

# Rattlesnake commercialization: long-term trends, issues, and implications for conservation

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**Abstract** Rattlesnakes are commercially exploited to supply an international trade in skins, meat, gall bladders, and curios. Five species are used in 8 states: western diamondback rattlesnakes (*Crotalus atrox*) in Texas, Oklahoma, and New Mexico; eastern diamondback rattlesnakes (*C. adamanteus*) in Alabama, Florida, and Georgia; prairie rattlesnakes (*C. viridis*) in Kansas, Texas, Oklahoma, and New Mexico; and timber rattlesnakes (*C. horridus*) in Pennsylvania, Georgia, Alabama, and Florida. Blacktail rattlesnakes (*C. molossus*) occasionally appear in the trade in New Mexico and Texas. The trade is linked to rattlesnake roundups, which are economically important to local communities. We estimated that 15% of the western diamondback and eastern diamondback rattlesnakes entering the trade originate from roundups. In the 1990s, probably <125,000 rattlesnakes of all species entered the trade yearly. Analyses of long-term data from 3 rattlesnake roundups showed variable trends in rate of take, number of hunters, and pounds of snakes/hunter. Analysis of the take of western diamondback rattlesnakes from 1959 to 1997 at the roundup at Sweetwater, Texas, showed no long-term trends, but was characterized by extreme variability. Body size (snout-vent length [SVL] and mass) and sex ratios of hunted western diamondback rattlesnakes varied significantly by region and through time. These differences were probably due more to geographic and temporal variation than to the effects of hunting. Rattlesnake harvests of all species were male-biased, and a few hunters collected the majority of the take. A model of the economic impacts of imposing size restrictions on rattlesnake harvests showed that hunters earn 19% more money when restricting take to rattlesnakes >90 cm SVL (size at maturity of most females) whereas profit to the industry increased 6%. Size limits below 90 cm SVL would minimally impact total take; restricting take to rattlesnakes >90 cm SVL would reduce number of immature females by almost 50%. Rattlesnake species differ in susceptibility to overexploitation, and research on life-history variation of rattlesnakes should be an important management priority. Information also is needed on local versus regional impacts of hunting, and monitoring information is needed for the entire trade. Rattlesnakes are traded alive, and issues relating to the treatment of live rattlesnakes need to be considered when developing management plans for North American rattlesnakes.

**Key words** commercialization of wildlife, conservation, *Crotalus*, long-term trends, management, rattlesnakes, rattlesnake roundup, reptiles, sustainability, wildlife ethics

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The issues surrounding exploitation and conservation of rattlesnakes are complex and intertwined. Rattlesnakes are well-known venomous predators, having inspired respect and fear in people for as long as there have been historical records (Klauber 1972, Lee 1996, Greene 1997). Rattlesnakes also are economically valuable wildlife that are exploited to supply an unregulated international trade in skins, meat, gall bladders, clothes, and curios. This widespread exploitation is largely unknown to most North Americans and is a growing issue of concern for wildlife professionals. Five species of rattlesnakes are exploited commercially in at least 8 states.

The commercial trade in rattlesnakes is linked to well-known public events called rattlesnake roundups, which may generate huge amounts of money. Both the commercial trade and the roundups themselves are economically and socially important to the towns where they are held and to the small number of people involved in the rattlesnake trade. The 40th annual Sweetwater Rattlesnake Roundup, held in Sweetwater, Texas, in 1998, generated tens of thousands of dollars for civic projects, with \$3.00 spent in the community for every dollar made by the roundup (Weir 1992; Thomas and Adams 1993; Sweetwater Jaycees rattlesnake roundup public relations officer, personal communication). More than 70,000 paying customers attended the 1993 Freer, Texas, Rattlesnake Roundup.

The commercial trade in rattlesnakes occurs throughout the year independent of roundups, although it is practically impossible to quantify because it is unregulated (Adams et al. 1994). Conservation of exploited resources is compromised when trade patterns and value of the resource at different levels of the trade chain (i.e., value to hunters, to intermediaries, and to the industry) are unknown. Lack of scientifically defensible information about commercial trade impedes rattlesnake management.

