DESERT MULE DEER WATER CONSUMPTION

IN SOUTHCENTRAL ARIZONA

by

John Eric Hazam

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 7

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under the rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: John Hazam

APPROVAL BY THESIS COMMITTEE

This thesis has been approved on the date shown below:

Paul R. Krausman
P. R. Krausman, Thesis Director
Associate Professor of Wildlife Ecology

29 April 1987
Date

N S Smith
N. S. Smith
Arizona Cooperative Wildlife
and Fisheries Research Unit
Adjunct Professor of Wildlife Ecology

28 april 87
Date

R W Mannan
R. W. Mannan
Assistant Professor of Wildlife Ecology

29 April 1987
Date

ACKNOWLEDGMENTS

I am grateful for the valuable support of my major advisor, Dr. P. R. Krausman and my graduate committee members, Drs. N. S. Smith and R. W. Mannan. Additionally, I want to thank G. D. Warrick, D. L. Scarbrough, T. L. Myers, S. K. Friedman, and M. J. Crites for their field assistance. For their help during the 10 day telemetry study, I thank G. D. Warrick, G. G. Taylor, R. Mazaika, R. C. Etchberger, S. K. Friedman, T. L. Steel, P. R. Krausman, B. D. Leopold, M. C. Wallace, S. E. Rinekevich, and P. S. Becker. T. A. Kerpez, K. R. Rautenstrauch, M. C. Wallace, and S. Trachy helped with the pen studies. I am grateful for the invaluable assistance of K. R. Rautenstrauch and Drs. B. D. Leopold and D. K. Blough with statistical analysis. Finally, I wish to thank J. L. Tiss and W. M. Martin for their technical assistance. This study was funded by the U. S. Bureau of Reclamation and the U. S. Fish and Wildlife Service.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

I monitored desert mule deer (*Odocoileus hemionus crooki*) to determine their drinking frequency and water consumption in the Picacho Mountains in the summer of 1986 when temperatures were ≤ 46 C. Three radio-collared males consumed water 1 time/24 hours over 10 days. Deer consumed from 1.52 to 6.01 liters/visit ($\bar{X} = 3.70$, SE = 0.13, $N = 54$). Females drank more ($\bar{X} = 4.16$, $N = 20$) than males ($\bar{X} = 3.55$, $N = 24$) during late summer ($P < 0.05$). To measure water consumption of large, free ranging mammals, I developed a technique using a microflowmeter. Water consumption was measured in 0.01 liter units and measurements were linear for volumes ≥ 1 liter. Field accuracy was within 1%. I observed nocturnal behavior from 250 m using infrared lights and high magnification lenses with a nightscope. Desert mule deer can be censused in summer based on the frequency that they visit waterholes. The minimum water requirements for a captive female desert mule deer (55 ml/kg$^{0.8}$/day) indicate an ability to conserve water.

INTRODUCTION

Heat and drought in the arid Southwest may influence local distribution and recruitment of deer (Anthony 1976, Wallmo 1981, Brown 1984). The development of water catchments for wildlife has been a common management practice in Arizona since the 1950's (Wright 1959), but their value and use have not been widely documented. Hervert and Krausman (1986) determined the drinking frequency of female desert mule deer, but the drinking frequency of males has not been determined. Water requirements of desert mule deer and their adaptations to arid environments are poorly understood; few water intake data have been collected in the field (Elder 1954, Hervert and Krausman 1986). Knox et al. (1969) concluded that mule deer are not specially adapted physiologically for water conservation, but Wesley et al. (1970) stated that without water restriction experiments, such conclusions can not be made.

No efficient technique has been described for measuring the water intake of large, free ranging mammals, and the drinking behavior of desert ungulates is often nocturnal, making observation difficult. To study deer drinking behavior, I developed a technique with a microflowmeter, nightscope, and infrared lights to measure the water intake of desert mule deer in the Picacho Mountains, Arizona during the summers of 1985 and 1986.

My objectives were to: (1) observe the acceptability of the microflowmeter equipment by wildlife species, (2) measure the accuracy of the equipment, (3) evaluate the performance of the equipment under field conditions, (4) estimate the drinking frequency of male desert mule deer, (5) estimate the minimum water requirements of captive desert mule deer, and (6) record the water consumption of free ranging desert mule deer.

STUDY AREA

My study was conducted in the Picacho Mountains, 65 km northwest of Tucson, Arizona. A general description of the area is provided by Ordway and Krausman (1986).

