvieron paradas y viajando más que las cabras no expuestos a la actividad militar. Esas tendencias fueron las mismas con y sin actividades antropogénicas. Solo 7.3% del comportamiento ocurrió con estímulos identificables. Los sobrevuelos militares ocurrieron 363 veces (0.8%) y los no militares ocurrieron 77 veces (<0.2%). La cabra raramente respondió a vuelos militares, pero se movió frecuentemente >10 m cuando el estimulo terrestre estuvo presente.

Los niveles de ruido del ambiente tuvieron rangos de 123.1 decibeles (dB). La media del nivel de presión del sonido en días con actividad militar fue de 65.3 dB comparada con 35 dB sin la actividad militar. Los análisis auditivos de venados y de cabras nos permitieron desarrollar un coeficiente del sonido filtrado (ungulate weigting filter) por los ungulados con respecto al ruido generado de los sobrevuelo de aviones A-10 y F-16. Los ungulados del desierto no escuchan los niveles de presión del sonido generados por aviones como los humanos lo hacen (dB 14-19 mas bajo).

La actividad militar que examinamos tuvo solo influencia marginal en la cabra Sonorense. Las cabras utilizan terrenos compartidos con los militares a través del año y los patrones de comportamiento de las cabras fueron similar con y sin la presencia del estimulo militar. Además, el comportamiento de las cabras expuestas a la actividad militar fue similar al comportamiento de cabras no expuestas a actividades militares regularmente. Las características auditivas de las cabras fueron similares para esas que estaban expuestas y no a la actividad militar regular. La población de cabras Sonorenses en los Estados Unidos continua declinando y esta en serio peligro de extinción. Claramente, se necesita hacer trabajo adicional, pero la actividad militar como se midió en este trabajo no es un factor limitante.

INFLUENCE DES OPÉRATIONS MILITAIRES SUR LE COMPORTEMENT ET L'OUÏE DES ANTILOPES PRONGHORN DE SONORA

Résumé: Nos objectifs dans cette étude étaient de déterminer si les activités militaires (ex. le bruit du trafic aérien, le bruit causé par la délivrance de l'ordonnance, l'activité humain au sol) dans la Chaîne de Barry M. Goldwater (CBMG) a des effets sur le comportement et l'écoute de l'antilope d'Amérique de Sonora *(Antilocapra americana sonoriensis*). Nos avons comparé son comportement en BMGR avec la population la plus proche de l'antilope d'Amérique dans les Etats-Unis, qui n'était pas sujet à l'activité militaire ordinaire (ex., dans le Centre National de la Faune et la Flore de Buenos Aires [BANWR], Arizona). Les quarante pourcent de l'espace utilisé par l' antilope d'Amérique en voie de disparition, dans les Etats-Unis, constitue environ 5,739 km^2 BMGR, un moyen de bombardement et d'artillerie dans le sud-ouest d'Arizona. L'antilope d'Amérique constitue 88% de CBMG. Le nombre de 179 antilopes d'Amérique qui habitaient dans les Etats-Unis en décembre 1992, a baissé en 99, en décembre 2000. L'antilope d'Amérique est désignée comme espèce en disparition depuis 30 années mais les facteurs limités de sa population sont inconnus.

Puisque l'antilope d'Amérique utilise le CBMG, les directeurs du terrain et de la vie sauvage se sont inquiétés pour les effets potentiels des activités militaires sur sa population. Certains des effets indirects possibles de l'activité militaire, à part la mortalité directe ou les blessures, la délivrance d'ordonnance, les balles, le flamboiement, les munitions, les accidents des soldats de deuxième classe, l'interférence causée par les automobiles et le personnel au sol, tout cela comprend l'altération de son comportement ou de sa psychologie.

Nous avons conduit une étude dans le Nord et le Sud des Chaînes Tactiques (NTAC et STAC), CBMG, à partir du Février 1998 jusqu'en Juin 2000. Les examens d'écoute sont conduits dans Camp Verde, en Arizona, à L'Université D'Arizona, et dans la Chaîne Tactique d'Est (ETAC), CBMG. Les interactions entre l'antilope d'Amérique et l'activité militaire étaient limités à quatre points d'observation qui offraient des zones de vue d'où on pouvait les observer, d'une distance de ≤10 Km. Nous avons systématiquement localisé l'antilope d'Amérique avec un télémètre dans des endroits fixes. Au cas de localisation, nous avons décrit leur comportement et l'activité militaire utilisant des models au scanner. Nous avons testé son ouïe utilisant les réponses brainstem et auditives (auditory brainstem responses, ABR). Puisque nous n'avons pas pu tester l'ouïe de l'antilope d'Amérique de Sonora, à cause de leur statut d'espèce en vue de disparition, nous avons examiné et comparé son ouïe près de Campe Verde, Arizona, avec l'ouïe du cerf mulet du désert (*Odocoileus hemionus eremicus*) qui étaient et qui n'étaient pas exposés aux niveaux de pression de bruit causé par l'activité militaire.

Nous avons enregistré les observations du comportement de l'antilope de Sonora pendant une durée de 172 jours (44,375 événements d'observation [ex., 1 observation/30 seconds]) pendant 373 heures. Cette information est comparée avec l'observation de 93 jours (24,297 événements d'observation) pendant 202 heures pour l'antilope d'Amérique qui n'était pas influencé régulièrement par l'activité militaire. En général nous n'avons pas remarqué des différences de comportement (ex, le temps passé à dormir, rester debout, fourrager, marcher) entre les males et les femelles. Les antilopes d'Amérique exposés à l'activité militaire et celles qui n'étaient pas, passaient à dormir la même durée de temps. Les antilopes d'Amérique dans CBMG fourrageaient moins mais restaient et marchaient plus de temps debout, si on les comparaient avec les antilopes d'Amérique qui n'étaient pas exposées à l'activité militaire. Ces tendances étaient similaires avec ou sans l'activité anthropique. Seulement 7.3% des événements de comportement sont produits sans un stimulus identifiable. L'activité militaire aérienne a eu lieu 363 fois (0.8%) et l'activité aérienne non militaire a eu lieu 77 fois (<0.2%). L'antilope d Amérique a rarement réagi à l'activité militaire, mais souvent a bougé >10m quand le stimulus au sol était présent.

Les niveaux de bruit d'ambiance montaient à 123.1 décibels (dB). Le moyen de la pression du bruit pendant les jours d'activité militaire était 65.3 dB comparé avec 35.0 dB pendant les jours sans activité militaire. Puisque nous avons examiné et obtenu des tests d'ouïe du cerf et de l'antilope d'Amérique, nous étions capable de développer

un filtre ongulé de pondération dans le bruit produit par ces activités d'avion ou humain (ex., 14-19 dB plus bas).

L'activité militaire qu'on a examinée a eu une influence marginale sur l'antilope d'Amérique. L'antilope d'Amérique a utilisé les chaînes de montagnes, les partageant avec les militaires durant toute l'année et les réactions de son comportement étaient similaires avec ou sans la présence du stimulus militaire. En plus, le comportement de l'antilope d'Amérique exposé à l'activité militaire était similaire avec le comportement de l'antilope d'Amérique pas exposé à l'activité militaire régulière. Les caractéristiques auditives de l'antilope d'Amérique étaient les mêmes pour celles qui ont étés ou qui n'ont pas étés exposées à l'activité militaire. La population de l'antilope d'Amérique de Sonora dans les Etats-Unis continue d'abaisser et se trouve dans un grand danger d'extirpation. C'est évident qu'il faut mener plus de recherche mais l'activité militaire comme mesurée ci-dessus, ce n'est pas un facteur limité.

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INTRODUCTION

The Sonoran pronghorn is federally listed as an endangered species by the Endangered Species Act (ESA) of 1973, as amended. They inhabit the Sonoran Desert of southwestern Arizona and northern Sonora, Mexico, an extremely harsh environment characterized by extended droughts. Forty percent of the Sonoran pronghorn's home range in the United States is located within the BMGR, a bombing and gunnery range located in southwestern Arizona used by the Department of Defense (United States Fish and Wildlife Service [USFWS] 1997). The remaining 60% of Sonoran pronghorn range in the United States lies within the Cabeza Prieta National Wildlife Refuge (CPNWR), Organ Pipe Cactus National Monument, and on areas administered by the Bureau of Land Management. The range of Sonoran pronghorn covers about 88% (5,739 km^2) of the BMGR (USFWS 1997).

Although the Sonoran pronghorn has been listed as endangered for >30 years, population limiting factors are unknown (USFWS 1998). In December 1992 and March 1993 the population of Sonoran pronghorn was 179 and 414 animals in the U.S. and Sonora, Mexico, respectively (J. R. Morgart, CPNWR, personal communication). The population declined to approximately 99 animals in the United States and 346 animals in Mexico by December 2000 (J. J. Hervert, Arizona Game and Fish Department [AGFD], personal communication). Insufficient forage and water, predation, drought, movement barriers, poaching, habitat degradation due to livestock grazing, lowering of the Gila and Sonoyta rivers, and human encroachment may limit population growth (AGFD 1986, deVos 1990, USFWS 1998).

Presence of Sonoran pronghorn on the BMGR has raised concerns of the potential effects of military activities on their recovery. Possible effects of military activities on Sonoran pronghorn include death or injury as a result of ordnance delivery, chaff, flares, live rounds, aircraft mishaps, and collisions with ground vehicles (USFWS 1997). Indirect effects may include alteration of behavior or physiology (i.e., hearing loss).

The United States Air Force (USAF) is aware of the potential effects of military aircraft on Sonoran pronghorn, but studies that address influence of aircraft on pronghorn are limited. Completed research suggests jet overflights cause minor disturbance to pronghorn (e.g., interruption of grazing; Luz and Smith 1976, Hughes and Smith 1990, Workman et al. 1992). However, ground activities and hovering and noise from helicopters elicit stronger responses and higher heart rates than jet overflights (Luz and Smith 1976, Berger et al. 1983, Workman et al. 1992).

The effects of aircraft stimuli have been documented for other ungulate species. Based on habitat use before, during, and after overflights, Krausman et al. (1986) concluded that desert mule deer habituated to low flying, fixed-wing, single-engine aircraft. Caribou (*Rangifer tarandus*) appear more sensitive to fixed-wing and rotary aircraft overflights than other species; they panic, move, and display other overt reactions to overflights (Calef et al. 1973, Klein 1973, Miller and Gunn 1981, Harrington and Veitch 1992, Harrington 1993, Murphy et al. 1993, Murphy et al. 1994, Maier et al. 1998). Research on bighorn sheep (*Ovis canadensis* spp.) indicates overflights elicit short-term increases in heart rate but cause only a minor increase in stress (MacArthur et al. 1979, Krausman et al. 1993, Krausman et al. 1998). Bighorn sheep demonstrate a disturbance threshold from overflights at heights of 250 to 450 m above ground level (agl) (MacArthur et al. 1982, Stockwell et al. 1991). Bighorn sheep appear more sensitive to helicopter overflights and may abandon areas or travel greater distances following overflights (Bleich et al. 1990, 1994). Military aircraft have flown over Sonoran pronghorn on the BMGR since 1941, and several investigators have hypothesized that continued military activities on the BMGR are not expected to jeopardize the continued existence of Sonoran pronghorn (deVos 1989, Dames and Moore 1995, USFWS 1997) or impact habitat (USFWS 1997). However, no studies have been conducted to determine the effects of military activity on Sonoran pronghorn (USFWS 1997).

Information on behavior is essential to understand the ecology of a species such as pronghorn (Kitchen 1974). Activity and group size of pronghorn are linked to forage quality, dispersion, and productivity; social organization; presence of fawns; and predator pressures (Kitchen 1974; Reynolds 1984; Deblinger and Alldredge 1989; Maher 1991, 1997; Miller and Byers 1991; Byers 1997). Pronghorn exhibit a predator response to human disturbance, but appear to habituate to chronic human disturbance in some instances (Kitchen 1974, Berger et al. 1983, Krausman et al. 1998). Long-term behavioral and physiological effects of military activities on pronghorn populations have not been quantified.

There are numerous studies concerning the effects of noise on wildlife (Gladwin et al. 1988, Bowles et al. 1991, Larkin et al. 1996). Most of these studies investigated the behavioral responses of wildlife to various sounds (e.g., aircraft overflights, sonic booms, industrial or transportation noises). Although "most researchers have concluded that direct trauma to wildlife by noise is likely to be auditory," there are few studies regarding the effects on hearing in wild animals (Larkin et al. 1996). Hearing loss due to noise exposure is an area in need of additional research (Bowles 1995).

A loss in hearing sensitivity in bighorn sheep caused by auditory canal infection of psoroptic mites (*Psoroptes ovis*) may make them more susceptible to predation (Norrix et al. 1995). If pronghorn suffer hearing loss from military activity, they also may be at a greater risk of predation. Information on ABR or behavioral hearing sensitivity has not been measured for pronghorn.

Our objective was to determine whether military activities (e.g., overflight aircraft noise, noise from practice and live ordnance delivery, ground-based human activity) on the BMGR tactical ranges effect the behavior

and hearing of Sonoran pronghorn, and to examine specifically pronghorn behavior during fawning. We also contrasted behavior of pronghorn on the BMGR with the closest population of pronghorn in the U.S. (i.e., Mexican pronghorn [*A. a. mexicana*]) not subjected to routine military overflights (i.e., BANWR, southern Arizona). To examine these objectives we asked 6 questions:

1. Are behavior patterns of pronghorn similar with and without the presence of military activity?
2. Are direct overflights (i.e., aircraft flying over ≥1 pronghorn [±100 m]) associated with a change in behavior of pronghorn?
3. Are behavior patterns of pronghorn exposed to regular military activity at BMGR similar to the behavior of pronghorn at BANWR that are not exposed to regular military activity?
4. Are fawning behavior (e.g., behavior of females with fawns and fawns only) patterns similar at BMGR where animals are exposed to military activity to BANWR where they are not exposed to regular military activity?
5. Are auditory characteristics different for desert ungulates that have and have not been exposed to sound from military activities?
6. What are the characteristics of sound levels that animals are exposed to at BMGR and BANWR?

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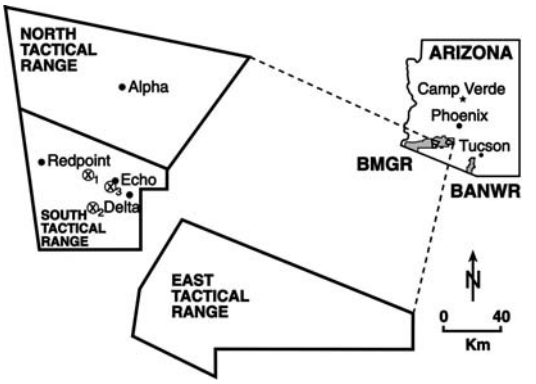


Figure 1. Barry M. Goldwater Range (BMGR) and Buenos Aires National Wildlife Refuge (BANWR), Arizona, including observation sites for biologists (•) and sound monitoring sites (X).

STUDY AREA

We conducted our study on the NTAC and STAC, BMGR (Fig. 1) and BANWR (Fig. 2), Arizona. Aridity and heat characterize climate in the Sonoran Desert. Average

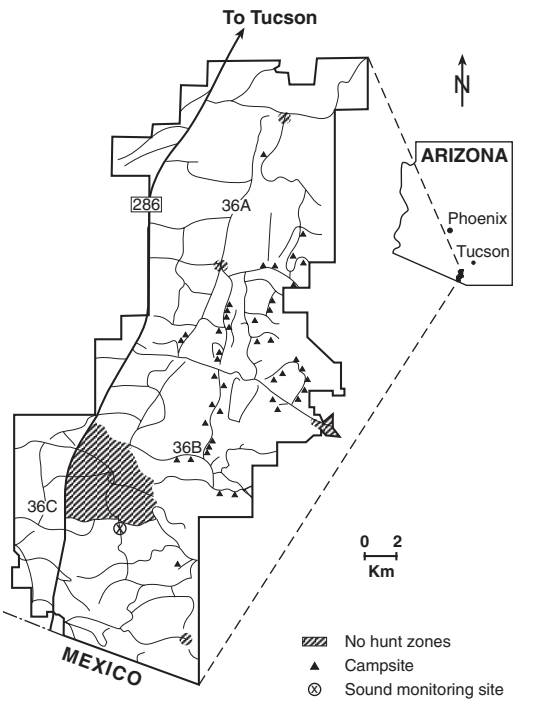


Figure 2. Buenos Aires National Wildlife Refuge, Arizona.

daily temperatures ranged from 19 to 32°C annually. Temperatures in winter rarely dropped below 0°C, but maximum temperatures exceeded 43°C during July and August (Sellers and Hill 1974). Average annual precipitation of 127 mm occurred in a bimodal pattern from December to February and July to September. Arroyos (i.e., ephemeral streambeds) flowed briefly after rains during summer monsoons and after sustained winter rains.