Although rattlesnake ecology and population biology remain poorly understood, lack of data has not prevented proponents and opponents of rattlesnake commercialization from drawing hard conclusions. A general belief among proponents is that rattlesnake populations cannot be extirpated (Kilmon and Shelton 1981, N.C.S. News 1993a). Those favoring unrestricted harvest claim they provide a public service to rid the countryside of dangerous vermin or to maintain the balance of nature (Weir 1992, Thomas and Adams 1993, MacGregor

1998). Ironically, if rattlesnakes were eliminated, an important cultural feature of the towns supporting roundups and the millions of dollars in revenue thereby generated would be lost. In contrast to proponents' claims, professional biologists have expressed concern that removal of thousands of rattlesnakes annually might adversely affect rattlesnake populations (Campbell et al. 1989, Reinert 1990, Brown 1993, Pisani and Fitch 1993). Yet it is difficult to reconcile that claim with the fact that after 4 decades of exploitation, roundups in Texas, Oklahoma, Alabama, and Georgia continue to bring in large and variable numbers of western diamondback (*Crotalus atrox*) and eastern diamondback rattlesnakes (*C. adamanteus*).

Rattlesnakes are unique among exploited wildlife in North America because they are venomous and traded alive. Thus, issues of proper treatment of live animals are imposed on the already complex problem of managing a commercially traded wild resource. The western diamondback rattlesnake is a mascot for several Texas towns, signaling the unique cultural value of rattlesnakes. Several towns elect beauty queens in honor of their rattlesnake roundup, and a giant statue of a western diamondback stands outside the Freer, Texas, Chamber of Commerce (Figure 1). It is therefore ironic that rattlesnakes are often mistreated, including being butchered in public at some roundups. "Educational" shows stress the risk of snakebite, to the exclusion of accurate natural history information (Weir 1992). Meanwhile, handlers perform daredevil tricks with hundreds of rattlesnakes in a pit, sending an unclear message to the public that has little to do with the natural lives of these secretive, solitary predators.



Figure 1. This monument to the western diamondback (*Crotalus atrox*) stands outside the Freer, Texas, Chamber of Commerce and symbolizes the cultural and economic value of rattlesnakes to local people. Photo by Charles W. Painter.

Our goals are to review and quantify the use of rattlesnakes in North America and substantiate or refute claims about the rattlesnake trade and rattlesnake roundups. We present original results and draw extensively from published studies and commentary. While some excellent work has been done (Campbell et al. 1989, Reinert 1990, Brown 1993, Adams et al. 1994), issues surrounding the rattlesnake trade are clouded by unsubstantiated claims and non-reviewed literature. To infer about the sustainability of rattlesnake hunting, we analyze long-term data on take of the most exploited species, the western diamondback, from several rattlesnake roundups. From these data we examine interactions among hunting methods, hunting season, and gender vulnerability of rattlesnakes. We address the contributions of geographic variation and the effects of hunting on the size distributions of harvested western diamondback rattlesnakes by analyzing morphological data from harvests in northern Texas, southern Texas, and New Mexico. We also synthesize information on the use of other rattlesnake species to reveal general patterns of exploitation. Examination of life history characteristics of exploited rattlesnake species allows us to infer why some species or populations are susceptible to overexploitation while others appear able to withstand sustained hunting pressure (Congdon and Dunham 1994). To gain insight into the feasibility of managing rattlesnakes, we modeled the economic and biological impacts of imposing minimum size limits on a hypothetical rattlesnake harvest. Finally, we evaluated the treatment of live rattlesnakes in the context of proper resource management and make recommendations for a management program.