Weather data recorded 13 km west of the study area in Eloy, Arizona, indicated average daily minimum temperatures ranged from 2.5 C in January to 23.9 C in July. Average daily maximum temperatures ranged from 19.4 C in January to 40.5 C in July (Sellers et al. 1985). Annual precipitation averaged 22 cm, approximately 40% of this falling in July, August, and September (Sellers et al. 1985). I considered early summer to be from 1 May to the arrival of the rains in July. Late summer was from the onset of the rains to 15 October.

Close to and within the mountainous terrain, free standing water is available in 6 big game water catchments, 1 spring, and ephemeral rain pools. In the creosote (*Larrea tridentata*) flats away from the mountains, there are 21 stock ponds which are dependent upon precipitation runoff (Ordway and Krausman 1986).

MATERIALS AND METHODS

Male Drinking Frequency

Four desert mule deer males were captured and fitted with radio collars in February 1986. Two other radio-collared males from a previous study (Scarbrough and Krausman, in press) were also in the area. In June, 4 of the males were located near 3 water catchments (catchments 689, 111, and 112). Catchment 111 was located 2.5 km from catchment 689 and 1.5 km from catchment 112. Catchments 689 and 111 were monitored continuously for 10 days in July with scanner-receiver chart recorders (SRCR) (Telonics, Mesa, Ariz.) (Hervert and Krausman 1986). The SRCR's were calibrated to detect the presence of a transmitter $\leq$25 m from the water source and to record the event on paper. In order to detect possible visits to alternative water sources, male movements were monitored (triangulation of signal bearings) throughout each day of the 10 day study. Two portable-fixed antenna stations were positioned between the 3 water catchments in the foothills and the stock ponds in the creosote flats. The telemetry locations were also used to indicate visits to catchment 112 where there was no SRCR. Whenever the SRCR at catchment 111 recorded a visit, the telemetry locations were $\leq$300 m from the catchment, and whenever the telemetry locations were $\leq$300 m from the catchment the SRCR recorded a visit. Therefore, I recorded telemetry locations $\leq$300 m of catchment 112 as a visit. The antenna array at each station consisted of 2 RA-2A beam antennas (Telonics, Mesa, Ariz.) mounted on top of a 4 m mast.

Each antenna station was operated by a team of 4 people, working in pairs and alternating every 24 hours. Signal bearings were recorded for 10 continuous days for each of the males every 15 minutes from 1600 to 0800 hours, and every 30 minutes from 0800 to 1600 hours. A recording by the SRCR or a telemetry location within 300 m of catchment 112 was considered a visit to drink water. One male left the monitored range of the equipment so that 1,735 locations were recorded for the remaining 3 males during the 10 days.

Minimum Water Requirements

I determined the minimum drinking water requirements of desert mule deer based on a method (Taylor 1968) that restricts drinking water in order to stimulate adaptive mechanisms for water conservation. The experiment was conducted at the University of Arizona's Campbell Avenue Farm in Tucson. A 3-year-old captive female was provided water and forage (alfalfa hay and hog breeder pellets) ad libitum and was weighed daily to determine her stable body weight and average daily water consumption. Her drinking water was gradually reduced to a level at which she was just able to maintain her weight at 85% of her initial stable weight. Her average daily water consumption over the next 10 days while maintaining her 85% weight level is an estimate of her minimum water requirements. The average is expressed as liters/day and as $ml/kg^{0.8}/day$ for comparison with animals of different size or species (Richmond et al. 1962).

Water Consumption

I used waterflow, electronic and nightscope equipment to measure water consumption of free ranging deer (Fig. 1).

Waterflow Equipment

All plastic tubing to transport water had to be 4.76 mm (3/16") ID to match the calibration of the microflowmeter. Also, this water tubing was placed inside larger, black plastic tubing to protect it from sunlight, animal damage, and any source of constriction.

Water Drum. A 200 liter plastic drum (1 m high) was placed 2 m above the ground to provide sufficient height for water to be siphoned from the water drum to the water basin. The plastic drum was painted white to reduce the water temperature. A weighted end of water tubing was placed 5 cm above the inside bottom of the water drum, and the other end, after passing through 1 of the 2 openings in the top of the drum, was connected to the inlet fitting of the float valve inside the water basin. The other opening to the water drum was used when filling the drum with water. Both openings were normally closed.