Habitat of Sonoran pronghorn in the United States consists of broad alluvial valleys separated by block-faulted mountain and surface volcanics (USFWS 1998). Elevation varied from 122 m near Mohawk Valley in the west to 488 m in Valley of the Ajo to the east. Surrounding mountain ranges are oriented northwest to southeast with valleys draining to the north towards the Gila River and to the south towards Rio Sonoyta in Mexico. Major drainages run north and south. The BMGR includes the Lower Colorado River Valley and the Arizona Upland plant communities (Brown 1982). The majority of the Lower Colorado River Valley subdivision consists of creosote (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*). Species along arroyos include ironwood (*Olneya tesota*), blue palo verde (*Cercidium floridum*), and mesquite (*Prosopis* spp.). Species in the Arizona Upland include foothill palo verde (*Cercidium microphyllum*), catclaw acacia (*Acacia greggii*), jumping (*Opuntia fugida*) and teddy bear cholla (*O. bigelovii*).

Livestock contributed to the changing vegetation composition of the desert region. Cattle influenced changes in the desert grassland more than in other zones (Hastings and Turner 1972). Since cattle were removed from the BMGR in 1986, the distribution of pronghorn may have shifted (USFWS 1998).

The BANWR is located in south-central Arizona, 97 km southwest of Tucson (31°41′N, 111°27′W) (Fig. 2). The 455 km^2 fenced refuge is within the Altar Valley east of the Baboquivari Mountains and west of the Cerro Colorado, Las Guijas, and San Luis mountain ranges. State, Bureau of Land Management, and National Forest Service lands surround the northern, eastern, and western borders of the refuge, with Mexico on the southern border. Elevation ranges from 925 to 1,400 m with topography characterized by rolling hills and numerous washes (McLaughlin 1992). The refuge serves as a watershed from the surrounding mountain ranges with drainage leading north to the Altar Wash. Many water catchments, earthen tanks, and washes on the refuge are ephemeral sources of water, although 25-33% of these sources contained water all year. Mean annual precipitation was 40 cm occurring in a bimodal distribution with summer rainfall in July and August and winter rainfall from December to February. Annual daily temperatures averaged 15°C, with extremes ranging from –11°C in winter to 41°C in summer (USFWS 1995).

Physiography and recent land use practices at BANWR support a semi-desert shrub-grassland defined by a mixture of native and exotic plant species with remnants of Sonora savanna grassland (McClaran 1995). Exotics such as Lehmann lovegrass (*Eragrostis lehmanniana*) in upland areas and Johnson grass (*Sorghum halepense*) in floodplains dominate native species (S. P. McLaughlin. 1990. Flora of Buenos Aires National Wildlife Refuge, including Arivaca Cienega, The University of Arizona, Tucson, unpublished report). Dense stands of woody growth, including mesquite, catclaw acacia, wait-a-minute (*Mimosa biuncifera*) and prickly pear and cholla cacti (*Opuntia* spp.) were present throughout the refuge because of historic land use and lack of natural wildfires (S. P. McLaughlin 1990). Native grasses included dropseeds (*Sporobolus* spp.), gramas (*Bouteloua* spp.), threeawns (*Aristida* spp.), Arizona cottontop (*Digitaria californica*), and plains lovegrass (*Eragrostis intermedia*) (S. P. McLaughlin 1990).

The deeper soils of wash basins were characterized by a mixture of Johnson grass, sacaton (*Sporobolus* spp.), and Russian thistle (*Salsola kali*). The foothills and higher elevations supported a mixture of half-shrubs such as snakeweed (*Guitierrezie sarothrae*) and burroweed (*Isocoma tenuisecta*), grasses, prickly pear and cholla cacti, ocotillo (*Fouquieria splendens*), and numerous annual and perennial forbs (S. P. McLaughlin 1990). Common forbs throughout the refuge during the biannual rainy seasons included spiderlings (*Boerhaavia* spp.),

spurges (*Chamaesyce* spp.), purslanes (*Portulaca* spp.), globe amaranths (*Gomphrena* spp.), milkvetches (*Astragalus* spp.), vetches (*Lotus* spp.), and evening primrose (*Oenothera* spp.). Other forbs prevailed after heavy rains or were limited to riparian areas such as corridors along major washes, Arivaca Cienega, and earthen tanks (S. P. McLaughlin 1990).

Four-strand barbed wire fence surrounded the entire refuge and existed within the refuge. This fencing restricted pronghorn movement. More than 320 km of unimproved dirt roads and trails were open to the public all year for travel by motorized vehicle, horse, mountain bike, or foot. The refuge encouraged wildlife viewing all year, allowed primitive camping in >90% of designated backcountry areas, and supported hunting seasons for waterfowl, rabbits, and big game (excluding pronghorn) (USFWS pamphlet for hunting on BANWR, BANWR, Arizona). Most pronghorn inhabited no-hunt zones and were not seen near primitive camping areas (BANWR records, BANWR, Arizona).

We conducted baseline ABR or behavioral hearing sensitivity testing on American pronghorn (*A. a. americana*) that the AGFD translocated from Utah to Arizona. We tested the translocated pronghorn prior to their release in December 1997 in the hills east of Camp Verde, Arizona (34.6°N, 111.6°W). We also conducted ABR comparison testing on 2 groups of desert mule deer. Three desert mule deer were tested on 23 November 1998 at The University of Arizona's Wildlife Research Facility, Tucson, Arizona. The wildlife research center was within a high altitude (>305 m agl) military training route for aircraft from Davis Monthan Air Force Base, Tucson. Four desert mule deer were tested on 17 December 1998 at the East Tactical Range (32.7018°N, 112.5618°W), BMGR (Fig. 1).

We conducted sound level monitoring at 3 sites on STAC, BMGR and 1 site on BANWR. Site 1 was located near High Explosive Hill (HE) (32°32.239′N, 113°13.953′W). Site 2 was on flat terrain in Growler Valley (32°28.355′N, 113°11.686′W). Site 3 was located at the foot of the hills between pronghorn observation points Delta and Echo (32°30.008′N, 113°10.191′W) (Fig. 1). The BANWR site was located southeast of the visitor center in an area frequented by pronghorn (31°32.494′N, 111°29.298′W).

METHODS

Behavior

We observed pronghorn at BMGR from February 1998 through June 2000. From February through June in 1999 and 2000 we doubled the field effort to locate fawns. We observed pronghorn at BANWR from February to June in 1999 and from February to August 2000. Most observations were during weekdays.

We made observations of daily activity of pronghorn throughout their range on the BANWR, but were restricted to 4 observation points at the BMGR. Behavior of pronghorn is commonly sampled by following animals to observe daily activities (Kitchen 1974; Maher 1991, 1997; Byers 1997). Military operations, research safety, and the ESA precluded such observational methods for Sonoran pronghorn. Section 4(d) and 9 of the ESA prohibit taking, which includes pursuit of listed species without a permit (USFWS 1997). We were prohibited from following Sonoran pronghorn to gather observation data even when military ranges were not in operation. However, the USAF has 1 site on the NTAC and 3 sites on the STAC of BMGR designated as "no drop zones" where behavioral observation of Sonoran pronghorn could be made (Fig. 1). Each site offered an expansive view from which pronghorn and military activity could be observed from 10 km in relative safety. Range scheduling at Luke Air Force Base coordinated access to each site. From these sites, we observed behavior of Sonoran pronghorn while overflights, ordnance training, and other activities occurred on or over the ranges.

Locating Pronghorn.—Because of the small population of pronghorn, the large landscape they occupied, and our objective of determining how they responded to military overflights and activity, we used 2 methods of locating animals. At BMGR, we arrived at observation points before daylight (0400–0500) and stayed until we could safely leave (1200–2000). We used telemetry equipment

and a Telonics® frequency monitor (TDP2 advance digital data processor, Telonics, Mesa, Arizona) to perform an initial radiotelemetry scan for ≤4 radiocollared pronghorn in the area. The radiocollared animals were part of an unrelated study by the AGFD. We took a compass bearing for each signal heard and then used binoculars (Zeiss 10 × 56) and spotting scopes (Swarovski AT-80 20-60X, Bushnell 15-45X) to search for animals in these areas. Each observation team consisted of 2 observers.

If radiocollared pronghorn were not located in the area, we began a systematic visual scan using spotting scopes. The scan area was a circle divided into 4 quadrants with the observer as the center. We accomplished scans by systematically scanning each quadrant, overlapping viewing areas of each section until the entire area was searched. We started a new systematic scan 1 hr after completion of the previous scan when no animals were detected, alternating scan direction clockwise and counterclockwise. We conducted periodic telemetry checks during systematic scans. If we heard a radio signal, we abandoned the systematic scan and searched for the radiocollared pronghorn. If we failed to observe the collared pronghorn within 1 hr, then a biologist began systematic scans of the quadrants while the other observer continued to scan for collared pronghorn.

We observed behavior of pronghorn at BANWR in a similar manner with several exceptions. We were able to approach pronghorn and were not limited in our observation sites. We divided the day into 4 quarters (i.e., activity periods) and divided the refuge into 5 sections. Each day, we searched for pronghorn in 1 section during 1 activity period. We chose activity period and refuge section randomly without replacement on a weekly basis. We systematically searched for pronghorn in each section by driving along roads and conducting visual scans using binoculars and a spotting scope. When we located a group of pronghorn, we found a position where we did not disturb animals and began collecting data using the same scan sampling method applied at BMGR (Altmann 1974).

Data Collection.—We used data forms to record behavior and all stimuli. Main categories of behaviors included bedding, standing, foraging, traveling, and other (e.g., grooming, copulation). We defined general (e.g., bedding, standing) versus discrete (e.g., bedding with head down versus bedding with head raised) behaviors to ensure consistency among all data collected (Lehner 1979, Martin and Bateson 1993). Military stimuli included activities such as aircraft overflights, bombing, strafing, heat flares, impact with noise, and impact with smoke but no noise. We defined aircraft overflights by their altitude in relation to the known elevations of mountains surrounding the study areas. A low overflight was ≤300 m agl and a high overflight was ≥300 m agl. Non-military specific stimuli included vehicles or people in the observation area.

We collected behavioral data on pronghorn when we could distinguish defined behaviors. The ability to distinguish behaviors varied with distance from pronghorn, time of day, and temperature changes that altered our visual range. When we sighted pronghorn, we recorded location and initial behavior of the group, and counted and classified the gender and age of animals. We classified fawns as pronghorn <1 year old. We made behavioral observations using a scan sampling method (Altmann 1974, Lehner 1979, Martin and Bateson 1993). We recorded instantaneous observations of individual behaviors of all visible pronghorn at 30-second intervals. We established a short observation interval relative to mean duration of behavior measured so we could reliably estimate activity budgets without conducting continuous sampling (Lehner 1979). We also recorded presence of aircraft noise and any other human stimuli present during each interval. We specifically noted when animals moved ≥10 m within 30 seconds after an overflight occurred. We continued observations until animals were no longer visible or we were required by the military to leave the study site.

Observer presence potentially influenced behavior of pronghorn at both sites. Studies have mentioned breaks in behavioral patterns of pronghorn when approached by vehicles or predators (Hlavachick 1968, Kitchen 1974, Bruns 1977, Byers 1997). Pronghorn return to normal activity if the observer moves out of sight, waits several

minutes, and then approaches animals using topography as a shield and avoids tangential movements to the animals (Hlavachick 1968, Kitchen 1974). Distance from observer to animal varied at each site (BMGR, 1 to 10 km; BANWR, 0.1 to 5 km). Our data analyses assumed that potential visibility bias because of restricted access (at BMGR), topography, and vegetation associations would have no effect on observed behavioral patterns of pronghorn (Wood 1989). We also had a concern with representation bias of individual animals because when radiocollared animals were not present, we could not identify individuals, and groups changed throughout the study period. Our analysis assumed equal representation of all pronghorn groups available. Randomization of areas observed and time of observations minimized this bias at BANWR, but military protocol (i.e., they determined which sites we could visit) prevented such randomization at BMGR.

Fawning Behavior.—We followed the same protocol for observing fawns as for other pronghorn with 2 exceptions. First, we prioritized observation efforts in the following order: fawns, fawns and females, and other pronghorn. Second, to maximize our opportunities to observe fawns we increased the field crew at BMGR from 2 to 4 observers from February through June in 1999 and 2000. This allowed the possibility (when approved by the USAF) of viewing pronghorn from 2 observation points at the same time or at the same site for a longer period (i.e., morning and evening versus morning or evening).

Hearing

The ABRs are electrical potentials generated by the brainstem when the ear is stimulated by sound (Hall l992). The sound stimulus may be a click, which is used to measure broadband hearing sensitivity; a toneburst, which is used to measure frequency-specific sensitivity; or more complex stimuli. Electrical potentials are measured as voltage differences between electrodes located on an animal's head. These potentials are averaged for several hundred or thousand stimuli presented, thereby increasing the signal-to-noise ratio. Auditory brainstem response waveforms typically consist of a series of peaks and troughs that are generated by the discharge of neurons in major cell groups in the brainstem.

The ABR is a popular method in hearing research for several reasons (Burkard and Voigt 1989). In most cases, it is not affected by subject state, including the effects of most anesthetics typically used to restrain animals chemically (Bobbin et al. 1979). Also, ABR testing is relatively fast, especially in comparison to behavioral hearing studies in which animals must be trained, for weeks or even months, greatly limiting the sample size that can be tested. Using ABR techniques, information on an animal's hearing acuity can be collected in as little as 30-45 minutes, with no investment in behavioral training. In addition, ABR testing has been successful for a wide variety of animals, including mustelids (Kelly et al. 1989), cetaceans (Carder and Ridgeway, in press), rodents (Francine and Bowles 1995), pinnipeds (Thorson et al. 1998), and ungulates (DeYoung et al. 1993). Finally, ABRs are precise, with variability of 5% in peak latencies. In laboratory studies, ABR is commonly used to assess hearing function (Reinis 1976, Hammernik et al. 1991, Counter et al. 1993), and is routinely used to evaluate hearing disorders in humans (Hall 1992).

We could not test the hearing of Sonoran pronghorn because of their endangered status. Thus, we conducted ABR testing on 3 groups of desert ungulates. The first group consisted of 5 American pronghorn near Camp Verde, Arizona. The second group consisted of desert mule deer living on the BMGR that were exposed to routine military aircraft overflights (e.g., F-15, F-16, A-10, and helicopters). The third group was a control of 3 desert mule deer at The University of Arizona's wildlife research center, Tucson, Arizona. The first and third groups were not routinely exposed to noise from low-flying aircraft.

Prior to the AGFD releasing pronghorn into Arizona from Utah in December 1997, we restrained 5 animals (>1 year old; 2 M, 3 F) with ketamine hydrochloride (HCL) and xylazine HCL at the release site. At BMGR in December 1998, we captured 4 mule deer (>1 year old; 1 M, 3 F) with a net-gun fired from a helicopter and then transported the animals in a helicopter to the site of the ABR

testing. During the short flights to the testing site, the deer were fitted with standard hearing protectors (headphone type) to attenuate the relatively high sound levels inside the helicopter. We restrained the captured deer and those tested at The University of Arizona by injection of ketamine HCL and xylazine HCL.

Once restrained, we anesthetized animals with Halothane. We performed otoscopic examinations on all animals to rule out impacted cerumen or debris lying in the ear canal. We conducted examinations with a hand-held halogen otoscope (Welch-Allyn, Skan Falls, New York, USA) with an appropriate diameter and length speculum, inserted into each ear. We examined the ear canal and tympanic membrane for debris and defects. If debris was found we thoroughly cleaned and dried the ear canal before proceeding. Remote testing was required at the Camp Verde site and the BMGR, so we powered the ABR equipment using 12-volt deep-cycle batteries converted to AC via an inverter. We used standard AC power for the testing at The University of Arizona. Following ABR testing, the animals were aroused from anesthesia with yohimbine HCL and doxapram HCL and released into the wild or returned to their pen.

We presented 2 different sound stimuli to animals through standard audiometric insert tubephones: a broadband click, and tonebursts of 1, 2, 4 and 8 kilohertz (kHz). We also presented a toneburst of 0.5 kHz to the pronghorn near Camp Verde. The click measures general hearing function in the frequency range of 1 to 4 kHz and the tones measure hearing function at those specific frequencies. The tonebursts had a 2-cycle rise and fall time and a single cycle at the plateau. We used a Blackman ramping window to enhance the spectral characteristics of the tones (Hall 1992:1151). We initially presented the stimuli to pronghorn at sound pressure levels (SPL) of 100 to 110 decibels (dB) peak equivalent (pe) SPL and then decreased in 10 dB steps until the animal's response was no longer reliably observed. For mule deer, we initially presented the stimuli at 85 to 105 dB pe SPL and then decreased in 10-dB steps until the animal's response was no longer reliably observed. We delivered the sound stimulus at a rate of 31.1 stimuli per second. A Bio-logic Systems Corporation (Mundelein, Illinois, USA) evoked-potential system produced the stimulus sounds, and collected and averaged the evoked responses from the animals.