## Methods

### *Visits to rattlesnake roundups*

We visited 8 roundups and a rattlesnake show: Sweetwater, Texas; Big Spring, Texas; Freer, Texas; Cross Fork, Pennsylvania; and Albuquerque, New Mexico, were each visited once, and we visited the roundup in Alamogordo, New Mexico, yearly from 1993 to 1997. Western diamondbacks were the target species in Texas and New Mexico; timber rattlesnakes (*C. horridus*) were targeted in Pennsylvania. We conducted extensive interviews with 5 roundup organizers, 3 snake traders, snake handlers, curio vendors, and hunters. We also conducted formal surveys of 93 spectators and 11

hunters at the rattlesnake roundup at Alamogordo in 1993. To facilitate comparisons, we used the questionnaires for spectators and hunters used by Adams et al. (1991) at rattlesnake roundups in Texas. We noted species appearing at each roundup, general condition of snakes, and numbers of each species. We classified snake condition as good or poor; snakes in poor condition were obviously emaciated or had visible serious wounds.

### *Measurements of rattlesnakes at roundups*

To quantify geographic variation in body size and sex ratios of hunted rattlesnakes, we measured samples of western diamondbacks at roundups in 3 distinct regions of the species' range: northern Texas (Big Spring), southern Texas (Freer), and New Mexico (Alamogordo). We measured snout-vent length (SVL) and tail length (TL) to the nearest 0.5 cm and mass on an electronic balance to the nearest gram. Gender was determined by inspecting tail morphology and relative tail length (Klauber 1972). We tested the null hypotheses that SVL and mass of males and females did not vary significantly ( $\alpha=0.05$ ) among regions and through time using analysis of variance (ANOVA) followed by Tukey's tests to distinguish groups of means. We performed separate analyses for each gender. We tested null hypotheses that sex ratio did not differ from unity ( $\alpha=0.05$ ) using chi-square tests of equal proportions. We also tested null hypotheses that frequencies of males and females were similar ( $\alpha=0.05$ ) among roundups and through time using contingency analyses (SAS Institute Inc. 1988).

### *Analyses of trends*

We obtained annual records of harvest and hunters participating each year from roundup organizers at the Big Spring, Texas, and Alamogordo, New Mexico, roundups. Published records on harvest at Sweetwater, Texas, were available from 1959 to 1997 and total number of hunters at Sweetwater from 1971 to 1991 (Kilmon and Shelton 1981, Weir 1992, DelMonte and Miller 1997). We used total mass as the variable for analyses of rattlesnake harvest because total mass of rattlesnakes is traditionally recorded at roundups and western diamondbacks are traded commercially by mass. We estimated rate of change in harvest of rattlesnakes, rate of change in number of hunters, and rate of change in mass of snakes/hunter at Sweetwater, Big Spring, and Alamogordo using the average of log-transformed ratios of values for each variable between years:

$$\text{rate} = 1/\text{no. yr} \left[ \sum_{i=1}^{\text{yr}} \ln(n_t / n_{t-1}) \right],$$

where yr = the number of years included in the estimate and  $n$  = the value (i.e., kg of rattlesnakes, number of hunters, or kg/hunter) at year  $t$ . This method of estimating long-run rates is analogous to estimating long-run growth rates of populations in a stochastic environment and is the numerical analog of the infinitesimal mean in an analytical model (sensu Tuljapurkar and Orzack 1980, Dennis et al. 1991, Fitzgerald 1994a). A rate of zero means the trend is neither increasing nor decreasing. As the calculated rate is an arithmetic mean, the reliability of rate estimates can be expressed as 95% confidence limits. Throughout the results, rates are expressed as means  $\pm$  95% confidence limits. We analyzed the time to convergence to the long-run mean harvest rate by calculating harvest rates with increasingly longer subsets of the time series until all years were included.

Autocorrelation in harvest records through time may interfere with identifying factors that cause shifts in harvest trends (Rasmussen et al. 1993). Raw harvest data from Sweetwater were autocorrelated significantly up to 24 years ( $P < 0.05$ , PROC ARIMA, SAS Institute Inc. 1996), indicating that take in a given year was correlated with take up to 23 years previous. We removed autocorrelation beyond a lag of 2 years by transforming the data into the year-to-year ratios for analyses of rates.