Water Basin. The water basin was 40 cm high, leakproof and white with a 55 cm diameter. It was placed on top of a 1 m high metal drum. I set the drum on top of a berm just behind the water trough to increase the water level in the water basin to 180 cm higher than the water level in the water bucket beside the trough. The resulting pressure head to the bucket provided more than a 500 ml/min flow rate through the microflowmeter. A Little Giant Float Valve (Miller Manufacturing, St. Paul, Minn.) maintained a relatively constant

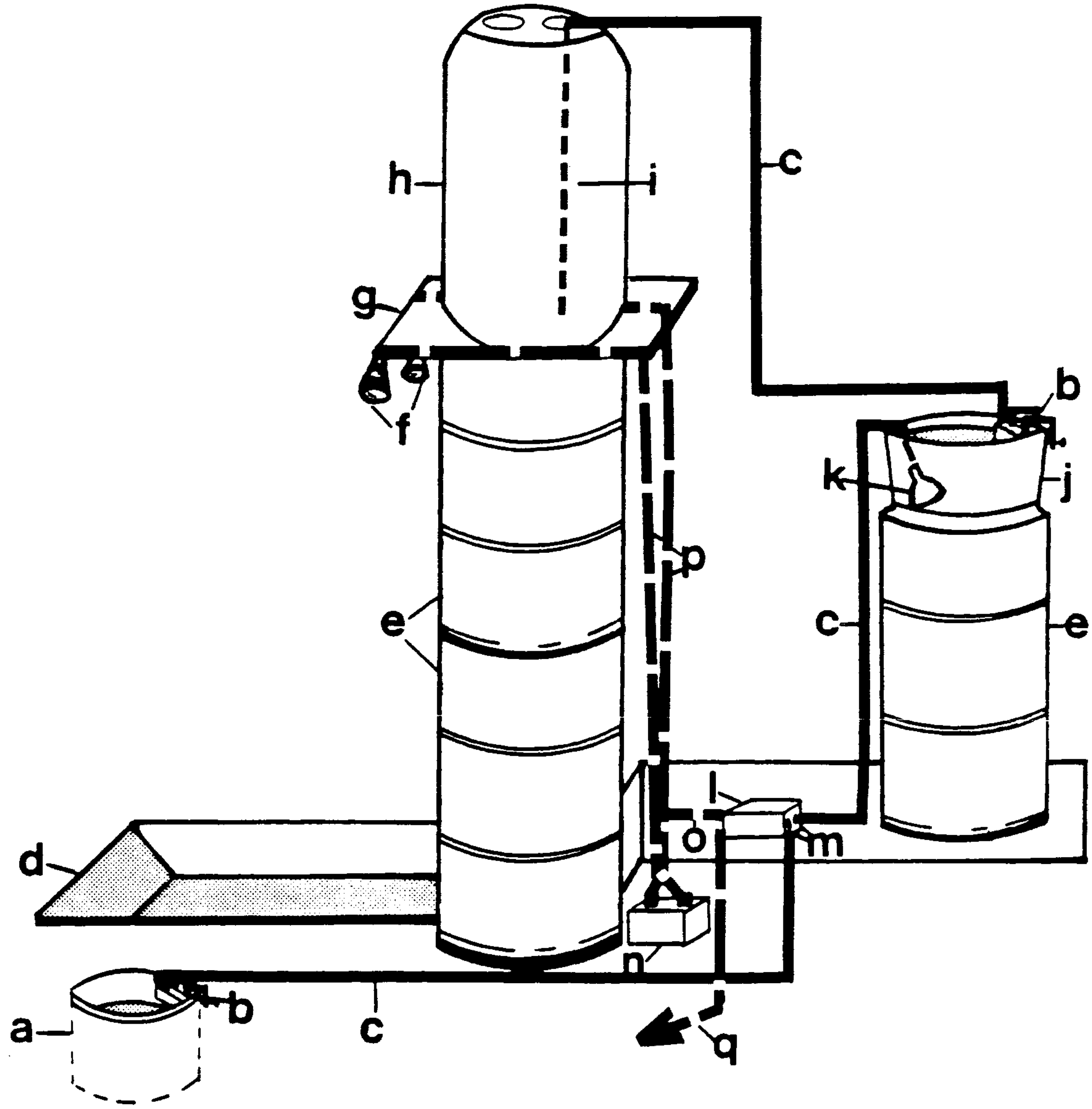

Figure 1. Schematic of equipment used to measure water consumption by desert mule deer in the Picacho Mountains, Arizona, 1985-1986.