We measured the ABR from 1 ear of each animal using sterile, sub-dermal, stainless steel electrodes (10-mm length) with a conventional electrode array (Hall 1992: 192). We also presented low-level white noise (20-30 dB) to the non-tested ear, reducing any electrical potentials generated by that ear.

Prior to testing, the Bio-logic ABR system and the insert tubephones were calibrated at the Speech and Hearing Science center, The University of Arizona. At the Camp Verde site, we also measured the background or ambient noise present during the ABR testing using 2 different systems. For long-term averaging we used a Larson-Davis (Provo, Utah, USA) model 820 sound level meter (SLM). For frequency-specific information we made recordings using a TEAC RD120TE (TEAC America, Montebello, California, USA) digital audio tape (DAT) recorder gathering the signal from a Bruel and Kjaer (Irvine, California, USA) Type I model 4193 microphone and powered by a Bruel and Kjaer type 5935 power supply. On the BMGR, we measured the background and ambient noise present during the ABR testing using a Larson-Davis model 820 SLM.

Ambient Noise Exposure

We measured ambient noise from 23 September to 24 October 1998, 21 January to 8 March 1999, and 9 June to 13 July 1999 at BMGR and from 21 October to 3 November 2000 at BANWR. We used 2 types of sound monitoring systems (SLM) to quantify the sound pressure levels at STAC. These were identical to the systems used at Camp Verde, Arizona, to measure ambient noise during hearing testing. We used the Larson Davis SLM to quantify sound pressure levels at BANWR.

The Larson Davis SLM measures sound from individual sound events, such as explosions or aircraft overflights, and the ambient and background noise. The SLM does not make recordings of sound like the DAT recorder but simply computes acoustical metrics of sound. The microphone for each SLM was mounted in a short length of PVC

pipe and attached to a steel pole. The steel poles were driven into the ground so that the microphones were 1.2 m agl (a standard microphone placement). The winds that occur on BMGR and BANWR can be strong enough to have an influence on noise measurements. To minimize wind noise we mounted the microphones in extra-large windballs (18 cm diameter versus the typical 9 cm). These large windballs do not substantially alter the measurement of the anthropogenic or background noise under study (Hosier and Donavan 1979). Each SLM was packaged in a weatherproof Pelican case and powered by external 12-Volt (DC) deep-cycle batteries. The large external batteries provided the systems enough power to operate for ≥5 weeks without recharging or replacement.

We calibrated each SLM over the frequency range of 25 Hz to 10 kHz (Appendix A). In the field, each system was calibrated at set-up and just prior to shutdown using a Bruel and Kjaer model 4230 calibrator. Each SLM was set to begin measuring sound events when the sound level exceeded 70 dB (except the system at Site 2, which was set to 65 dB).

The DAT system records sound digitally to tape, which allows for detailed analysis of the frequency content and the calculation of other acoustical metrics. Starting at around 0900 on 18 September 1998, we operated the DAT recorder system near Site 3 for 3 hours. The recorded sound was post-processed using a 16-bit analog to digital PC card and analyzed using SpectraPRO FFT Spectral Analysis System software (Sound Technology, Campbell, California, USA).

ANALYSIS

Behavior

We estimated activity budgets of each population as the average percent time pronghorn groups spent in each major behavior (i.e., bedded, standing, foraging, traveling) during an observation period. We contrasted behavior (i.e., 95% confidence intervals) with military activity present versus behavior with no military activity present, and then specifically looked at behavior of fawns with and without military activity present. We also compared behavior of males, females, and fawns. We compared overall activity budgets of Sonoran pronghorn at BMGR versus that of Mexican pronghorn at BANWR.

Because many observations at BMGR were at distances ≥10 km we could only determine if animals were bedded, standing, foraging, or moving. To determine if military overflights were associated with a change in behavior, we contrasted behavior prior to, during, and after overflights.

Hearing

Evoked responses to the click were band-pass filtered at 100 Hz to 3,000 Hz, and the evoked responses to the tonebursts were filtered from 30 Hz to 3,000 Hz (Hall 1992:117-212). For the 500 Hz stimulus for pronghorn the sampling analysis time was 15 milliseconds; all other stimuli for pronghorn and deer were at 10 milliseconds. We measured the dominant peak for each waveform to calculate the mean latency-intensity functions. We also calculated the linear slope of the latency-intensity function. The threshold was determined as the signal amplitude where identifiable peaks were not reliably present.

There are 2 weighting filters commonly used in sound analysis: A-weighting and C-weighting (Fig. 3). There also is an unweighted or flat sound measurement, through which the sound is analyzed without filtering. A-weighting is a standard filter

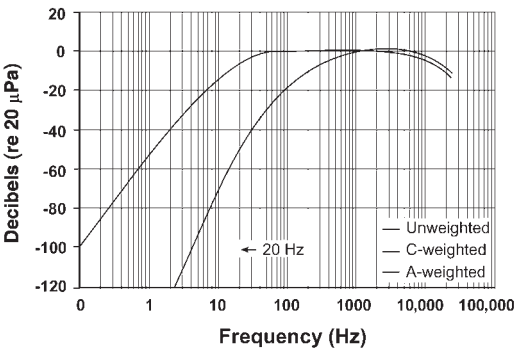


Figure 3. A-weighted and C-weighted acoustical filters. The line labeled 20 Hz shows the amount that sound is reduced, at that frequency, for these 2 weighting filters. Using the A-weighted filter (bottom curve), a sound at 20 Hz would be reduced about 50 dB, while with C-weighting (top curve) the same 20 Hz sound is only reduced about 6 dB. For aircraft and bomb noise, much of the sound is at relatively low frequency, thus A-weighting will lower the overall sound level measurements more than C-weighting.

used in acoustics that approximates human hearing and in many cases is the most appropriate weighting filter when investigating sound effects on mammals. C-weighting approximates human response to loud, usually transient sounds, such as a sonic boom, and may be a better predictor in some cases of animal response to loud sounds. There is no general consensus on either the most appropriate weighting filter to use in animal studies, or which acoustic metrics best correlate with animals response. The unweighted measurement most likely overstates the sound heard by animals because it is a composite noise level from all sources, but it is useful for comparing the sound to other transient sounds (Hall 1992).

Ambient Noise Exposure

The most useful background noise measurement for our studies on the effects of sound on wildlife is the 1-hr average sound level (L_{eq}). The L_{eq} can be thought of in terms of *equivalent* sound; that is, if a L_{eq} is 45.3 dB, this is what would be measured if the SLM was placed in a sound field of 45.3 dB for 1 hr. However, this is not what happens during real sound measurements. In real sound environments, when a L_{eq} level of 45.3 dB is measured, the sound level has fluctuated above and below 45.3 dB, but the *average* during that hour is 45.3 dB. Averaging times for L_{eq} are not limited to 1 hr. Twenty-four hour levels are also commonly employed. Average levels also are calculated for single sound events, such as a jet overflight or an explosion. In this case, L_{eq} is the average level over some defined time period. This time period is usually defined as when the sound level exceeds a threshold level and then decreases below the hysteresis level (i.e., begin averaging when the level exceeds 70 dB and then stop when the level drops below 64 dB). The L_{eq} measurements are A-weighted, unless specified otherwise.

Another commonly used metric is sound exposure level (SEL). The SEL is the total sound energy in a sound event *if that event could be compressed into 1 second.* In essence, SEL is an average sound level condensed into 1 second. Sound exposure level is often reported as unweighted, A-weighted, or C-weighted.

Maximum fast sound level (Lmax), usually with A-weighting applied, is the greatest sound level reached during a sound event with exponential time weighting applied. The time weighting causes sound levels to be dampened by sounds that most recently occurred (up to 1 second). The "fast" refers to specific exponential moving average time weighting. Although this is a standard metric in acoustics, SEL and L_{eq} measurements are usually better descriptors for sound impacting wildlife.

Peak sound level is the greatest instantaneous sound level reached during a sound event. Peak levels also can be reported using the various frequency weightings. Peak levels, though useful in some cases, can often be misleading, as a single peak can be substantially greater than the majority of the levels occurring over a sound event. Peak levels always should be presented with ≥1 of the metrics discussed above to better describe the sound.

There has only been 1 behavioral *hearing* study on ungulates (i.e., domestic sheep) (Wollack 1963). Two recent ABR studies on ungulate hearing (Francine and Bowles 1995, Krausman et al. 1998) demonstrated little difference in hearing sensitivity between desert mule deer, pronghorn, and bighorn sheep. Bighorn sheep hearing, however, is substantially different from humans. Below about 8 kHz, humans hear much better than bighorn sheep, but >8 kHz, bighorn sheep hearing is more sensitive than human hearing.

To gain a better understanding of how aircraft noise is likely perceived by pronghorn, we created a frequency-weighting filter, similar to what A-weighting is for humans, based on the data from ungulate hearing studies. The filter closely modeled the best estimate of ungulate hearing. The ungulate filter was applied to the jet overflight sound data in a manner similar to the other weighting filters (A and C). First the sound data is averaged in the frequency domain over the duration of the overflight noise, and then the data are passed through the appropriate weighting network.

The ungulate filter was created using MatLab software and then integrated into a custom sound analysis program (Soundnet). The filter was constructed using cubic spline

interpolation. Because most anthropogenic noise is at low frequency and no ungulate hearing sensitivity information is available below 100 Hz, the low frequency hearing sensitivity was extracted following the slope of the curve near 100 Hz. The true roll-off in hearing sensitivity is likely greater than the extrapolated line and would therefore attenuate even more sound.

RESULTS

Behavior

Our data were collected from collared and uncollared Sonoran pronghorn. Four collared pronghorn used the NTAC and STAC ranges at least part of the year. These 4 animals represented 27 to 40% of the entire collared population (15 in 1998, 10 in 1999, and 9 in 2000) (J. J. Hervert, AGFD, personal communication). A minimum of 21 pronghorn (ca. 20% of the entire population in the U.S.) used the NTAC and STAC ranges at least part of the year, based on surveys conducted by the USFWS and AGFD (J. R. Morgart, USFWS, personal communication).

We recorded behavior observations of Sonoran pronghorn on 172 days (i.e., $n = 48$, 53, and 71 in 1998, 1999, and 2000, respectively) (Table 1). We obtained 15,339 observation events (i.e., 1 observation/30 seconds) in 1998, 11,547 in 1999, and 17,889 in 2000 (Table 2) during 373 hrs of observing Sonoran pronghorn. Animals were visible 90% of the time (13,900 events in 1998, 10,453 in 1999, and 16,034 in 2000) for 336.5 hrs of observation (115.8, 87.1, 133.6 hrs in 1998, 1999, and 2000, respectively).

We recorded behavior of Mexican pronghorn at BANWR on 93 days (51 in 1999, 42 in 2000) (Table 3). We obtained 14,882 observation events in 1999 and 9,415 in 2000 (Table 3) during 202 hrs of observing Mexican pronghorn. Animals were visible 90% of the time (13,269 and 8,504 observation events in 1999 and 2000, respectively) for 181.5 hrs of observation (110.6 in 1999, 70.9 in 2000).

Anthropogenic Stimuli.—We recorded anthropogenic stimuli on 134 of 172 (78%) days of observation at BMGR (Table 1). We documented 56 days that included anthro-

Table 1. Anthropogenic stimuli associated with 172 days of observing Sonoran pronghorn, Barry M. Goldwater Range, Arizona, February 1998 through June 2000.

	Year			
Variable	1998	1999	2000	Total
No. days observations made	48	53	71	172
No. days any anthropogenic stimuli present[a]	40	39	55	134
No. days aircraft noise present	40	37	46	123
No. days other stimuli present[b]	29	33	50	112
No. days with overflights[c,d]	18	26	20	64
No. days with direct overflights	11	17	10	38
Military	9	12	5	26
Non-military	2	3	0	5
Unidentified	0	1	5	6
No. days with other overflights	13	20	18	51
Military	13	17	14	44
Non-military	0	2	1	3
Unidentified	0	1	0	1
No. days with other military air stimuli[e]	25	25	25	75
No. days with ground stimuli[f]	11	6	34	51
No. days with multiple stimuli[g]	7	6	12	25

[a] Anthropogenic stimuli include all military and non-military visual and aural stimuli.

[b] Days with other stimuli do not include days when aircraft noise (no visual on aircraft) was the only stimulus present. Other stimuli include overflights, other military air stimuli, and ground stimuli.

[c] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Unidentified overflights could be military or non-military aircraft.

[d] Overflights that occurred during events with multiple stimuli are included in these totals.

[e] Other military air stimuli include bombing, smoke, strafing, and heat flares.

[f] Other ground stimuli include people, vehicles, and generators.

[g] Multiple military stimuli includes stimuli from >1 of the previous categories (overflights, other military air stimuli, ground stimuli).

Table 2. Percent of 30-second observation recordings of Sonoran pronghorn with anthropogenic stimuli present, Barry M. Goldwater Range, Arizona, February 1998 through June 2000.

	Year			
Variable	1998	1999	2000	1998–2000
Total events recorded[a]	15,339	11,547	17,889	44,775
% events any anthropogenic stimuli present[b]	55	35	28	39
% events aircraft noise present	52	34	21	35
% events other stimuli present[c]	6	4	11	7
% events with overflights[d]	1.1	1.3	0.8	1.0
% of events with direct overflights	0.3	0.6	0.2	0.3
Military	0.2	0.4	0.1	0.2
Non-military	0.1	0.2	0	0.1
Unidentified	0	0.01	0.04	0.02
% of events with other overflights	0.8	0.6	0.7	0.7
Military	0.8	0.3	0.6	0.6
Non-military	0	0.2	0.1	0.1
Unidentified	0	0.13	0	0.03
% events with other military air stimuli[e]	1.3	1.7	1.1	1.3
% events with ground stimuli[f]	3.4	0.5	8.6	4.7
% events with mulitiple stimuli[g]	0.1	0.1	0.3	0.2
% of events with multiple stimuli that included overflights	85	100	65	73

[a] Event = 1 observation/30 sec.

[b] Anthropogenic stimuli include all military and non-military visual and aural stimuli.

[c] Events with other stimuli do not include events when aircraft noise (no visual on aircraft) aircraft was the only stimulus present. Other stimuli include overflights, other military air, ground stimuli, and multiple stimuli.

[d] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Unidentified overflights could be military or non-military aircraft.

[e] Other military air stimuli include bombing, smoke, strafing, and heat flares.

[f] Other ground stimuli include people, vehicles, and generators.

[g] Multiple military stimuli includes stimuli from >1 of the previous categories (overflights, other military air stimuli, ground stimuli).

pogenic stimuli at BANWR similar to stimuli that occurs at BMGR (e.g., aircraft noise, overflights, heat flares, sonic booms, vehicles, and people) (Table 3). However, the actual level of human activity at BMGR (39%) was >3 times higher than that at BANWR (12%) based on 30-second observation events. During observations at BMGR, pronghorn were exposed to 157 direct overflights of aircraft: 109 were military but only 6 were <300 m agl (Table 4). Overflights by military aircraft are not regularly scheduled at BANWR. Mexican pronghorn were exposed to 27 direct military overflights and 12 other military overflights during observations (Table 5). Military overflights coincided with observations 5.9 times more at BMGR (0.94%) than that at BANWR (0.16%) (Tables 3,4). Other military air stimuli were present for 1.3% and 0.03% of observation events at BMGR and BANWR, respectively (Tables 2,3).

We also documented days that included stimuli not necessarily specific to military activities, including non-military overflights (Table 4,5) and ground stimuli (e.g., vehicles and people). Non-military overflights coincided with 0.2% and 0.1% of observations at BMGR and BANWR, respectively (Tables 2,3). People and ground vehicle stimuli were present during observation events 1.7 times more at BANWR (7.9%) than that at BMGR (4.7%) (Tables 2,3).

Behavior of Adult Pronghorn at BMGR.—We did not detect differences in the amount of time spent bedded, standing, foraging, or traveling by year for males (Fig. 4A) or females (Fig. 4B) in 1998, 1999, or 2000. Because there were no differences among years, or sexes (Fig. 5), we pooled behavior data for all adult animals. Other behaviors (i.e., grooming, pushing, playing, urinating, defecating, nursing) comprised <0.2% of observations, and were not included in activity budget analysis (i.e., totals do not add to 100%).

Table 3. Anthropogenic stimuli associated with 93 days of observing Mexican pronghorn, Buenos Aires National Wildlife Refuge, Arizona, 1999 and 2000.