### *Modeling effects of size restrictions on economics of rattlesnake hunting*

We modeled the economic impact of imposing size restrictions on harvests of western diamondbacks to elucidate the degree to which size restrictions might impact economics of harvest as well as the demography of rattlesnake populations. The model randomly selected individual western diamondbacks from a normal distribution of body sizes with mean and variance equal to those observed from a sample of 691 rattlesnakes measured at roundups in Big Spring, Texas; Freer, Texas; and Alamogordo, New Mexico, in 1993. For each randomly selected rattlesnake, the model calculated the price paid to the hunter based on the snake's mass, as well as the total wholesale value of the rattlesnake's parts. Prices were based on data collected during interviews at roundups.

Price to the hunter was fixed at \$9.37/kg and was

calculated for individual rattlesnakes from a SVL-mass regression on the same sample of 691 western diamondbacks measured in 1993 (predicted  $\text{Log}_{10}$  mass =  $[(\text{Log}_{10} \text{ SVL})(3.1829)] - 3.5171$ ;  $R^2 = 95.0$ ). Wholesale values of individual snakes were calculated as follows: Meat and bones comprised 46% of the total mass of an individual rattlesnake and was valued at \$15.43/kg (from 12 carcasses at the Alamogordo roundup in 1994, unpublished data); skins were valued at \$13.12/m, and their lengths were calculated from SVL of whole rattlesnakes minus 10 cm to account for the head and neck; heads and rattles were each worth \$0.50; gall bladders were worth \$1.00. The model calculated gross profit as the wholesale value minus the price paid to the hunter.

We conducted simulations where the distribution of rattlesnakes from which hunters could draw was truncated at the minimum SVLs of 30, 45, 60, 75, and 90 cm to represent management restrictions on the minimum size of rattlesnakes allowed to enter the harvest. Each simulation consisted of 2,000 iterations of the model. The model assumed that hunters complied with restrictions and did not incur additional costs associated with leaving snakes below the minimum size. Therefore, no adjustment was made to account for increasing effort that might be required under constraints of increasing minimum size limits. We address this assumption in the interpretation of results. Finally, we assessed the impact on the total harvest of restricting the maximum and minimum sizes of harvested rattlesnakes, as in a slot-size restriction.

## Results

### *Snake species appearing at roundups*

Five species of rattlesnakes are hunted as part of roundups in at least 8 states. The western diamondback is harvested in Texas, Oklahoma, and New Mexico. Prairie rattlesnakes (*C. viridis*) are collected at the roundup in Sharon Springs, Kansas, and occasionally at roundups in Texas, New Mexico, and Oklahoma. Blacktail rattlesnakes (*C. molossus*) are uncommon in Texas and New Mexico roundups. Eastern diamondbacks are collected at roundups in Opp, Alabama, and Fitzgerald, Claxton, and Whigham, Georgia, and are commercially exploited in Florida. Timber rattlesnakes are targeted during at least 12 organized hunts in Pennsylvania and West Virginia (Reinert 1990, N.C.S. News 1993). Southern populations of the

timber rattlesnake are traded commercially in Florida, Alabama, and Georgia. Various other native venomous and nonvenomous snakes were displayed, sold, or used in daredevil shows at several roundups we visited. At least 10 genera of non-venomous species, including bullsnakes (*Pituophis melanoleucus*), coachwhips (*Masticophis flagellum*), and garter snakes (*Thamnophis* spp.) were purchased from hunters and sold at the Freer roundup and were used in shows at other roundups (Fitzgerald and Painter 1994).

### *Types of roundups and rattlesnake shows and geographical distribution of roundups*

All rattlesnake roundups and organized hunts share the common characteristics of being public events held on a weekend and including activities such as a rattlesnake show, flea market, and food concessions. Depending on the roundup, hunters compete for prizes for the longest or heaviest rattlesnake, the most rattlesnakes, longest rattle string, and sometimes the smallest rattlesnake. Within this basic format, each roundup has its own level of organization and specific activities (Weir 1992, Thomas and Adams 1993, Pisani and Fitch 1993).