a - water bucket, b - float valve, c - water tubing, d - water trough, e - metal drums, f - infrared lights, g - plywood board, h - water drum, i - water tubing inside drum, j - water basin, k - filter funnel, l - instrument box, m - microflowmeter fittings, n - 12 V battery, o - wire to amplifier, p - wires to lights, q - wire to accumulator.

pressure head to the microflowmeter . Consequently, variation due to changing flow rates was minimized. The float valve is designed for use with domestic livestock and has a guard to protect the float mechanism from animals while drinking. The float valve was attached to the basin with clamps and the inlet fitting was adapted to the water tubing coming from the water drum. The water was siphoned from the basin to the microflowmeter and on to the bucket. The end of the outlet tubing in the water basin was fixed inside a 12 cm diameter funnel with a 15 cm milkfilter paper attached by a rubber band to the funnel flange. The narrow end of the funnel through which the tube passed was made water tight with rubber electrical tape. All water going to the microflowmeter passed through the filter to remove particulates. A lid was secured over the top of the water basin and duct tape was used around the edge of the lid to prevent sunlight, insects, and dirt from getting into the basin.

Water Bucket. The drinking bucket was an enamel, leakproof pot 40 cm high with a 40 cm diameter. It was sunk 30 cm into the ground beside the water trough to prevent it from being tipped over. The water tubing from the outlet fitting of the microflowmeter was run to the inlet fitting of the float valve clamped to the water bucket. By running the water tubing through the protective tubing and using duct tape as necessary, constriction and exposure to sunlight were avoided. Due to the constraints of the microflowmeter and pressure head, the bucket did not completely refill until approximately 10 minutes after an animal stopped drinking.

Electronic Equipment

Microflowmeter. The Signet MK5Ø5-1 Microflosensor (Signet Scientific, El Monte, Calif.) is designed for (+/-) 1% (full scale) linearity, and (+/-) Ø.5% repeatability at extremely low flow rates of 2ØØ-2,ØØØ ml/min. It is calibrated for use with 4.76 mm (3/16") ID plastic tubing, and can measure units as small as 1 ml. The rotation rate of the paddle wheel is obtained from an electro-optical system emitting energy in the infrared spectrum. Clear, transparent, or translucent liquids are necessary. The parent instrument (accumulator) supplies the required 5 Vdc regulated at 6Ø mA maximum.

Amplifier. The Signet MK514 Signal Conditioner functions as a noise free amplifier and transmits signals from the microflowmeter to the accumulator ($\leq$33Ø m). The amplifier can be calibrated to most volumetric units. The amplifier requires 12 Vdc, 8Ø mA. The microflowmeter and the amplifier were housed inside a plastic instrument box for protection. Two holes were cut in one end of the instrument box to allow the inlet and outlet fittings of the microflowmeter to protrude for easy connection with the water tubing. When removing the instrument box, the 2 free ends of the water tubing were connected with a short length of copper tubing so that water continued to flow to the bucket as necessary. The electrical connections between the microflowmeter, amplifier, and battery were fitted with Jones plugs so that all connections could be rapidly made at the instrument box.

Accumulator. The Signet MK579R Accumulator is a 5 digit, front resettable, electro-mechanical digital counter with a power requirement of 12 Vdc, 285 mA, and an accuracy of (+/-) 2% at the calibrated rate.

The accumulator was factory adjusted to register 0.01 liters/10 ml that the microflowmeter registered, because the mechanics of the accumulator can not reliably perform such rapid turnover. If the distance between the accumulator and microflowmeter is ≤ 60 m, then no amplifier is needed and the accumulator should be factory installed with a P30507 pin input module (16 pin integrated circuit). When the amplifier is being used, it requires the P30507 pin module while the accumulator uses a M00177 pin module. If an amplifier is being added to or removed from a previously operating system, then the pin modules may also have to be changed. This is not clearly presented in the instruction manuals. One wire from the instrument box was run to the accumulator at the observation site. The wire was run through 2 cm diameter plastic tubing to prevent it from being damaged by rodents. Rocks were placed along the top of the tubing to keep it flat to the ground.

Batteries. Two 12 Vdc deep cycle marine/RV batteries powered the infrared lights, the amplifier, and the accumulator. The second battery was used for the accumulator at the observation site. The 2 infrared lights together used 1,000 mA; the battery at the catchment had to be recharged after 3 nights (42 hours). Both batteries were housed in plastic battery cases.

Nightscope Equipment

During the day a spotting scope was used at the observation site to classify the species, sex, and age of the animal drinking, to observe that the animal completed a normal drink, and to observe that no other animal drank from the bucket while it was refilling. For nocturnal observations, I developed a technique using a nightscope and infrared lights.