Variable	Year and Date: 10 Feb–15 Jun 1999	11 Feb–3 Aug 2000	1999 and 2000
No. days observations made	51	42	93
No. days any anthropogenic stimuli present[a]	27	29	56
No. days aircraft noise present	11	17	28
No. days other stimuli present[b]	25	24	49
No. days with overflights[c]	12	6	18
Direct overflights	12	5	17
Military	11	3	14
Non-military	3	3	6
Other overflights	5	3	8
Military	5	3	8
Non-military	1	0	1
No.days other military air stimuli present[d]	5	1	6
No. days other ground stimuli present[e]	22	20	42
Total observation events recorded[f]	14,882	9,415	24,297
% events any anthropogenic stimuli present[a]	4.7	22.5	11.6
% events aircraft noise present	2.3	7.1	4.1
% events other stimuli present[b]	2.7	16.9	8.2
% events with overflights present[c]	0.3	0.2	0.3
% events direct overflights present	0.19	0.10	0.16
Military	0.15	0.05	0.11
Non-military	0.05	0.04	0.05
% events other overflights present	0.12	0.06	0.10
Military	0.04	0.06	0.05
Non-military	0.08	0	0.05
% events other military air stimuli present[d]	0.05	0.01	0.03
% events other ground stimuli present[e]	2.3	16.8	7.9

[a] Anthropogenic stimuli include all military and non-military visual and aural stimuli.

[b] Days/events with other stimuli do not include events when aircraft noise (no visual on aircraft) was the only stimulus present. Other stimuli include overflights, other military air- and other ground stimuli.

[c] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include rotary and fixed wing aircraft affiliated with Arizona Game and Fish Department, U.S. Border Patrol, U.S. Drug Enforcement Agency, and private.

[d] Other military air stimuli include sonic booms and heat flares.

[e] Other ground stimuli include people and vehicles (refuge personnel and visitors).

[f] Event = 1 observation/30 sec.

Pronghorn spent the most time traveling, followed by standing, bedding, and foraging (Fig. 5) from 1998 to 2000. On days with anthropogenic stimuli the pattern was the same (i.e., more traveling followed by standing, bedding, and foraging), but on days without anthropogenic stimuli pronghorn foraged more than they bedded (Fig. 6). This difference was attributed to observations collected in 2000 when we documented a difference between time spent bedding with and without anthropogenic stimuli. When anthropogenic stimuli were present, pronghorn bedded 19 to 27% of the time compared to 2 to 14% of the time when anthropogenic stimuli were not present (95% CI). No other behaviors were different.

Behavior of Adult Pronghorn at BANWR.—We did not detect differences in the amount of time spent bedded, standing, foraging, or traveling by year for males or females in 1999 or 2000 (Fig. 7). Because there were no differences between years or sexes, we combined the behavior of all adult animals for both years (Fig. 8). Pronghorn spent the most time foraging, with remaining time equally divided between the 3 other major behaviors (Fig. 8). We did not detect differences in behavior between days with and

Table 4. Breakdown of 30-second observation recordings of behavior of Sonoran pronghorn associated with aircraft overflights, Barry M. Goldwater Range, Arizona, February 1998–June 2000.

Variable	Year			Total
	1998	1999	2000	
Total events recorded	15,339	11,547	17,889	44,775
No. events with overflights[a,b]	179	162	182	523
No. events with direct overflights	47	79	31	157
Military	31	55	23	109
≤300 m agl[c]	2	2	2	6
>300 m agl	29	53	21	103
Non-military	16	23	0	39
≤300 m agl	4	3	0	7
>300 m agl	12	8	0	20
unknown agl	0	12	0	12
Unidentified	0	1	8	9
>300 m agl	0	0	8	8
unknown agl	0	1	0	1
No. events with other overflights	132	83	151	366
Military	132	48	133	313
≤300 m agl	12	3	0	15
>300 m agl	120	32	2	154
unknown agl	0	13	131	144
Non-military	0	20	18	38
≤300 m agl	0	7	0	7
>300 m agl	0	1	0	1
unknown agl	0	12	18	30
Unidentified				
unknown agl	0	15	0	15

[a] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Unidentified overflights could be military or non-military aircraft.

[b] Overflights that occurred during events with multiple stimuli are included in totals.

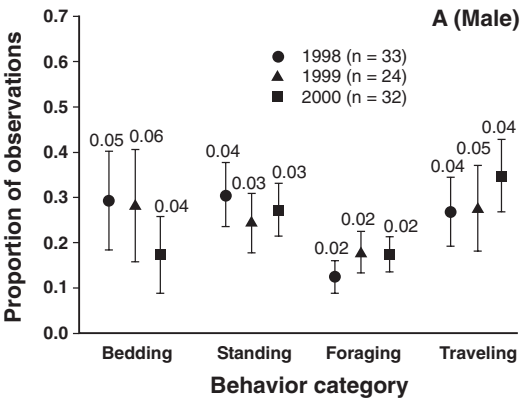
[c] m agl = m above ground level.

Table 5. Breakdown of 30-second observation recordings of behavior of Mexican pronghorn associated with aircraft overflights, Buenos Aires National Wildlife Refuge, Arizona, 1999 and 2000.

Variable	Year and Date		
	10 Feb–15 Jun 1999	11 Feb–3 Aug 2000	1999 and 2000
Total events recorded	14,882	9,415	24,297
No. events with overflights[a]	40	11	51
No. events with direct overflights	29	9	38
Military	22	5	27
≤300 m agl[b]	2	0	2
>300 m agl	20	5	25
Non-military	7	4	11
≤300 m agl	6	4	10
>300 m agl	1	0	1
No. events with other overflights	18	6	24
Military	6	6	12
≤300 m agl	1	5	6
>300 m agl	5	1	6
Non-military	12	0	12
≤300 m agl	12	0	12
>300 m agl	0	0	0

[a] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include rotary and fixed wing aircraft affiliated with Arizona Game and Fish Department, U.S. Border Patrol, U.S. Drug Enforcement Agency, and private.

[b] m agl = m above ground level.



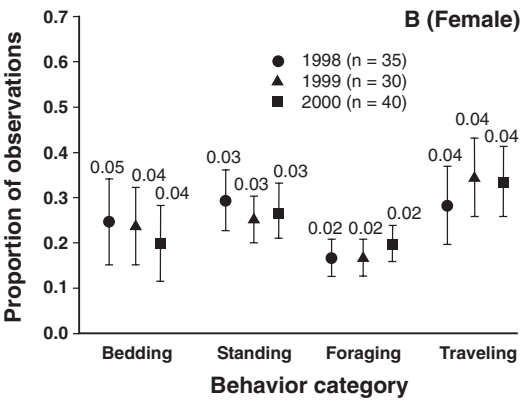


Figure 4. Comparison of male (A) and female (B) behavior by year, based on daily observations of Sonoran pronghorn, Barry M. Goldwater Range, Arizona, 1998–2000. SE is above the 95% CI.

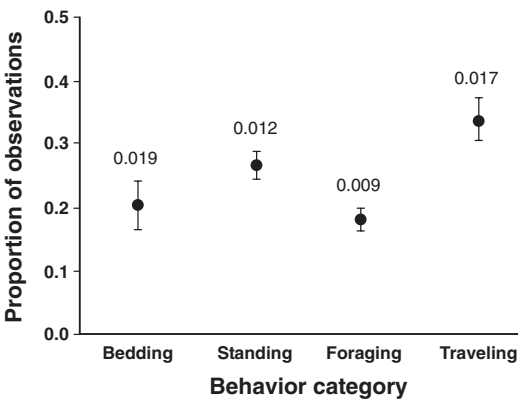


Figure 5. Overall behavior of adult Sonoran pronghorn based on daily observations, Barry M. Goldwater Range, Arizona, 1998–2000. SE is above 95% CI.

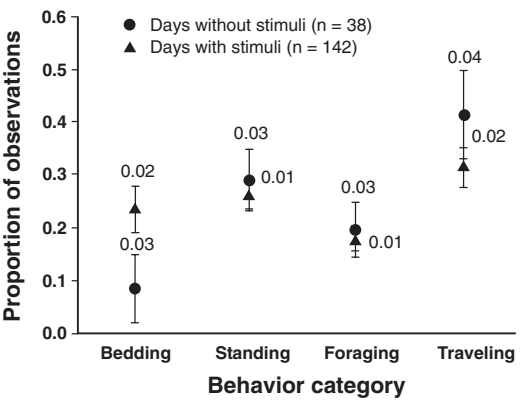
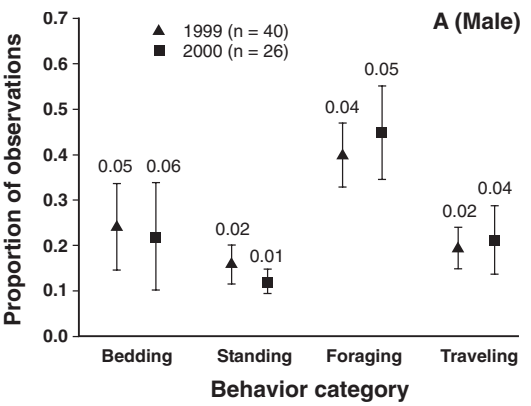


Figure 6. Comparison of behavior of adult Sonoran pronghorn for days with and without anthropogenic stimuli, Barry M. Goldwater Range, Arizona, 1998–2000. SE is above the 95% CI.



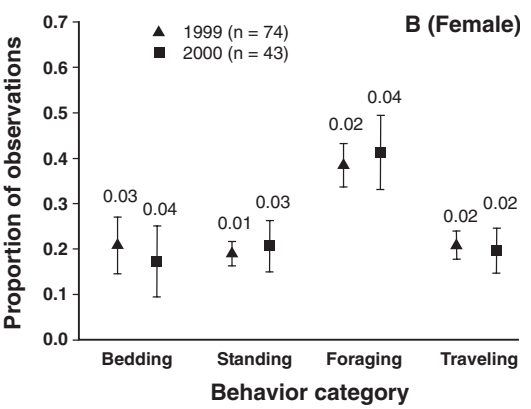


Figure 7. Comparison of male (A) and female (B) behavior by year, based on daily observations of Mexican pronghorn, Buenos Aires National Wildlife Refuge, Arizona, 1999-2000. SE is above the 95% CI.

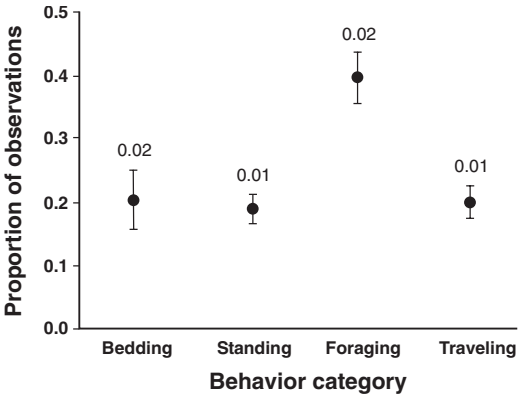


Figure 8. Overall behavior of adult Mexican pronghorn based on daily observations, Buenos Aires National Wildlife Refuge, Arizona, 1999–2000. SE is above the 95% CI.

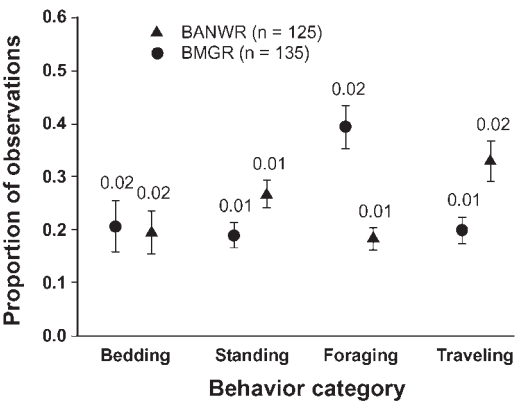


Figure 10. Comparison of behavior of adult Mexican pronghorn, Buenos Aires National Wildlife Refuge (BANWR), Arizona, 1999-2000, to adult Sonoran pronghorn, Barry M. Goldwater Range (BMGR), Arizona, February through July, 1998–2000. SE is above the 95% CI.

without military activity (Fig. 9).

Behavior of Adult Pronghorn at BMGR versus BANWR.—To examine how the behavior of pronghorn that are regularly exposed to military overflights differ from the behavior of those that do not regularly receive military stimuli, we contrasted behavior of pronghorn at BMGR and BANWR during February to June 1999 and February to August 2000. We combined 1998 data with the 1999 and 2000 data (i.e., February to July for all 3 years) from BMGR because there was no difference ($P \leq 0.02$) between the 2 year (i.e., 1999-2000) and 3 year (i.e., 1998-2000) data sets.

In all years, pronghorn bedded the same amount of time at both sites (Fig. 10). However, they foraged less, and stood and traveled more at BMGR compared to BANWR (Fig. 10). These trends were the same with and without the presence of anthropogenic stimuli, except that pronghorn also stood the same amount of time at both sites in the absence of anthropogenic stimuli (Fig. 11).

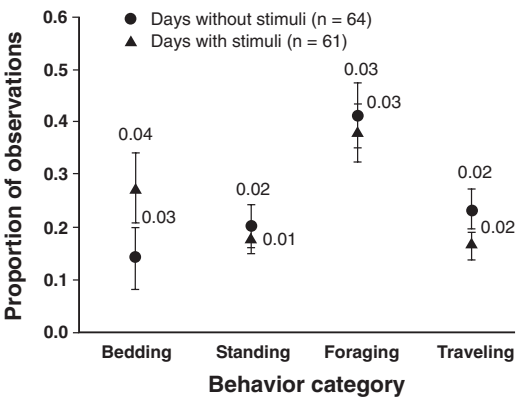


Figure 9. Comparison of behavior of adult Mexican pronghorn for days with and without anthropogenic stimuli, Buenos Aires National Wildlife Refuge, Arizona, 1999–2000. SE is above the 95% CI.

Behavior of Fawns at BMGR.—Observing fawns was difficult because of their size, distances from the observer, and limited numbers. We were able to observe fawns as early as 21 March (e.g., 2000) until 6 October (e.g., 1998). We observed 18 fawns on 70 days from 1998 to 2000 (Table 6). Because fawns spend much of the time hiding in the early stages of life, we only were able to record behavior observations of these fawns on 61 days (23, 2, and 36 days in 1998, 1999, and 2000, respectively) for 109.9 hrs (51.8, 1.8, and 56.3 hrs in 1998, 1999, and 2000, respectively). Exposure of fawns to anthropogenic stimuli (Tables 6, 7) includes days when fawns were seen in the area, regardless of whether behavior observations were recorded.

Fawns were present during 42% of all observations made from February 1998 through June 2000, but were exposed to a greater proportion (52%) of anthropogenic stimuli other than aircraft noise (Tables 2, 6). This included 24% of overflights and 68% of ground stimuli recorded during the study. Overflights, other military air stimuli, and ground stimuli occurred on 12, 23, and

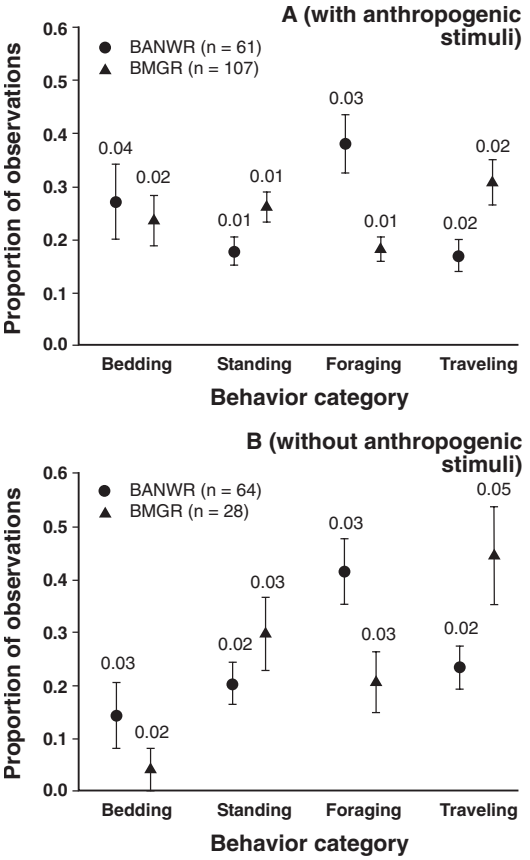


Figure 11. Comparison of behavior of adult pronghorn on days with anthropogenic stimuli (A) and without anthropogenic stimuli (B), Buenos Aires National Wildlife Refuge (BANWR), Arizona, 1999–2000, and Barry M. Goldwater Range (BMGR), Arizona, 1998–2000, February through July. SE is above the 95% CI.