Most roundups in Texas and Oklahoma are organized by nonprofit civic groups whose objective is to raise money for charity and promote the community (Weir 1992, Pisani and Fitch 1993). The roundup at Sharon Springs, Kansas, which originated in 1992, is similar to roundups in Oklahoma (Fitch and Pisani 1993). A second type of roundup is organized by individuals who are motivated by profits from admission and concession fees and from selling rattlesnakes to a trader. Roundups of this nature are held in Alamogordo, New Mexico, and similar ones have been held in Lubbock and El Paso, Texas. Organized snake hunts in Pennsylvania differ from other types of roundups because the treatment of rattlesnakes, as well as the hunt, are regulated by law, and snakes are not killed. Snake hunts in Pennsylvania are organized by local clubs who work with civic groups to raise funds for worthy causes.

As many as 50 separate rattlesnake roundups have been reported to occur in Texas and Oklahoma (Warwick et al. 1991). Adams et al. (1991) listed 26 towns in Texas where rattlesnake roundups have been held and 17 towns with recently active roundups (16 of these held roundups in 1991). The N.C.S. News (1993a) reported 14 rattlesnake roundups in Texas in 1993.

A roundup has been held annually in Alamogordo since 1987. Organized rattlesnake hunts have continued in Oklahoma since they originated in Okeene in 1939 (Weir 1992), and the state is now home to 5 traditional roundups (Pisani and Fitch 1993, N.C.S. News 1993a).

### *Hunting methods and characteristics of hunters*

All species of rattlesnakes are hunted by cruising roads in vehicles, walking, and by extracting snakes from dens or burrows. Timber rattlesnakes are hunted almost exclusively by walking forested habitat and finding them around den sites in fall, spring, and summer (Brown 1993). Interestingly, most eastern diamondbacks entering the commercial trade are found sporadically, rather than from hunting, and include many road-killed and nuisance snakes (Berish 1992). Depending on region and season, western diamondbacks are taken by road collecting and den hunting. At the Freer roundup, held in late spring, practically all western diamondback rattlesnakes were collected by road cruising or by walking fence lines (Fitzgerald and Painter 1994). In New Mexico, 82% of the hunters concentrated on snake dens, whereas 64% of all hunters also hunted on roads. In northern Texas and Oklahoma, western diamondbacks are hunted in early spring as they emerge from wintering sites. In these areas, it is common to spray gasoline fumes deep into dens, forcing snakes to emerge (Kilmon and Shelton 1981, Adams et al. 1994, Fitzgerald and Painter 1994). Eastern diamondbacks also are commonly hunted by pouring gasoline through a hose placed deep inside the burrow of a gopher tortoise (*Gopherus polyphemus*) (Williams 1990, Jones 1995). Not surprisingly, experiments showed that gasoline fumes harmed rattlesnakes and co-inhabitants of snake dens (Speake and Mount 1973, Campbell et al. 1989).

Of the 17 hunters who sold rattlesnakes at Alamogordo during 1993, 11 agreed to be interviewed. All 11 were white males and had previously sold rattlesnakes at organized roundups. Fifty-five percent lived in towns or cities, 45% in rural areas. One individual claimed to have hunted rattlesnakes for over 50 years, although he sold snakes at only 4 roundups. Seven of 11 hunters attended only 1 roundup/year; one hunter attended 3 roundups during 1992. Because there is only one roundup in New Mexico, this hunter must have attended roundups out of state.

In New Mexico, 6 hunters (55%) claimed that rattlesnake hunting had minimal effects on populations; 4 (36%) believed that hunting controlled rattlesnake populations. Similarly, in Texas, 60% of the hunters believed rattlesnake hunting had minimal effects and 31% believed hunting controlled populations (Adams et al. 1994). Five of 11 hunters (45%) at Alamogordo said they hunted rattlesnakes to control population size, and 64% also claimed to hunt the same den sites each year. Other individuals hunted for the experience (45%), the income (36%), and recreation (9%).