Nightscope. The Litton M-841 Pocketscope (Litton Industries, Electron Tube Division, Tempe, Ariz.) is an image intensifier system which amplifies available light. It was improved by using a C-1 adaptor to attach a 300 mm lens and a 2X teleconverter (for a 35 mm camera system), which gave the nightscope an effective magnification of 12X. However, the nightscope was still ineffective without the addition of artificial light.

Infrared Lights. Two 6 Vdc, 500 mA headlamps were clamped to a 60 cm x 60 cm plywood board underneath the water drum 2 m above the water bucket. Voltage regulators and heat sinks were connected to the headlamps so that they could run off the same 12 V battery that powered the amplifier. The lenses were fitted with infrared filters (Kodak No. 88A). Both lights were aimed at the front of the water bucket, providing additional light to an area 10 m in front of the bucket. One light served as a backup to the other if a bulb burned out.

Operation

Daily operation began by pumping water from the water trough up to the water drum with a hand operated bilge pump. Rubber gloves were used when handling equipment at the water trough and bucket to minimize human scent. One of the 12 V batteries was placed on the ground behind and below the water drum (Fig. 1). The infrared lights were installed with their wires connected to the battery. The water bucket and float valve were cleaned as necessary, and 2 liters of water were removed from the bucket to begin water flow from the basin to the bucket. Connections were then made to the instrument box. The accumulator and second battery were connected at the observation site. If the water bucket was still refilling, the accumulator should start registering immediately. When the bucket was refilled, a cup and graduated cylinder were used to make 3 successive 1 liter measurements. In the morning, or when the data collection session was finished, 3 more calibration measurements were made. The 6 calibrations were averaged to adjust the night's data. These measurements were the first and best indication that equipment was malfunctioning or that previous data were suspect. Before retreating to the observation tent, the infrared lights were switched on and, as necessary, a plywood board was used to block all or part of the water trough to make deer drink from the bucket.

Deer Drinking Records

Deer were classified as males or females. Water consumption was recorded by season and expressed as liters/visit. A 2-way analysis of variance using unweighted cell means and t-tests for simple effects (Snedecor and Cochran 1967) were used to determine if significant differences in water consumption occurred between sexes and early or late summer.

RESULTS

Acceptability of Equipment

Desert mule deer, javalina, mountain lion (*Felis concolor*), bobcat (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), ringtail (*Bassariscus astutus*), and great horned owl (*Bubo virgineanus*), all drank from the water bucket. No species were seen to approach the water trough but not drink from the bucket. Only desert mule deer were persistantly cautious, though considerable variation between individuals was observed. Some deer walked up to the bucket and drank, but others milled around the catchment for ≥ 2 hours without drinking. Although deer did show an initial alertness towards the new equipment for a period ≤ 10 days, subsequent and persistant cautiousness was not focused at the new equipment.

Success in measuring a complete drink by an individual was affected by the number of animals at the catchment at one time. For desert mule deer, if ≤ 3 deer were at the catchment simultaneously, 1 or 2 valid readings might be made. If ≥ 3 were present, success was unlikely. The strong herding behavior of javalina resulted in valid measurements only from the occassional solitary individual. Equipment was set up at 3 different water catchments so that observers could change from one to the other on a daily basis by carrying the electronic instruments, nightscope, and lights with them. The catchment which had the most deer was unsuccessful because the deer usually arrived in groups of 4. Another catchment had ≤ 2 deer/night. The third provided 4 valid readings/night during a 1 month period because deer usually arrived one or two at a time with a total of 4 to 8 deer/night. Group size and visitation frequency of the target species were the factors that determined the quantity of data collected.

Accuracy of Equipment

The accuracy of the equipment was demonstrated by 24 repeated measurements of 5 liters of water removed from the bucket. These measurements were adjusted by 6 calibration measurements as in the normal data collection procedure. The results averaged 4.96 liters (SE = 0.03 liters). Repeated measurements of 1, 3, 4, and 5 liters confirmed the linearity of the microflowmeter readings. However, repeated measurements of 0.10 and 0.30 liters were nonlinear. Volumes this small did not open the float valve enough to allow the flow rate to reach the minimum 200 ml/min requirement. Repeated measurements at different time intervals (X) between the measurements showed some variation (Y) indicating that some water was slowly passing the float valve into the bucket after the microflowmeteer had stopped registering. A logarithmic regression, $Y = -25.19 + 28.62 \ln X$, ($\underline{r} = 0.98$) was used to adjust the readings. However, after a time interval of 2 hours, the float valve was completely closed so that the maximum adjustment was +110 ml.