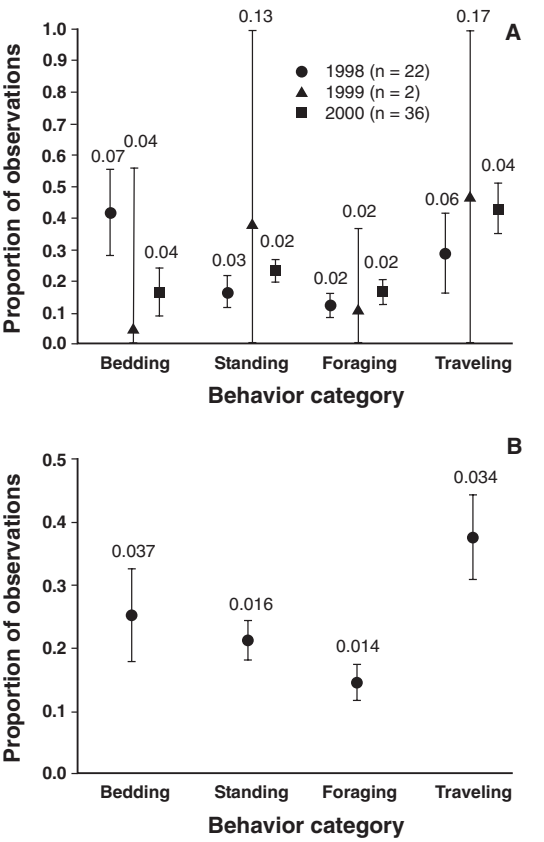


Figure 12. Comparison of fawn behavior by year (A) and overall behavior (B), based on daily observations of Sonoran pronghorn, Barry M. Goldwater Range, Arizona, 1998–2000. SE is above the 95% CI..

27 days, respectively, coinciding with 0.54%, 0.6%, and 7.5% of observation events, respectively (Table 6). Fawns were exposed to 27 direct overflights and 100 other overflights (Table 7). Twenty-one of the direct overflights were military, with 3 <300 m agl. All 4 of the non-military overflights were <300 m agl. Two direct overflights >300 m agl could not be classified as military or non-military.

In 1998 fawns bedded more than in 2000, but there were no other differences between standing, foraging, or traveling (Fig. 12). Throughout the study, fawns traveled more followed by bedding, standing, and foraging (Fig. 12). We documented a similar pattern when fawns were exposed to anthropogenic stimuli. However, when anthropogenic stimuli were present, fawns spent less time bedded (Fig. 13).

Behavior of Fawns at BMGR versus BANWR.—We found no significant difference in fawn behavior between BMGR and

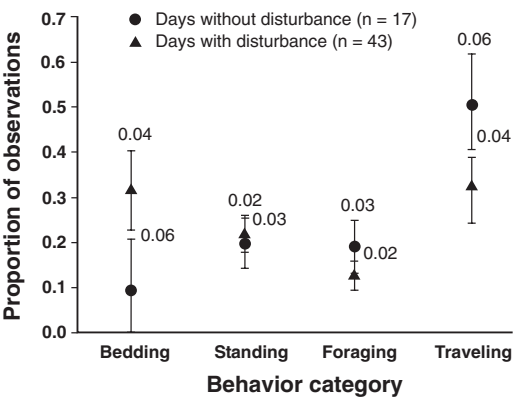


Figure 13. Comparison of behavior of Sonoran pronghorn fawns for days with and without anthropogenic stimuli, Barry M. Goldwater Range, Arizona, 1998–2000. SE is above the 95% CI.

Table 6. Observations of Sonoran pronghorn fawns associated with anthropogenic stimuli, Barry M. Goldwater Range, Arizona, 1998–2000.

Variable	Year and observation period			
	16 Apr–6 Oct 1998	13 Apr–18 May 1999	21 Mar–28 Jun 2000	1998–2000
Minimum no. fawns	6	3	9	18
No. days observations made	28	2	40	70
No. days any anthropogenic stimuli present[a]	21	2	27	50
No. days aircraft noise present	21	1	21	43
No. days other stimuli present[b]	15	2	24	41
No. days with overflights[c]	5	1	6	12
Direct overflights	2	0	3	5
Military	1	0	2	3
Non-military	1	0	0	1
Unidentified	0	0	1	1
Other overflights	4	1	6	11
Military	4	1	6	11
No. days other military air stimuli present[d]	13	1	9	23
No. days other ground stimuli present[e]	8	1	18	27
No. days multiple stimuli present[f]	3	0	5	8
Total observation events recorded[g]	8,754	340	9,924	19,018
% events any anthropogenic stimuli present	51.2	45.3	25.7	37.8
% events aircraft noise present	44.0	41.5	15.3	29.0
% events other stimuli present	7.2	3.8	10.6	8.9
% events overflights present	0.66	0.29	0.43	0.54
% events direct overflights present	0.09	0.0	0.18	0.14
Military	0.05	0.0	0.16	0.11
Non-military	0.05	0.0	0.0	0.02
Unidentified	0.0	0.0	0.02	0.01
% events other overflights present	0.57	0.29	0.25	0.40
Military	0.57	0.29	0.25	0.27
% events other military air stimuli present	0.94	1.18	0.28	0.60
% events other ground stimuli present	5.5	2.4	9.5	7.5
% events multiple stimuli present	0.05	0.0	0.40	0.23

[a] Anthropogenic stimuli include all military and non-military visual and aural stimuli.

[b] Events with other stimuli do not include events when aircraft noise (no visual on aircraft) was the only stimulus present. Other stimuli include overflights, other military air, stimuli, ground stimuli, and multiple stimuli.

[c] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Unidentified overflights could be military or non-military aircraft.

[d] Other military air stimuli include bombing, smoke, strafing, and heat flares.

[e] Other ground stimuli include people, vehicles, and generators.

[f] Multiple military stimuli includes stimuli from >1 of the previous categories (overflights, other military air stimuli, ground stimuli).

[g] Event = 1 observation/30 sec.

BANWR (Fig. 14). Fawns spent similar amounts of time in the 4 major behavior categories on sites regularly exposed to military activity (i.e., BMGR) and those not regularly exposed to military activity (i.e., BANWR).

Response of Pronghorn at BMGR to Military Stimuli.—From 1998 to 2000 we documented 44,775 30-second behavior events of Sonoran pronghorn; 3,260 (7.3%) were associated with stimuli we could classify (Table 8). Military overflights occurred 363 times (0.8%) and non-military overflights occurred 77 times (<0.2%). Other military air stimuli (e.g., flares, bombs, smoke) occurred 592 times (1.3%) and military ground stimuli (i.e., vehicles, people) occurred 2,121 (4.7%) times during observations. Multiple military stimuli (i.e., >1 stimuli from any of the previous categories occurring simultaneously), occurred 83 times (<0.2%). Seventy-three percent of the multiple stimuli included overflights. We considered a change in activity from any behavior (i.e., bedded, standing, foraging, walking, grooming) to trotting or running as biologically significant.

Table 7. Breakdown of 30-second observation recordings of behavior of Sonoran pronghorn fawns associated with aircraft overflights, Barry M. Goldwater Range, Arizona, February 1998–June 2000.

Variable	Year			Total
	1998	1999	2000	
Total events recorded	8,754	340	9,924	19,018
No. events with overflights[a,b]	60	1	66	127
No. events with direct overflights	8	0	19	27
Military	4	0	17	21
≤300 m agl[c]	2	0	1	3
>300 m agl	2	0	16	18
Non-military	4	0	0	4
≤300 m agl	4	0	0	4
>300 m agl	0	0	0	0
Unidentified	0	0	2	2
>300 m agl	0	0	2	2
No. events with other overflights	52	1	47	100
Military	52	1	47	100
≤300 m agl	8	0	0	8
>300 m agl	44	1	0	45
unknown agl	0	0	47	47
Non-military	0	0	0	0

[a] Direct overflights are <100 m to side of animal. Other overflights are >100 m to side of animal. Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Unidentified overflights could be military or non-military aircraft.

[b] Overflights that occurred during events with multiple stimuli are included in these totals.

[c] m agl = m above ground level.

Military overflights. From 1998 to 2000 we documented 109 direct overflights (i.e., ≤100 m to side of animal) and 313 other overflights (>100 m to the side of animals) of military aircraft over pronghorn we observed (Table 4, 8). Seven direct and 52 other of these military overflights occurred during events with multiple military stimuli present. During direct overflights, pronghorn changed behavior (e.g., from bedded to standing, walking to bedded, foraging to bedded) 45 times (41%) with 4 changes from any other activity to trotting or running (3.7%) (Table 9). During overflights >100 m to the side of animals, pronghorn changed behavior 105 times (34%), with 5 changes to trotting or running (1.6%) (Table 10). Pronghorn moved ≥10 m during 2 of these running events. The first event occurred on 16 February 2000 at 1209.5 hrs near observation point Echo on the STAC. Five pronghorn were seen running at the moment of impact of an F-16 crash. The group was out of sight before the crash, and ran >10 m during and after the event. The second event occurred 9 March 2000 at 1021 hrs also near observation point Echo. Two male pronghorn were foraging and walking prior to the overflight (>300 agl), ran >10 m during the overflight and were standing after the event. Other changes in pronghorn behavior could not be associated to aircraft and were likely similar to normal changes in pronghorn behavior (Table 8).

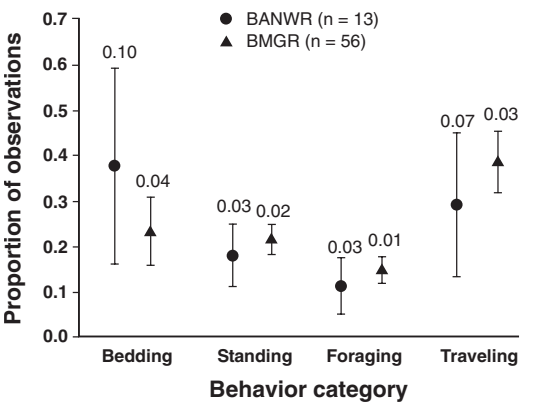


Figure 14. Comparison of behavior of Mexican pronghorn fawns, Buenos Aires National Wildlife Refuge (BANWR), Arizona, May through August, 1999–2000, to Sonoran pronghorn fawns, Barry M. Goldwater Range (BMGR), Arizona, March through June, 1998–2000. SE is above the 95% CI.

Other military air stimuli. We found no association between other military stimuli (e.g., flares, bombs, smoke) and pronghorn behav-

Table 8. Sonoran pronghorn behavior associated with anthropogenic stimuli other than background aircraft noise, Barry M. Goldwater Range, Arizona, 1998–2000.

	Year			
	1998	1999	2000	Total
No. events[a] 15,339	11,547	17,889	44,775	
No. events with stimuli[b]	900	420	1,940	3,260
Military overflights				
<100 m to side of animal	30	50	22	102
>100 m to side of animal	122	40	99	261
Non-military overflights				
<100 m to side of animal	16	23	0	39
>100 m to side of animal	0	20	18	38
Unidentified overflights				
<100 m to side of animal	0	1	8	9
>100 m to side of animal	0	15	0	15
Other military air	205	198	189	592
Other military ground	514	60	1,547	2,121
Multiple military	13	13	57	83
No. events with stimuli and any change in behavior[c]	422	164	702	1,288
Military overflights				
<100 m to side of animal	10	17	14	41
>100 m to side of animal	50	9	30	89
Non-military overflights				
<100 m to side of animal	11	2	N/A	13
>100 m to side of animal	N/A	12	13	25
Unidentified overflights				
<100 m to side of animal	N/A	0	5	5
>100 m to side of animal	N/A	15	N/A	15
Other military air	69	84	94	247
Other military ground	277	21	534	832
Multiple military	5	4	12	21
No. events with change in behavior to running	16	10	51	77
Military overflights				
<100 m to side of animal	0	2	2	4
>100 m to side of animal	3	1	1	5
Non-military overflights				
<100 m to side of animal	1	0	N/A	1
>100 m to side of animal	N/A	1	0	1
Unidentified overflights				
<100 m to side of animal	0	0	2	2
>100 m to side of animal	N/A	0	N/A	0
Other military air	1	1	4	6
Other military ground	11	4	41	56
Multiple military	0	1	1	2

[a] Event = 1 observation/30 sec.

[b] Non-military overflights include Arizona Game and Fish Department and U.S. Border Patrol. Other military air stimuli include bombing, smoke, strafing, and heat flares. Other ground stimuli include people, vehicles, and generators. Multiple military stimuli indicates stimuli from more than one of the previous categories (overflights, other military air stimuli, ground stimuli).

[c] A behavior change is measured 30 sec before or after the stimulus is recorded.

ior. We documented 592 events with other military air stimuli present during pronghorn observations. Pronghorn changed behavior 247 times (42%), with 6 changes to trotting or running (1.0%) (Tables 8, 11). No animals moved ≥10 m when any of these other military stimuli were present.

Ground stimuli. Ground stimuli activities included the presence of vehicles or people in the study area. Ground stimuli occurred during 2,121 events (4.8%) and comprised the majority (65%) of all anthropogenic

Table 9. Behavioral changes to running by Sonoran pronghorn associated with military aircraft flying ±100 m to either side of pronghorn, Barry M. Goldwater Range, Arizona, 1998–2000.

Date	No.animals and sex	Time	Approximate elevation (m agl)[a]	Movement >10 m	Behavior[b] Before	During	After
23 Mar 1999	1 (Ad. F)	820.0	>300	N[c]	W[d]	R	W
23 Mar 1999	1 (Ad. F)	824.0	>300	N	W	R	W
16 Feb 2000	5 (unknown)	1209.0	≤300[e]	Y	5 OS	5R	5R
9 Mar 2000	2 (Ad. M)	1210.0	>300	Y	2W	2R[f]	2S

[a] m agl = m above ground level.
[b] Behavior at 30-sec interval before, during, and after the stimulus.
[c] N = no, Y = yes.
[d] B = bedded, S = standing, F = foraging W = walking, R = running or trotting, N = nursing, OS = out-of-sight.
[e] This was an aircraft crash.
[f] This was noted as an instaneous change in behavior, so it does not correspond to the typical 30-sec before, during, and after interval.

Table 10. Behavioral changes to running by Sonoran pronghorn associated with military aircraft flying >100 m to either side of pronghorn, Barry M. Goldwater Range, Arizona, 1998–2000.

Date	No. of animals and sex	Time	Approximate elevation (m agl)[a]	Movement >10 m	Behavior[b] Before	During	After
1 Oct 1998	1 (f[c])	802.5	>300[d]	N[e]	W[f]	R	W
1 Oct 1998	1 (f[c])	804.5	>300[d]	N	W	R	W
7 Dec 1998	1 (Ad.F[g])	1311.0	>300[d]	N	W	R	R
9 Feb 1999	3 (unknown)	951.0	>300[h]	N	3W	2W-R	3W
21 Mar 2000	3 (1 Ad. F[g],2f[g])	1314.0	unknown	N	S-N-W	3W	2W-R

[a] m agl = m above ground level.
[b] Behavior at 30-sec interval before, during, and after the stimulus.
[c] Fawn of radiocollared female no. 31.
[d] There were two aircraft during these overflights.
[e] N = no Y = yes.
[f] B = bedded, S = standing, F = foraging W = walking, R = running or trotting, N = nursing.
[g] Radiocollared female no. 28.
[h] Another stimulus (another visible aircraft) was associated with overflight.

Table 11. Behavioral changes to running by Sonoran pronghorn associated with other military air stimuli, Barry M. Goldwater Range, Arizona, 1998–2000.

Date	No. animals and sex	Time	Description of stimulus	Behavior[a] Before	During	After
9 Feb 1998	1 (Ad. M)	1631.5	bombing	S[b]	F	R
18 Aug 1999	3 (Ad. M, 2 Ad. F)	907.0	strafing	B-W-S	3R	OS-2R
5 Jan 2000	2 (unknown)	949.0	strafing	S-W	R-W	2OS
5 Jan 2000	2 (unknown)	1035.5	visual aircraft[c]	2W	OS-W	2R
16 Feb 2000	5 (unknown)	1146.0	flares, visual ac[d]	3W-S-OS	W-4OS	W-2R-2OS
11 Apr 2000	3 (3 Ad. M)	858.5	hear noise	2P-S	2P-S	2R-S

[a] Behavior at 30-sec interval before, during, and after the stimulus.
[b] B = bedded, S = standing, F = foraging W = walking, R = running or trotting, P = pushing, OS = out-of-sight.
[c] Aircraft visible but not audible.
[d] ac = aircraft (visible but not audible).

stimuli present during pronghorn observations (Table 8). Ground stimuli was associated with 866 instantaneous changes in behavior (39%), with 56 of these changes to trotting or running (2.6%) (Table 8, Appendix B).

Ground stimuli occurred for >1 consecutive events 62% of the time, for an average 14 consecutive events (95% confidence interval 10 to 19 events) making up a bout. The 2,121 ground stimuli events occurred in 154 bouts on 51 days, averaging 14 events per bout (95% confidence interval 10 to 20 events). Pronghorn were trotting or running during 25 (16%) bouts, averaging 4 events (95% confidence interval 2 to 7 events) of running. Pronghorn ran continuously for extended periods of time (2 to 12 minutes) in association with ground stimuli on 12 days during the study: 3 in 1998, 2 in 1999, and 7 in 2000. This represents 7% of the 172 days we observed pronghorn at BMGR and 24% of the 51 days we observed ground stimuli and pronghorn.

Movement ≥10 m. We recorded pronghorn movement ≥10 m in association with direct overflights on 6 days during the study: 3 in 1998, 1 in 1999, and 2 in 2000 (see below). This represents 4% of the 172 days we observed pronghorn at BMGR and 16% of the 38 days we observed direct overflights and pronghorn.

30 April 1998 from Redpoint. We observed collared female 28 with her fawn from 0620 to 0703. The pair moved 800 to 1,000 m from 0640 to 0703. There were numerous activities in the area: observers' vehicle and observers, a second vehicle, and 4 overflights by the AGFD (0655, 0656, 0658, and 0659). Animals were moving prior to the overflights. No other 10-m movements were recorded. From 0640 to 1447 hrs, vehicles were within 5 km of the pronghorn for 23 minutes and distant strafing occurred 12 times (6 min) from 1000 to 1528.

28 June 1998 from Toss Tower. We observed collared female 28, her fawn, another female and fawn, and an adult male. An AGFD airplane was in the study area prior to the observation period (0629 to 0743). At 0604, the aircraft flew over the animals 3 times and animals were running. During the observation period the animals did not move ≥10 m during any 30-second interval.

18 November 1998 from Echo. Collared female 31 was moving during the entire observation period (0812 to 0908). She moved 1 km from 0812 to 0837 and 4 km from 0848 to 0907. There were multiple stimuli in the area: 0848 to 0855, 2 vehicles; 0846, 2 F-16s >300 m agl and >100 m to side of the female; 0856, 2 F-16s >300 m agl and ≤100 to side of female; and 0903 and 0904, military aircraft >300 m agl and >100 m to side of the female.

14 April 1999 from Delta. A single adult male was walking in a burn close to a road and airstrip during the entire observation period (0800 to 0924.5). There were multiple overflights in the area: 0812.5, 2 F-16s >300 m agl and <100 m to 1 side of the animal; 0815.5, 1 F-16 >300 m agl and <100 m to 1 side of animal; 0820.5, 1 F-16 >300 m agl and <100 m to 1 side of animal. The male moved 25 m 1 minute prior to the first overflight, 35 m in the minute after the first overflight, 10 m between the second and third overflights, and 50 m after the third overflight. He walked into a riparian area after the first overflight and foraged on palo verde. The male continued walking around the riparian area and airstrip for the rest of the observation period. He moved 85 m from 0833 to 0835.5, 150 m from 0837 to 0844 (moving onto airstrip), and 130 m from 0845 to 0852. The male did not trot or run, but walked and displayed territorial marking behavior throughout the period.

16 February 2000 from Echo. Three adult males and 2 unknown pronghorn were walking and trotting throughout the observation period (1143 to 1210.5). The group moved and remained out of sight from 1200 to 1209. All 5 animals were seen running at the moment of impact of an F-16 crash at 1209.5 hours. The plane crashed within 1 km of the pronghorn. The animals ran to the south and were out of sight at 1210.5 hours.

9 March 2000 from Echo. Two adult males moved >10 m at 1021 immediately after a direct overflight >300 m agl. The 2 males walked and displayed territorial sparring and marking behavior throughout the observation period (0941 to 1049). They also trotted several times during observations, but were only seen running immediately after the direct overflight.

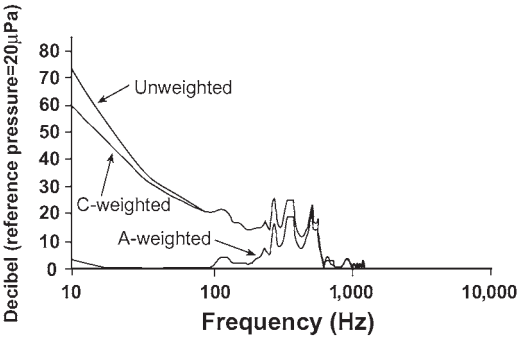


Figure 15. Weighted spectral levels of the ambient noise occurring during pronghorn auditory brainstem response testing, Camp Verde, Arizona, 1997.

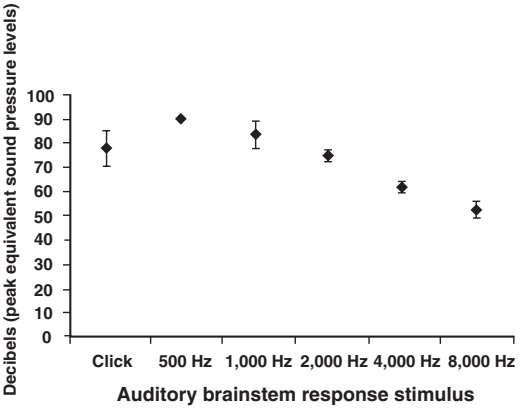


Figure 17. Mean auditory brainstem response for American pronghorn, Camp Verde, Arizona, 1997. Bars represent 1±SE.

Hearing

Baseline Pronghorn ABR.—The ambient noise at the remote testing site (i.e., hills east of Camp Verde, Arizona) was modestly low, with hourly averages ranging from 42 dB to 47 dB. The majority of noise was at frequencies <100 Hz (Figs. 15, 16). None of the ears examined were defective. We had some contamination of the ABR waveforms with apparent cochlear microphonics (CM). Cochlear microphonics is an evoked potential that follows the waveform of the stimulus. That is, a sine-wave stimulus will produce a sine-wave CM. At the lower frequency tonebursts (500 Hz and 1,000 Hz), the stimulus duration takes more time, thus creating a longer CM. In some lower frequency trials, the CM interfered with the interpretation of the ABR. These waveforms were excluded from the analysis.

Measurable click-evoked responses were obtained from 2 animals and resulted in an unusually high mean threshold of 77.5 dB pe SPL (Fig. 17). For all animals, clearer waveforms were collected for tonebursts of 2 kHz and higher (Fig. 17). Mean thresholds were 90 dB, 83 dB, 74 dB, 61 dB, and 50.5 dB for 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz and 8,000 Hz, respectively. The mean slope of the latency-intensity function was 19 μs/dB for 8,000 Hz tones and 21 μs/d for 4,000 Hz tones.

Comparison of Mule Deer ABR.—The ambient noise at the remote testing site at BMGR (i.e., ETAC) was modestly low and the hourly average sound level during the test ranged from 42 to 53 dB. The sound level in the helicopter during the captures ranged from 95 to 97 dB.

None of the ears examined were defective. A few of the ABR waveforms had some contamination with apparent CM. This was most evident for the 1 kHz stimulus. In 1 animal (control group adult F) the CM interfered with the interpretation of the ABR. These waveforms were excluded from the analysis.

The first animal tested at The University of Arizona (adult M) and the last animal tested on the BMGR (adult M) had very poor waveform shape and elevated thresholds. It was raining on the BMGR during the capture and testing of the adult male, and the animal was wet. This was the most likely reason for the difficulty in obtaining good ABR from this individual. The poor quality waveforms from the male at The University of Arizona are unexplained. The waveforms from these 2 animals were excluded from

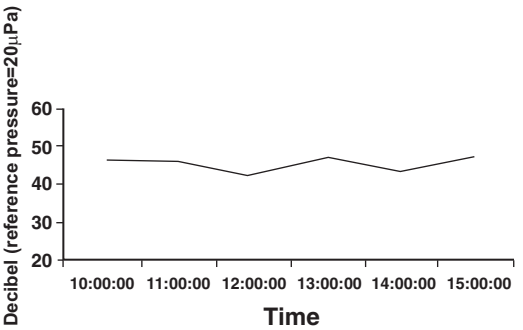


Figure 16. One-hour ambient sound levels during pronghorn auditory brainstem response testing, Camp Verde, Arizona, 1997.

Table 12. Auditory brainstem repsonse thresholds (dB) for desert mule deer exposed to noise from military aircraft (e.g., F-15, F-16, helicopters) on the Barry M. Goldwater Range, Arizona, December 1998 (i.e., exposed deer) and captive desert mule deer at The University of Arizona, Tucson, Arizona, November 1998, that were not exposed to regular noise from military aircraft (i.e., control deer).

	Threshold				
Animal	Click	1 kHz	2 kHz	4 kHz	8 kHz
Control deer 1	70.0	95	95.0	80	90.0
Control deer 2	55.0		70.0	60	60.0
Control deer 3	55.0	85	70.0	65	<70.0
Exposed deer 1	55.0	80	65.0	65	55.0
Exposed deer 2	50.0	75	62.5	55	57.5
Exposed deer 3	42.5	80	60.0	40	57.5
Exposed deer 4					82.5

the analysis. There was no difference in the ABR thresholds between the control and exposed animals (Table 12). We obtained measurable click- evoked responses from all but the 2 animals mentioned previously. The click- evoked threshold for the control group (n = 2) was 55 dB pe SPL and the exposed group (n = 3) was 50 dB pe SPL. One animal from the exposed site had substantially lower thresholds than all the other animals. Without this animal's thresholds included, the click-evoked response for the exposed group was 52.5 dB pe SPL, essentially identical to the control group. This pattern held for all the stimuli tested (Table 12).

Ambient Noise Exposure

BMGR.—Site 1 was near High Explosive Hill (e.g., a regular bombing target) and experienced the most (Table 13) and highest A-weighted sound exposure levels (ASELs) in autumn 1998. The largest sound recorded on site 1 was 121.8 ASEL dB. This loud sound occurred at 1400 on 22 October 1998 and had a duration of 59.1 seconds. The relatively long duration suggests that this sound pressure level was produced by ≥1 low-flying aircraft. The greatest L_{max} was from the same event and reached 123.1 dB (Table 13). The regularity of high amplitude sound events at site 1 raised the long-term average sound levels. Thirty-five of the 737 hours monitored (4.8%) had average sound levels >70 dB, with 8 hrs (1.0%) exceeding 80 dB (Table 13).

Table 13. Summary of sound events measured at South Tactical Range, Barry M. Goldwater Range (BMGR) and Buenos Aires National Wildlife Refuge (BANWR), Arizona, 1998-2000.

	BMGR									BANWR
	Autumn 1998[a]			Winter 1999			Summer 1999			Autumn 2000
	1[b]	2	3	1	2	3	1	2	3	1
Days sampled	30.8	36.2	7.2	46.9	39.9	—	33.9	41.1	5.5	1.3
No. events with ASEL[c] > 80 dB[d]	744	542	36	415	997	—	530	596	N/A	27
No. events with ASEL > 80 dB/day	24.2	14.1	5	8.5	24.9	—	15.6	14.5	N/A	2.0
No. events with ASEL > 100 dB	107	67	—	40	80	—	30	71	—	1
Max ASEL	122	112	107	117	117	—	116	119	N/A	104.4
Max L_{eq}[e]	86.2	78.9	73.0	84.4	81.8	—	81.9	84.9	60.6	68.9
Max 24-hr L_{eq}[f]	73.1	66.3	59.9	72.8	69.1	—	68.1	71.3	51.7	55.4
Max L_{max}[g]	123	112	107	122	119	—	117	119	N/A	104.8
Mean ASEL > 80 dB	95.7	93.4	90.0	95.7	99.3	—	92.1	94.0	N/A	91.8
Mean of 30 highest ASELs	113	106	91.0	106	108	—	106	109	N/A	93.8

[a] Autumn 1998 sampling period = 23 Sep–24 Oct 1998; Summer 1999 = 9 Jun–13 Jul; Winter 1999 = 21 Jan–9 Mar.

[b] Universal Transverse Mercator coordinates for site 1, 0290340 northing, 3602194 easting; site 2, 0293741 northing, 359492 easting; site 3, 0296145 northing, 3597949 easting; BANWR site, 0453649 northing, 3489727 easting.

[c] A-weighted Sound Exposure Level.

[d] Decibels.

[e] 1-hr average sound level.

[f] 24-hr average sound level.

[g] Maximum sound level.

The sound levels at site 2, 8 km from site 1, were generally lower than at site 1 (Table 13). The loudest ASEL measured at site 2 was 119.3 dB in summer 1999. In winter 1999 site 2 received the most ASELS >80 dB and the highest number of events (n = 80) with ASEL measurements >100 dB.

The SLM at site 3 stopped recording after 7.2 days in Autumn 1998 because of a broken external battery wire. The sample sizes are thus smaller than for sites 1 and 2 (Table 13). The unit also failed in summer 1999 for unknown reasons.

Overall sound level. A good technique for determining how military operations contribute to sound pressure levels is to compare metrics from times without military operations to times when military operations are in progress. For example, at site 1 in winter 1999 the average 24-hour L_{eq} for Mondays through Fridays was 65.3 dB. The same metric measured for Saturdays and Sundays was 35.0 dB, a reduction of 30.3 dB (Fig. 18). The few events (i.e., aircraft overflights that did occur on weekends) were removed from the sound analysis. There was an anomalous data reading for weekday analysis also. On 24 February 1999 there were 20 sound events around 2200 hours. Each of these events had a duration <1 second (e.g., wind generated noise or bird vocalizations) and were removed from analysis. The 1-hr L_{eq} is >25dB higher with military activity compared to periods of inactivity (Fig. 18).

Ungulate weighted sound. Because we obtained hearing information on desert ungulates we developed and tested a new ungulate weighting filter on the noise recorded from 2 aircraft overflights: an A-10 and an F-16. The unweighted SELs were arbitrarily set to 107 dB and 122 dB for the A-10 and F-16, respectively. These levels were used because they are comparable to typical levels for normal military training routes. Applying A-weighting to the SEL measurement of the A-10 overflight reduced the SEL by 2 dB to 105 dB. When the ungulate filter is applied the ASEL is reduced to 87.3 dB, about 18 dB lower than A-weighting (Fig. 19).

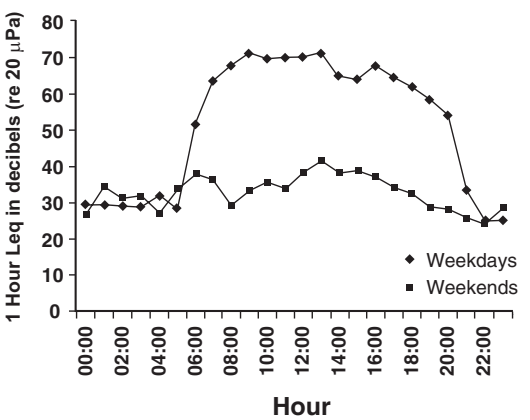


Figure 18. Hourly sound pressure levels (Leq) during the week and on weekends, site 1, south tactical range, Barry M. Goldwater Range, Arizona, 21 January 1999–2 March 1999.

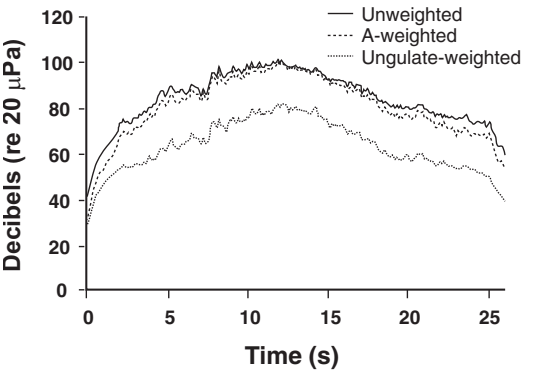


Figure 19. Average sound level over time for an A-10 overflight using no frequency weighting (unweighted), A-weighting, and ungulate-weighting.

The results for the F-16 overflight were similar. With the unweighted SEL set to 122 dB, the ASEL was reduced to 119.3 dB and the ungulate-weighted SEL was reduced to 105.4 dB (Fig. 20). There was less difference between the weighted levels for the F-16 likely because the overflight was faster and there was substantially higher frequency noise (>1,000 Hz). The higher frequency sound is less affected by the A-weighting and the ungulate weighting filters. The ungulate-weighted SEL was nearly 14 dB below the ASEL.

BANWR.—Noise levels at BANWR were higher on weekdays than weekends with 1 exception. On the weekend of 21-22 October 2000, we measured the highest sound levels at BANWR beginning around 0400. We measured 130 events, with most (n = 67) occurring 21-22 October. These sounds were storm-related and thus excluded from analysis. The remaining 63 events occurred on weekdays.

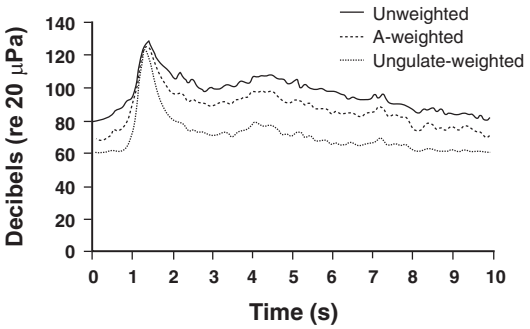


Figure 20. Average sound level over time for a F-16 overflight using no frequency weighting (unweighted), A-weighting, and ungulate-weighting.