Equipment Performance

Waterflow Equipment

The water tubing had to be inspected periodically for dirt, algae, insects, and other obstructions. Algae caused air bubbles and constrictions that varied readings. Any suspect section was replaced. The filter paper in the basin was inspected ≤ 3 days and usually replaced. Clogged filters altered flow rates. The operation of the float valve in the water bucket was critical. It was firmly clamped and kept clean for free movement. Spare float valves were kept for immediate exchange with a dirty one. The water bucket was emptied and cleaned every other day to eliminate any dirt, debris, and algae that might interfere with the float valve.

Bees that were present in the water trough during the day periodically attempted to use the bucket where they interfered with the float valve. By keeping a mosquito net over the bucket when not in use, the bees did not habituate to using the bucket. Toads in the trough were more of a problem when they entered the bucket at night.

Electronic Equipment

The microflowmeter did not show any problem with dirt when dismantled and inspected. However, it did malfunction due to poorly soldered joints on both of its small printed circuit boards. The original solder was removed and new solder applied.

The amplifier malfunctioned twice. One time a capacitor was replaced. Another time a broken wire on the printed circuit board was replaced and resoldered.

The accumulator had 2 problems. Deer were sometimes alarmed by the clicking sound of the digit wheels as they turned. This noise was only a problem at 100 m with desert mule deer, and was not a problem at 200 m. A box made from a plastic battery case and styrofoam padding partially muffled the sound. The second problem was that the right-most digit wheel would sometimes jam when the measurement was almost finished. The reset button was ineffective, but a momentary interruption of the power wire at the back of the instrument would correct the problem.

Male Drinking Frequency

Three males (P29, P39, P43) made 33 visits to water catchments over 10 days. Their individual totals were 9, 11, and 13 visits respectively. Deer P29 did not water 1 night, visited catchment 111 on 1 night, and visited catchment 112 on 8 other nights. Deer P39 visited catchment 111 once a night on 9 nights and twice on 1 night. Deer P43 usually watered once a night for 7 nights at catchment 111, but on 3 nights he visited catchments 111 and 689. These results indicate a watering pattern of 1 visit/24 hours.

Minimum Water Requirements

Before water restriction the captive female maintained a stable weight of 62 kg while drinking an average of 127 ml/kg$^{0.8}$/day (3.43 liters/day). While maintaining her weight of 53 kg for 10 days, she drank an average 55 ml/kg$^{0.8}$/day (1.32 liters/day).

Water Consumption

Fifty-four records of water consumption by free ranging desert mule deer were obtained. Two records were made in July 1985 and 52 records in the summer of 1986. In early summer males consumed an average of 2.66 liters/visit (SE = 0.27, *N* = 2) and females consumed an average of 3.29 liters/visit (SE = 0.36, *N* = 8). In late summer average consumption by males was 3.55 liters/visit (SE = 0.18, *N* = 24). Females drank an average of 4.16 liters/visit (SE = 0.19, *N* = 20). The average water consumed/visit by a deer during the summer was 3.70 liters (SE = 0.13, *N* = 54). For a 50 kg deer this average is 162 $ml/kg^{0.8}$/visit. Interaction between sex and season was significant ($F = 33.7$, $df = 1$, $P < 0.05$) and females drank more than males during the late summer ($P < 0.05$).

DISCUSSION

Equipment Performance

Waterflow Equipment

The largest source of error in the measurement of water consumption was in refilling the bucket to the same level each time. One way to reduce this is to use a bucket with a smaller surface area. Initially, I was concerned that if the bucket was too small, some animals might not drink from it. A second way to minimize variation is to find or develope a more sensitive float valve. However, the float mechanism must be protected from the animals while drinking. The regression equation used to adjust for different time intervals between readings may vary with different flow rates and float valves.

Electronic Equipment

The problems with the accumulator's noise and jammed digit wheel could be resolved by using a LCD digital readout accumulator, which the manufacturers said they were going to market. Also, an LCD accumulator could record in ml rather than cl.

Nightscope Equipment

Several times the lightbulbs in both headlamps burned out at the same time. An automatic relay switch between 2 lights would save on bulbs and battery drain. With such an automatic backup system, 2 pairs of lights could be used, 1 aimed at the bucket, and the other further forward so that other animals within the catchment could be better observed.