Twenty-seven events had A-weighted SEL measurements >80 dB and 1 event had ASEL measurements >100 dB (Table 13). The average weekday diel L_{eq} levels were greater than levels measured on the weekend by 11.2 dB (Fig. 21). On an hourly basis, L_{eq} were an average of 38 dB higher on weekdays than weekends.

Weekday noise levels measured at BANWR were not as loud as those measured at BMGR. Site 1 at BMGR had the highest weekly L_{eq} (63 dB) followed by site 2 (60.2 dB) and site 3 (50.5 dB). The average weekly L_{eq} at BANWR was 41.0 dB.

DISCUSSION

One role of the USAF is to train combat pilots for national defense. The rigorous demands placed on military tactical aircrews

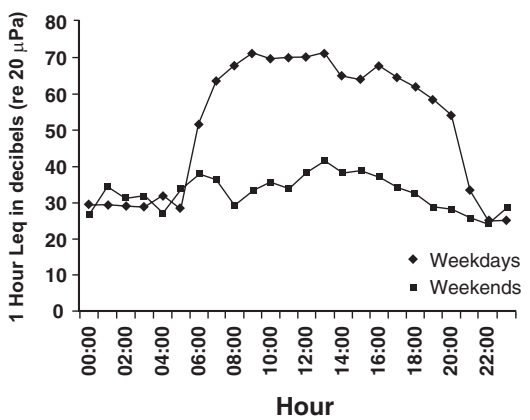


Figure 21. Weekday and weekend sound pressure levels (Leq), Buenos Aires National Wildlife Refuge, Arizona, 21 October–3 November 2000.

to maneuver high speed aircraft along carefully planned routes taking advantage of terrain to avoid detection by defensive forces, require frequent training to maintain proficiency (Holland 1991). Two types of air space (i.e., special use and military training routes), were designated in the 1950-1960s to minimize impacts with other air space users (Holland 1991). Recently, many public lands underlying military designated air spaces have been set aside as national parks, wildlife refuges, or wilderness areas to be preserved for public enjoyment (Holland 1991).

Human encroachment (including military operations) and development has altered wildlife habitat on private and federal lands throughout the United States (Leslie and Douglas 1980, Etchberger et al. 1989). Few studies have addressed human disturbance of pronghorn, but Berger et al. (1983) found that human disturbance reduces the foraging efficiency of pronghorn. Other researchers have expressed concern about the influence of military activities on ungulate populations, including the influence of overflights at CPNWR on mountain sheep and Sonoran pronghorn (Asherin and Gladwin 1988, Weisenberger 1996). For example, Hughes and Smith (1990) observed a group of 3 pronghorn that appeared unaffected by the low passage of 4-5 military aircraft, and Luz and Smith (1976) documented mild disturbance of pronghorn by helicopter noise at levels of about 60 dB and strong reaction at about 77 dB.

The most thorough field study of the effects of aircraft noise on pronghorn was conducted in Utah by Workman et al. (1992). They found that the first exposure to aircraft noise provoked the most pronounced increase in heart rate, and characterized pronghorn habituation to sonic booms as relatively quick and complete. Subsonic flyovers by F-16 aircraft had little effect on heart rate, and effects were short lived. Pronghorn did not see incoming F-16s; disturbance was entirely auditory. A Cessna 182 single-engine plane had greater and longer lasting effects on heart rate, and the 2 females studied developed the behavior of looking toward the incoming flight as the engine became audible. For 1 female,

the heart rate and duration of elevated heart rate declined with successive flyovers, whereas in the other female, the heart rate increased and stayed at a level twice the average undisturbed heart rate. Pronghorn became habituated to Huey helicopter flyovers, but hovering induced the greatest heart rate increase in the study (almost 3 times the undisturbed rate), with effects lasting several minutes in duration.

Some studies have been indirectly related to pronghorn and noise and concluded that military overflights probably constitute a minor influence on pronghorn (DeVos 1989, Dames & Moore 1995). These observations led to the conclusion that because there is no evidence that military activities have caused a decline in the Sonoran pronghorn population, mitigation for potential declines due to military activities is unwarranted (Geraghty & Miller, and SWCA 1996). Others concluded it was impossible to predict the impact of military aircraft on Sonoran pronghorn, but implied that such impact was a moot consideration because the probability of pronghorn encountering military aircraft at close range was miniscule (Naval Facilities Engineering Command and Dames & Moore 1988). The U.S. Air Force (1992) took a similar position, and concluded that military aircraft noise would have some short-term physiological and behavior effects, but that no effects would be "significant" or permanent. Others disagreed and implied that military activity was a threat to pronghorn and discussed techniques to minimize the effects of military activity (Thompson-Olais 1994). Among the techniques was the creation of a noise-profile map to ascertain potential problems areas. A noise map was developed, and based on the location of radiocollared pronghorn from September 1994 through August 1998, the pronghorn generally used areas with lower noise levels more than areas with higher noise levels (Landon et al. 2003). However, sound pressure levels are only 1 variable that may influence distribution.

Although studies of noise and pronghorn are limited (Krausman et al. 1998), the topic has been addressed for other species. Several studies have examined the behavioral and physiological effects of sonic booms on domestic animals and wildlife (Ewbank 1977, Manci et al. 1988). Subsonic aircraft can also affect wildlife. Reindeer (*Rangifer tarandus*) exhibited strong panic responses to fixed-wing aircraft flying ≤152 m but did not respond as strongly to helicopters (Calef et al. 1973). Fixed-wing overflights (Cessna 172, 182 aircraft; Krausman and Hervert 1983) ≥100 agl did not disturb mountain sheep or desert mule deer in Arizona (Krausman et al. 1986). However, Stockwell et al. (1991) studied mountain sheep in the Grand Canyon, Arizona and reported that in winter mountain sheep foraged less efficiently in the presence of helicopters than when helicopters were absent. In addition, Bleich et al. (1990) reported that mountain sheep moved 2-5 times farther the day following a helicopter survey than on the previous day and changed home-range polygons by 8–83 km following helicopter surveys. When aircraft (i.e., helicopters) fly close to the ground (≤100 m), they may create more disturbances than higher-flying aircraft.

Domestic animals and wildlife initially respond to aircraft noise with a startle reaction. Sporadic jumping, galloping, bellowing, and haphazard movement were a few responses of large farm animals observed by Cottereau (1978). Harrington and Veitch (1992) reported low jet overpasses caused woodland caribou (*Rangifer tarandus*) to be initially startled, but otherwise they exhibited only brief overt reactions when in late-winter alpine tundra habitats. These behavioral responses to noise have caused secondary injuries in domestic animals (e.g., broken legs [Cottereau 1978]) and may cause stampedes in wild animals that could result in drowning and trampling (Sinclair 1979) or other forms of mortality (Harrington and Veitch 1992).

Animals react differently to sound intensity and duration (Ames and Arehart 1972, Borg 1981) and direction (Tyler 1991). Ames and Arehart (1972) investigated the effects of intermittent bursts of white noise, music, and miscellaneous sounds from 75 to 100 dB. Habituation to intermittent sounds was gradual and minimal in each of the experiments.

Habituation to intermittent sounds ≥75 dB is gradual (Ewbank 1977, Espmark and Langvatn 1985). However, an array of stud-

ies with laboratory animals (i.e., rodents [Borg 1979]), domestic animals (i.e., sheep [Ames and Arehart 1972]), and wildlife (e.g., elk [*Cervus elaphus*] [Espmark and Langvatn 1985]) have shown that animals can become habituated to noise.

The effects of noise from low-altitude subsonic aircraft on animals have not been studied extensively. Military overflights concern land managers, because the unknown effects of auditory and visual stimuli from jet aircraft are a potential threat to wildlife populations. How animals respond to aircraft noise can be important in management decisions about USAF use of air space and wildlife subjected to overflights.

Behavior

The NTAC and STAC ranges constitute a small portion of the habitat used by Sonoran pronghorn in the United States. However, the ranges are used year round by some pronghorn and approximately 20% of the United States population used the ranges at least part of the year.

We obtained consistent information relating to the response of pronghorn to military stimuli. In general, we did not detect differences in the behavior of pronghorn with and without anthropogenic stimuli. In the few events with anthropogenic stimuli (7%), 40% were associated with changes in behavior (Table 8). Most of these behavioral changes were not likely the result of anthropogenic stimuli but were likely consistent with regular behavioral changes of pronghorn. We recorded 6 days when anthropogenic stimuli (i.e., overflights, other military air stimuli) coincided with pronghorn moving ≥10 m (<1%). These instances generally involved multiple military stimuli (i.e., aircraft, vehicles, people) and non-military surveillance aircraft. We only recorded 2 events when military overflights coincided with pronghorn movement ≥10 m. The response of pronghorn to low-flying light aircraft (i.e., Cessna) is consistent to that of other desert ungulates (Krausman and Hervert 1983).

Females and their fawns responded to direct overflights on 2 of the 6 days that we documented movement ≥10 m. These data are consistent with responses of other ungulates to military aircraft. Desert bighorn sheep females with lambs were more likely to be vigilant than when not caring for young in their response to military overflights (Krausman et al. 1998). Also, female caribou with young calves "may be less tolerant of aircraft disturbance than during other times of the year..." (Murphy et al. 1994:485).

In 77 instances, anthropogenic stimuli were associated with pronghorn changing their behavior to trotting or running for brief spurts (<10 m). This represents 2.4% of all stimuli. Other changes in behavior that occurred during the presence of overflights and other military air stimuli were minor and not considered biologically significant. Our results are similar to those reported by Krausman et al. (1993), Workman et al. (1992), Weisenberger et al. (1996), and Krausman et al. (1998). The bighorn sheep in these studies appeared to habituate to military overflights, and Workman et al. (1992) and Krausman et al. (1998) did not document detrimental effects from military overflights. This suggests pronghorn have habituated to their exposure to military activity. The studies of Krausman et al. (1993, 1998), Workman et al. (1992), and Weisenberger et al. (1996) were conducted on penned animals and the results have been criticized as not being applicable to free-ranging populations. However, studies by Zine and Krausman (2000) demonstrated that the behavior of captive ungulates in large enclosures and free-ranging ungulates is similar. Furthermore, Bernatas et al. (1998) demonstrated that free-ranging ungulates also were not influenced by military activity related to overflights.

In our study, we document differences in the behavior of adult pronghorn at BMGR and BANWR. The differences were primarily related to foraging. Pronghorn foraged less and traveled more at BMGR compared to pronghorn at BANWR (Fig. 10). These trends were the same with and without presence of military stimuli (Fig. 11). The difference is likely because of the allocation of resources throughout the habitat. Forage resources occur at higher densities at BANWR than at BMGR (P. R. Krausman and C. L. Blasch, unpublished data). As a result, animals using widely spaced forage have to travel more than animals using forage that

is more abundant and less widely distributed (McNab 1963). In our study, we did not document behavior patterns of adults that were biologically different between an area with regularly scheduled overflights (i.e., BMGR) and an area that was not exposed to regularly scheduled overflights (i.e., BANWR). There are several potential concerns with our comparisons (e.g., different area, different subspecies), but the population of pronghorn at BANWR was the closest with which we could make comparisons. Also, pronghorn at BANWR were exposed to military stimuli (Table 4), but not at the same level or frequency as pronghorn at BMGR.

We found no significant differences between fawn behavior at BMGR and BANWR. However, these data should be viewed cautiously because few fawns were produced and recruited during our study. When we did document pronghorn movement ≥10 m, fawns were involved in 2 of the 6 observations, suggesting they (or their mothers) may be more sensitive to anthropogenic stimuli than other pronghorn.

Hearing

Thresholds measured for pronghorn and desert mule deer in this study were similar. The thresholds measured are also similar to those DeYoung et al. (1993) found for desert mule deer and bighorn sheep. DeYoung et al. (1993) noted that the ABR thresholds for desert mule deer and bighorn sheep were similar to humans, at least around 4,000 Hz. Based on similarities found in this study and that of DeYoung et al. (1993), bighorn sheep, desert mule deer, and pronghorn hearing are likely less acute than human hearing at most audible frequencies. Human ABR is detected at lower amplitudes (Gorga et al. 1988) than that measured for deer, sheep, or pronghorn (Fig. 22).

Behavioral hearing tests, where an animal is trained to respond when a sound is presented, provide a more accurate indication of hearing acuity than ABRs. Wollack (1963) behaviorally measured hearing in 3 domestic sheep. In comparison to humans (Sivian and White 1933), sheep are 10 to 20 dB less sensitive in their hearing at frequencies below 10,000 Hz. Above this frequency, sheep hearing is more acute than human hearing. Ambient noise present during the ABR testing was lower than the stimuli presented to the animals, and as a result, ambient noise was unlikely to have altered our results.

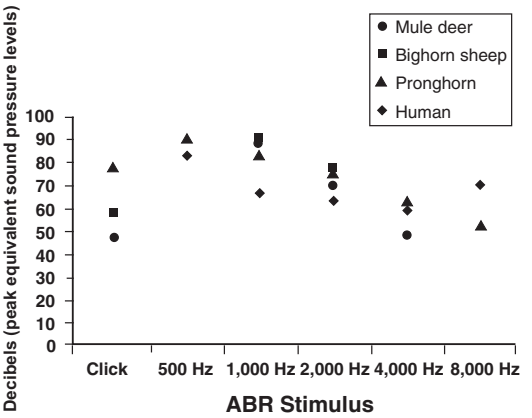


Figure 22. Comparison of auditory brainstem response (ABR) thresholds for desert mule deer, bighorn sheep, pronghorn, and humans.

Ambient Noise Exposure

The majority of the jet overflight noise on the BMGR is <2,000 Hz. Noise from explosions can have substantial sound energy about 2,000 Hz, but higher frequency sounds attenuate rapidly away from the sound source. For example, a 4,000 Hz sound is reduced about 15 dB more at 1 km than a 100 Hz sound. The sound levels reaching pronghorn on the BMGR and BANWR are not known. However, we characterized ambient noise present on both areas. Although the largest sound recorded at BMGR was 121.8 ASEL dB, the average diel L_{eq} was 65.3 dB with military stimuli and 35.0 dB without military stimuli. As expected, sound pressure levels at BANWR were lower than at BMGR (average weekly L_{eq} at BMGR was 50.5 to 63 dB versus 41 dB at BANWR). The average sound pressure levels at BANWR were similar to those reported in Pusch Ridge Wilderness, Arizona (<40 dB) (Schoenecker and Krausman 2002), which is located adjacent to an urban area, but higher than in other wilderness settings (i.e., 20 dB) (Bowles 1995). Although sound pressure levels were higher at BMGR than BANWR, pronghorn behavior was similar at both sites.

The new ungulate weighting filter developed from hearing information on 3 desert ungulates during this study indicates that the ASEL can be reduced by 18 dB from the reported A-weighted filter values commonly used for humans (and reported here). Not only did the influence of sound pressure levels from military activity have no influence on the hearing of desert ungulates, these ungulates cannot detect noise at these frequencies as well as humans.

In conclusion, from 1998 through 2000, Sonoran pronghorn were present on the NTAC and STAC ranges of BMGR each month of the year. Based on our data, (1) behavior patterns of pronghorn were similar with and without the presence of military stimuli, (2) behavior patterns of pronghorn exposed to military activity were similar to that of pronghorn not exposed to regular military activity, and (3) auditory characteristics were similar for ungulates that have and have not been exposed to sound pressure levels typical of military activity. Military activity was associated with changes in the behavior of pronghorn; however, these changes did not likely influence animals in a detrimental manner.

Because of low fawn productivity and recruitment we can not draw specific conclusions about their behavior in the presence of military activity. Based on the data we did collect, fawns were involved in 2 of the 6 times pronghorn moved >10 m. Fawns appear to respond to military stimuli as do their mothers, which may be more sensitive to anthropogenic stimuli than other pronghorn.

This study examined pronghorn on the NTAC and STAC ranges within the BMGR. The USAF, AGFD, USFWS, United States Marine Corps, Bureau of Land Management, and the National Park Service are also involved in conservation efforts that need to be considered when determining how to manage this rare and endangered subspecies of pronghorn. Military activity at the levels we documented on the NTAC and STAC ranges had minimal detectable biological influence on Sonoran pronghorn.

However, the influences that produced disturbance should be minimized or eliminated as much as possible. For example, all ground stimuli and activity that alerts or startles females and their fawns should terminate. The population continues to decrease in the United States. The last survey of Sonoran pronghorn habitat was from 30 November to 4 December 2002. Only 18 animals were observed (6 M, 12 F) in groups of 9, 8, and 1. The population is estimated at 21 animals (range = 18 – 33) (AGFD and USFWS, unpublished data).