When experimenting with a white light but alternating with a clear lens, a red filter, and an infrared filter, I found all to be equally bright when seen through the nightscope. Hervert (1985) reported that desert mule deer reacted to red lights, but I did not detect deer reactions to the infrared lights. The use of infrared lights greatly increased the light available to the nightscope and made possible the effective use of larger telephoto lenses. This technique may have applications to other nocturnal studies and may be practical with a mobile light.

Male Drinking Frequency

The results indicating that males water once every 24 hours matches the drinking frequency of females determined by Hervert and Krausman (1986). Their inability to discern a visitation pattern for males was because male movements possibly ranged beyond the monitored water sources to alternative sources (J. J. Hervert, pers. commun.). However, I do not know if the drinking frequency of the males using the monitored water sources in the foothills of the Picacho Mountains is the same as for the males using the stock ponds out on the creosote flats. Large males were not seen at the water catchments in the summer. The males observed using the water catchments appeared relatively small in body and antler size. I estimated their ages to be 2 - 3 years.

The drinking patterns of deer P39 and P43 were determined by records of the SRCR's because neither male ever used catchment 112. The drinking frequency of P29 was determined by the less accurate telemetry location method, but the pattern was very regular. He usually drank between 1830 and 2130 hours and never after 2400 hours.

Desert mule deer may drink more frequently than desert bighorn sheep (*Ovis canadensis spp.*), another ungulate of the Sonoran desert. Turner (1970) recorded drinking frequencies of 1 - 5 days and concluded that desert bighorn sheep must drink to replace their evaporative water loss during the summer months (Turner 1973). However, Krausman et al. (1985) monitored 2 adult females who did not drink during a 10 day summer study.

Minimum Water Requirements

The minimum drinking water requirements of the female desert mule deer indicate an ability to conserve water. Taylor (1968) determined daily minimum requirements for 6 wild East African bovids and 2 domesticated species under conditions simulating a hot arid environment. He partitioned the total water requirements into metabolic water produced, preformed water taken in with the food, and drinking water consumed. Metabolic and preformed water combined, ranged from 5 to 30% of the total water requirements. Drinking water was significantly correlated ($r = 0.99$, $P < 0.001$) with total minimum water requirements. The female desert mule deer's drinking rate of 55ml/kg$^{0.08}$ is similar to the the 3 lowest rates (51, 34, and 55) ml/kg$^{0.8}$) for oryx (*Oryx beisa*), Thomson's gazelle (*Gazella thomsonii*), and Grant's gazelle (*Gazella granti*). The other 5 species consumed 2 to 4 times the rate of the female desert mule deer. Two species, the oryx and the eland (Taurotragus oryx) are capable of surviving in arid regions without drinking water (Taylor 1969). A comparison of the total water requirments would yield the same relative results even if the metabolic and preformed water composed 30% of the total water requirements of the female desert mule deer.

The water requirements of desert mule deer may be less than the requirements of desert bighorn sheep. Turner (1970) estimated the minimum drinking water requirements of desert bighorn sheep to be 4% of their body weight. This estimate is higher than the 2.5% required by the desert mule deer and represents a consumption rate of 88 $ml/kg^{0.8}$. Zervanos and Day (1977) dehydrated 2 captive javelina (Tayassu tajacu) and measured a water turnover rate of 50 $ml/kg^{0.8}$ (2.7% of body weight). This rate indicates a water consumption rate at least as low as the desert mule deer's rate because water turnover includes metabolic and preformed water sources.

Turner (1973) reported physiological adaptations that minimize the water requirements of desert bighorn sheep. Use of rumen water, reduction of urine and fecal water loss, concentration of urine, and tolerance of decreased plasma volume and body water content enable desert bighorn sheep to survive in arid regions. Similar adaptations should be investigated in desert mule deer.

Water Consumption

Females drinking in late summer averaged the highest consumption rate, perhaps due to the higher water requirements of lactating does who fawn in July and August. However, males also increased their average in late summer.

My results of 4.16 liters/visit ($\underline{N}$ = 20) consumed by females in late summer differs from previous data. Elder (1954) reported that females in the Tucson mountains consumed 6.6 liters/visit ($\underline{N}$ = 6) and Hervert and Krausman (1986) recorded an average of 5.1 liters/visit ($\underline{N}$ = 3). Some of the difference may be due to their smaller sample sizes and less precise methods. The temperatures that Elder (1953) reported were lower than the temperatures in the Picacho Mountains during my study. However, forage conditions were not evaluated during any of the studies.

Water consumption can also provide a quantitative measure of the role that animal behaviors and habitat components play in animal adaptations to arid environments. For example, the differences in the nocturnal activity of 2 species using the same area may account for a significant difference measured in their rates of water consumption. In another hypothetical example, the difference in the distances to available water in 2 similar areas used by the same species may result in a difference in their water consumption rates. In both cases, water consumption rates may provide a quantitative evaluation of animal behaviors or habitat components.

Management Applications

Hervert and Krausman (1986) suggested using water catchment visitations as a censusing technique for desert mule deer. Because both males and females visit water every 24 hours, censuses are simplified.

If a total count of a population is desired, discrimination of sexes is not necessary and sample size is increased by using both sexes. Observations need not be restricted to daylight hours if a nightscope and infrared lights are used. Also, nocturnal counts may more than double the sample size (Hervert and Krausman 1986). Population trends might also be estimated by monitoring water catchment levels, if all water sources can be monitored and if water intake rates are known.

Average water intake rates together with drinking frequency may enable managers to estimate the number and size of water developments required for an estimated population. Based on my results, a population of 200 deer in the Picacho Mountains would require 22,000 liters of water/month (after evaporation). If the population were evenly distributed over the 6 water catchments, each catchment would require a storage capacity of 3,700 liters/month, for desert mule deer alone.

LITERATURE CITED

Anthony, R. G. 1976. Influence of drought on diets and numbers of desert deer. J. Wildl. Manage. 40:140-144.

Brown, D. E. 1984. The effects of drought on white-tailed deer recruitment in the arid Southwest. Pages 7-12 in P. R. Krausman and N. S. Smith, eds. Deer in the Southwest: a symposium. School of Renewable Nat. Resources, Univ. Arizona, Tucson.

Elder, J. B. 1953. Utilization of man-made waterholes by wildlife in southern Arizona. M. S. Thesis, Univ. Ariz., Tucson. 114pp.

_____. 1954. Notes on summer water consumption by desert mule deer. J. Wildl. Manage. 18:540-541.

Hervert, J. J. 1985. Mule deer use of water developments in Arizona. M. S. Thesis, Univ. Ariz., Tucson. 24pp.

_____, and P. R. Krausman. 1986. Desert mule deer use of water developments in Arizona. J. Wildl. Manage. 50:670-676.

Knox, K. L., J. G. Nagy, and R. D. Brown. 1969. Water turnover in mule deer. J. Wildl. Manage. 33:389-393.

Krausman, P. R., S. Torres, L. L. Ordway, J. J. Hervert, and M. Brown. 1985. Diel activity of ewes in the Little Harquahala Mountains, Arizona. Desert Bighorn Counc. Trans. 29:24-26.

Ordway, L. L., and P. R. Krausman. 1986. Habitat use by desert mule deer. J. Wildl. Manage. 50:677-683.

Richmond, C. R., W. H. Langham, and T. T. Trujillo. 1962. Comparative metabolism of titrated water by mammals. J. Cell. and Comp.

Physiol. 59:45-53.

Scarbrough, D. L., and P. R. Krausman. In press. Sexual segregation by desert mule deer. The Southwest. Nat.

Sellers, W. D., R. H. Hill, and M. Sanderson-Rae. 1985. Arizona climate: the first hundred years. Univ. Arizona Press, Tucson. 143pp.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods. Sixth ed. Iowa State Univ. Press, Ames. 593pp.

Taylor, C. R. 1968. The minimum water requirements of some East African bovids. Symp. Zool. Soc. Lond. 21:195-206.

_____. 1969. The eland and the oryx. Sci. Am. 220:89-95.

Turner, J. C. 1970. Water consumption of desert bighorn sheep. Desert Bighorn Counc. Trans. 14:198-197.

_____. 1973. Water, energy and electrolyte balance in the desert bighorn sheep, *Ovis canadensis*. Ph.D. Thesis, Univ. Calif., Riverside. 138pp.

Wallmo, O. C. 1981. Mule and black-tailed deer distribution and habitats. Pages 1-25 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln.

Wesley, D. E., K. L. Knox, and J. G. Nagy. 1970. Energy flux and water kinetics in young pronghorn antelope. J. Wildl. Manage. 34:908-912.

Wright, J. T. 1959. Desert Wildlife. Ariz. Game and Fish Dep. Wildl. Bull. 6. 78pp.

Zervanos, S. M., and G. I. Day. 1977. Water and energy requirements of captive and free-living collared peccaries. J. Wildl. Manage.

41:527-532.