Clearly, emergency measures are necessary if the remaining Sonoran pronghorn in the United States are to increase to viable levels without severe management (e.g., captive propagation). Federal and state agencies are aggressively moving to halt the downward population trend by habitat restoration with watering projects, seasonal closures of pronghorn habitat during fawning, planning for translocations from Mexico, and placing some or all of the remaining pronghorn in an enclosure to allow the population to increase. These drastic steps and others will be necessary to pull the population back from the brink of extinction where it currently resides.

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APPENDICES

Appendix A: Calibration of Sound Level Meters

A standard technique for testing the functioning of a SLM is to first present steady sine waves that have frequencies centered on standard third octave frequencies. The signal is sent to the SLM through an 18-µf-microphone adapter. To calibrate the 3 Larson-Davis 820 SLMs used to monitor sounds on the STAC, we presented tones from 25 Hz to 10,000 Hz generated by a Hewlett-Packard 3312A Function Generator, increasing in third octave intervals (Tables A1, A2, and A3). The frequencies of the signals were verified by simultaneously routing the signal through a 16-bit A/D board and into the sound analysis software package SpectraPro (Sound Technologies, Campbell, California). This allowed us to verify that the A-weighting filters of the SLMs were operating within specification. After testing the SLM with the steady sine waves, we then sent single cycle sine waves to the system at the representative 1/3-octave frequencies. The theoretical sound exposure level of the single cycle sine waves is known. This latter signal allowed us to verify the integrating mechanisms of the SLMs. The mean error in A-weighting for the unit with the serial number (S/N) 459 was a negligible –0.11 dB. The mean error for the SLM (S/N 448) was close at –0.042 dB and SLM (S/N 450) had an error of 0.058 dB. All 3 systems functioned well.

Appendix A1. Results of the sine-wave calibration for the Larson-Davis model 820 sound level meter (S/N 459) used to monitor sound at site 1, South Tactical Range, Barry M. Goldwater Range, Arizona, 1998–2000. A-weighted sound pressure level (A-wt SPL) read by the SLM with the reference at 1 kHz measured at 113.3 dB.

1/3 Octave Hz	A-wt SPL	Measured A-wt[a]	Theo A-wt[b]	A-wt error[c]	1-cycle ASEL[d]	Measured delta[e]	Theoretical delta[f]	ASE error[g]
10,000	113.8	–1.9	–2.5	0.6	68.8	45.0	38.9	–6.1
8,000	114.8	–0.9	–1.1	0.2	71.5	43.3	38.4	–4.9
6,300	115.8	0.1	–0.1	0.2	75.0	40.8	37.7	–3.1
5,000	116.4	0.7	0.5	0.2	77.1	39.3	37.0	–2.3
4,000	116.8	1.1	1.0	0.1	79.2	37.6	36.1	–1.5
3,150	117.0	1.3	1.2	0.1	81.3	35.7	35.2	–0.5
2,500	117.0	1.3	1.3	0.0	82.2	34.8	34.3	–0.5
2,000	116.9	1.2	1.2	0.0	82.6	34.3	33.4	–0.9
1,600	116.6	0.9	1.0	–0.1	83.6	33.0	32.6	–0.4
1,250	116.3	0.6	0.6	0.0	84.1	32.2	31.7	–0.5
1,000	115.7	0.0	0.0	0.0	84.5	31.2	30.7	–0.5
800	115.0	–0.7	–0.8	0.1	84.4	30.6	29.8	–0.8
630	113.9	–1.8	–1.9	0.1	84.2	29.7	28.8	–0.9
500	112.4	–3.3	–3.2	–0.1	83.6	28.8	27.7	–1.1
400	110.9	–4.8	–4.8	0.0	83.6	27.3	26.7	–0.6
315	108.9	–6.8	–6.6	–0.2	82.9	26.0	25.6	–0.4
250	106.6	–9.1	–8.6	–0.5	81.4	25.2	24.4	–0.8
200	104.5	–11.2	–10.9	–0.3	81.1	23.4	23.3	–0.1
160	102.4	–13.3	–13.4	0.1	79.7	22.7	22.1	–0.6
125	99.4	–16.3	–16.1	–0.2	78.0	21.4	20.8	–0.6
100	97.0	–18.7	–19.1	0.4	76.8	20.2	19.5	–0.7
80	93.0	–22.7	–22.5	–0.2	74.7	18.3	18.1	–0.2
63	89.1	–26.6	–26.2	–0.4	72.1	17.0	16.5	–0.5
50	85.2	–30.5	–30.2	–0.3	69.8	15.4	14.8	–0.6
40	82.1	–33.6	–34.6	1.0	68.5	13.6	12.9	–0.7
31.5	75.9	–39.8	–39.4	–0.4	64.5	11.4	10.6	–0.8
25	66.5	–49.2	–44.7	–4.5				

[a] Measured A-wt = the difference from theoretical A-weighted read by the SLM.
[b] Theo A-wt = the theoretical A-weighted level.
[c] A-wt Error = the difference between the theoretical and measured A-weighted levels.
[d] 1-cycle ASEL = the measured A-weighted sound exposure level of a single cycle sine wave at each 1/3 octave frequency.
[e] Measured delta = the difference between the measured steady sine wave and the single cycle sine wave.
[f] Theoretical delta is the theoretical sound exposure level of the single cycle sine wave.
[g] ASEL error = the difference between the measured and the theoretical ASEL.

Appendix A2. Results of the sine-wave calibration for the Larson-Davis model 820 sound level meter (S/N 459) used to monitor sound at site 2, South Tactical Range, Barry M. Goldwater Range, Arizona, 1998–2000. A-weighted sound pressure level (A-wt SPL) read by the SLM with the reference at 1 kHz measured at 113.3 dB.

1/3 Octave Hz	A-wt SPL	Measured A-wt[a]	Theo A-wt[b]	A-wt error[c]	1-cycle ASEL[d]	Measured delta[e]	Theoretical delta[f]	ASE error[g]
10,000	112.2	–2.1	–2.5	0.4				
8,000	113.5	–0.8	–1.1	0.3				
6,300	114.4	0.1	–0.1	0.2				
5,000	115.1	0.8	0.5	0.3				
4,000	115.5	1.2	1.0	0.2				
3,150	115.8	1.5	1.2	0.3				
2,500	115.8	1.5	1.3	0.2				
2,000	115.6	1.3	1.2	0.1				
1,600	115.5	1.2	1.0	0.2				
1,250	115.0	0.7	0.6	0.1				
1,000	114.3	0.0	0.0	0.0	87.6	31.8	30.7	–1.1
800	113.5	–0.8	–0.8	0.0				
630	112.4	–1.9	–1.9	0.0				
500	111.0	–3.3	–3.2	–0.1	89.6	28.3	27.7	–0.6
400	109.5	–4.8	–4.8	0.0				
315	107.8	–6.5	–6.6	0.1				
250	105.9	–8.4	–8.6	0.2	89.3	25.7	24.4	–1.3
200	103.4	–10.9	–10.9	0.0				
160	101.0	–13.3	–13.4	0.1				
125	97.9	–16.4	–16.1	–0.3	86.9	22.4	20.8	–1.6
100	94.8	–19.5	–19.1	–0.4				
80	91.6	–22.7	–22.5	–0.2				
63	87.7	–26.6	–26.2	–0.4				
50	83.8	–30.5	–30.2	–0.3	79.4	15.7	14.8	–0.9
40	79.5	–34.8	–34.6	–0.2				
31.5	74.9	–39.4	–39.4	0.0				
25	68.0	–46.3	–44.7	–1.6				
20	63.2	–51.1	–50.5	–0.6				

[a] Measured A-wt = the difference from theoretical A-weighted read by the SLM.
[b] Theo A-wt = the Theoretical A-weighted level.
[c] A-wt error = the difference between the Theoretical and Measured A-weighted levels.
[d] 1-cycle ASEL = the measured A-weighted sound exposure level of a single cycle sine wave at each 1/3 octave frequency.
[e] Measured delta = the difference between the measured steady sine wave and the single cycle sine wave.
[f] Theoretical delta is the theoretical sound exposure level of the single cycle sine wave.
[g] ASEL error = the difference between the measured and the theoretical ASEL.

Appendix A3. Results of the sine-wave calibration for the Larson-Davis model 820 sound level meter (S/N 459) used to monitor sound at site 3, South Tactical Range, Barry M. Goldwater Range, Arizona, 1998–2000. A-weighted sound pressure level (A-wt SPL) read by the SLM with the reference at 1 kHz measured at 113.3 dB.

1/3 Octave Hz	A-wt SPL	Measured A-wt[a]	Theo A-wt[b]	A-wt error[c]	1-cycle ASEL[d]	Measured delta[e]	Theoretical delta[f]	ASE error[g]
10,000	102.4	–1.8	–2.5	0.7				
8,000	103.5	–0.7	–1.1	0.4				
6,300	104.4	0.2	–0.1	0.3				
5,000	105.0	0.8	0.5	0.3				
4,000	105.3	1.1	1.0	0.1				
3,150	105.5	1.3	1.2	0.1				
2,500	105.6	1.4	1.3	0.1				
2,000	105.5	1.3	1.2	0.1				
1,600	105.2	1.0	1.0	0.0				
1,250	104.8	0.6	0.6	0.0				
1,000	104.2	0.0	0.0	0.0	62.3	29.7	30.7	1.0
800	103.6	–0.6	–0.8	0.2				
630	102.4	–1.8	–1.9	0.1				
500	101.2	–3.0	–3.2	0.2	62.9	27.8	27.7	–0.1
400	99.7	–4.5	–4.8	0.3				
315	97.8	–6.4	–6.6	0.2				
250	95.7	–8.5	–8.6	0.1	63.5	24.6	24.4	–0.2
200	93.3	–10.9	–10.9	0.0				
160	91.1	–13.1	–13.4	0.3				
125	88.2	–16.0	–16.1	0.1	60.4	21.5	20.8	–0.7
100	85.2	–19.0	–19.1	0.1				
80	82.0	–22.2	–22.5	0.3				
63	78.7	–25.5	–26.2	0.7				
50	75.4	–28.8	–30.2	1.4				
40	69.7	–34.5	–34.6	0.1				
31.5	63.7	–40.5	–39.4	–1.1				
25	58.1	–46.1	–44.7	–1.4				
20	50.8	–53.4	–50.5	–2.9				

[a] Measured A-wt = the difference from theoretical A-weighted read by the SLM.
[b] Theo A-wt = the Theoretical A-weighted level.
[c] A-wt Error = the difference between the Theoretical and Measured A-weighted levels.
[d] 1-cycle ASEL = the measured A-weighted sound exposure level of a single cycle sine wave at each 1/3 octave frequency.
[e] Measured Delta = the difference between the measured steady sine wave and the single cycle sine wave.
[f] Theoretical Delta is the theoretical sound exposure level of the single cycle sine wave.
[g] ASEL Error = the difference between the measured and the theoretical ASEL.

Appendix B. Behavioral changes to running by Sonoran pronghorn associated with other military ground stimuli, Barry M. Goldwater Range, Arizona, 1998–2000.

Date	No. animals and sex	Time	Description of stimulus	Behavior[a]		
				Before	During	After
26 May 1998	3 (Ad. F[c], 2f[c])	0845.0	1 vehicle	W[b]	R	R
26 May 1998	3 (Ad. F[c], 2f[c])	0847.5	1 vehicle	W	R	S
26 May 1998	3 (Ad. F[c], 2f[c])	0850.5	1 vehicle	W	R	S
26 May 1998	3 (Ad. F[c], 2f[c])	0859.5	1 vehicle	W	R	W
26 May 1998	3 (Ad. F[c], 2f[c])	0903.5	1 vehicle	F	R	F
26 May 1998	3 (Ad. F[c], 2f[c])	0915.5	1 vehicle	W	R	S
17 Nov 1998	7 (unknown)	0722.0	1 vehicle	7W	7R	7R
18 Nov 1998	1 (Ad. F[d])	0848.5	2 vehicles	F	R	S
18 Nov 1998	1 (Ad. F[d])	0850.0	2 vehicles	S	R	R
18 Nov 1998	1 (Ad. F[d])	0851.5	2 vehicles	F	R	R
18 Nov 1998	1 (Ad. F[d])	0854.0	2 vehicles	S	R	R
23 Mar 1999	1 (Ad. F)	0746.5	1 vehicle	S	R	R
23 Mar 1999	1 (Ad. F)	0758.0	1 vehicle	W	R	W
18 May 1999	3 (Ad. F[c], 2f[c])	0606.0	1 vehicle	3S	3S	3R
4 Nov 1999	8 (unknown)	0753.5	1 vehicle	2P-2S-F-OS	2P-3S-OS	2P-2S-2R
28 Feb 2000	2 (unknown)	0839.0	3 vehicles	2S	R-W	2OS
17 Mar 2000	2 (Ad. M)	0801.5	1 vehicle	2S	2R	2R
11 Apr 2000	3 (Ad. M)	0814.0	1 vehicle	3S	3R	3R
11 Apr 2000	3 (Ad. M)	0818.0	1 vehicle	3S	3R	3S
11 Apr 2000	3 (Ad. M)	0821.0	1 vehicle	3S	3R	3S
11 Apr 2000	3 (Ad. M)	0822.0	1 vehicle	3S	3W	3R
11 Apr 2000	3 (Ad. M)	0822.5	1 vehicle	3W	3R	3W
11 Apr 2000	3 (Ad. M)	0831.0	1 vehicle	3W	3R	2W-F
17 Apr 2000	3 (Ad. F[e],2f[e])	1054.4	1 vehicle	3S	3R	3R
25 Apr 2000	3 (Ad. F[e],2f[e])[f]	0831.5	1 vehicle	W	R	R
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0827.0	4 vehicles	W	R	W
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0830.5	6 vehicles	2W	2R	W-OS
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0831.5	6 vehicles	W	2R	2OS
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0833.5	6 vehicles	2W	R-W	2R
26 Apr 2000	3 (Ad. F[e],2f[e])	0840.5	6 vehicles	W	R	R
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0841.5	6 vehicles[g]	2W[b]	2R	2W-F
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0842.5	6 vehicles	2W	2R	W-OS
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0849.0	6 vehicles	2W	2R	2W-F
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0850.0	6 vehicles	W	R	R
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0856.5	6 vehicles	2W	2R	2W
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0859.0	6 vehicles	W	OS	R
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0902.5	6 vehicles	2W	2R	R-W
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0904.0	6 vehicles	2W	2R	2W
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0905.5	6 vehicles	2W	2R	2R
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0907.5	6 vehicles	2W	2R	2OS
26 Apr 2000	3 (Ad. F[e],2f[e])[f]	0909.0	6 vehicles	2OS	2W	2R
29 Apr 2000	4 (fawns)	0819.0	People on foot	2W-2S	4R	4R
3 May 2000	1 (Ad. M)	0812.0	1 vehicle	S	R	R
3 May 2000	1 (Ad. M)	0814.5	3 vehicles	S	R	R
8 May 2000	2 (Ad. M)	0841.5	1 vehicle	2S	2R	2R
8 May 2000	2 (Ad. M)	0844.5	1 vehicle	2W	2R	W-F

(*Continued*)

Appendix B (*continued*). Behavioral changes to running by Sonoran pronghorn associated with other military ground stimuli, Barry M. Goldwater Range, Arizona, 1998–2000.

Date	No. animals and sex	Time	Description of stimulus	Behavior[a]		
				Before	During	After
8 May 2000	2 (Ad. M)	0845.5	1 vehicle	W-F	2R	R-W
18 May 2000	5 (fawns)	0741.0	1 vehicle	2W-F-S-OS	4W-R	2W-3OS
25 May 2000	2 (Ad. F, f)[f]	0821.5	Generator	W	R	W
6 Jun 2000	2 (Ad. F[e],f[e])	0651.5	1 vehicle	2S	2R	2OS
7 Jun 2000	1 (Ad. M)	0648.5	1 vehicle	S	R	W
7 Jun 2000	1 (Ad. M)	0650.5	2 vehicles	W	R	W
7 Jun 2000	1 (Ad. M)	0651.5	2 vehicles	W	R	W
10 Jun 2000	1 (f[c])	1902.5	1 vehicle	F	R	S
28 Jun 2000	4 (Ad. F[e], f[e], Ad. F, Ad. M)	0617.0	People on foot	S	R	OS
28 Jun 2000	4 (Ad. Fe, fe, Ad. F,Ad. M)f	0620.5	People on foot	W	R	W

[a] Behavior at 30-sec interval before, during, and after the stimulus.

[b] B = bedded, S = standing, F = foraging W = walking, R = running or trotting, N = nursing, P = pushing another pronghorn, OS = out-of-sight.

[c] Radiocollared female no. 14 and her fawns (no behavior recorded for fawns at this time).

[d] Radiocollared female no. 31.

[e] Radiocollared female no. 28 and her fawns.

[f] Only fawn(s) changed behavior to running.

[g] Another stimulus (strafing) was also present.