Three of 11 hunters (27%) at Alamogordo said they were expanding their hunting area. This result compares well to the findings of Adams et al. (1994), who found that 33% of 212 Texas hunters expanded their hunting areas during the previous 2 years. Thirty counties were reported to be used by hunters at Sweetwater from 1994 to 1997, with 11, 20, 15, and 15 counties used for snake hunting, respectively (DelMonte and Miller 1997). Fourteen of the counties were used only once, 6 were used twice, 5 were used in 3 years, and 5 in 4 years. Hunters in New Mexico collected primarily in Eddy, Lincoln, and Otero counties, although some claimed to hunt also in Santa Fe, Luna, and Sierra counties. Average distance traveled to the Alamogordo roundup by hunters was 93.15 km ( $n = 11$ ,  $SD = 89.94$  km). Similarly, hunters in Texas traveled 136 km on average to a roundup ( $n = 212$ ,  $SD = 333$  km, Adams et al. 1994). Fifty-five percent (6 of 11) of hunters at Alamogordo admitted they hunted on Bureau of Land Management (BLM), United States Forest Service (USFS), or State Trust public lands. It is illegal to take resources for profit from BLM federal lands without permits (M. Hakkila, Bureau of Land Management, 1996, letter).

### *Long-term trends in the take of western diamondback rattlesnakes at roundups*

The take of western diamondback at 3 roundups was highly variable among years, and trends varied among roundups. At Alamogordo during 1991-97, yearly take ranged from 247.3 to 870.6 kg, with peaks in 1993 and 1997 (Table 1, Figure 2). The rate of take at Alamogordo was great, though obscured by variation and strongly influenced by the large take in 1997. Mean rate of take (mean of ratios of the log-transformed values) at Alamogordo was  $0.14 \pm 0.57$  ( $n = 6$ ,  $SD = 0.71$ ). The take at Big Spring also varied greatly from 1985 to 1997, but the pattern was distinct. The rate of take there decreased through time and was influenced by large takes at the beginning of the time series ( $\bar{x} = -0.077 \pm 0.657$ ,  $n = 12$ ,  $SD = 1.161$ ). Range in the yearly take was 2,732.4 kg (Table 1, Figure 2b).

Long-term time series from Sweetwater (Kilmon and Shelton 1981, Weir 1992, Del Monte and Miller 1997) allowed detailed analyses of trends of a rattlesnake harvest. As in the other roundups, kilograms of western diamondbacks brought to the

Table 1. Summary statistics for hunter take among years at the rattlesnake roundups at Alamogordo, New Mexico; Big Spring, Texas; and Sweetwater, Texas.

Rattlesnake roundup	Total kg	No. of hunter bags <sup>a</sup>	Kg/hunter bag	Largest bag contribution <sup>b</sup>	Runner-up bag contribution	Top and runner-up combined
<i>Alamogordo, 1991, 1993-97</i>						
Mean	456.86	13.50	35.38	36%	17%	53%
Median	368.20	13.50	28.90	27%	18%	47%
Standard deviation	232.81	2.74	11.41	18%	04%	18%
Maximum	870.56	17.00	51.21	67%	21%	85%
Minimum	247.32	10.00	26.88	23%	11%	37%
<i>Big Spring, 1985-97</i>						
Mean	919.40	28.23	27.67	22%	13%	36%
Median	660.20	31.00	25.39	19%	13%	28%
Standard deviation	809.48	10.68	17.68	10%	04%	13%
Maximum	2811.37	43.00	68.57	44%	26%	64%
Minimum	78.93	11.00	7.18	12%	08%	25%
<i>Sweetwater, 1971-91</i>						
Mean	3300.21	83.38	38.56	n/a	n/a	n/a
Median	2599.08	78.00	32.09			
Standard deviation	2188.61	24.10	19.70			
Maximum	8158.31	131.00	77.39			
Minimum	1087.26	41.00	14.28			

<sup>a</sup>Hunter bags were the amount of rattlesnakes brought to the roundup by a hunter or team of hunters. Data on individual hunter bags were not available for Sweetwater, Texas, and the total number of hunters/hunting teams at Sweetwater was available only for 1971-1991.

<sup>b</sup>Largest bag contribution was the percentage of the total take in a given year; runner-up was the contribution of the second largest bag.

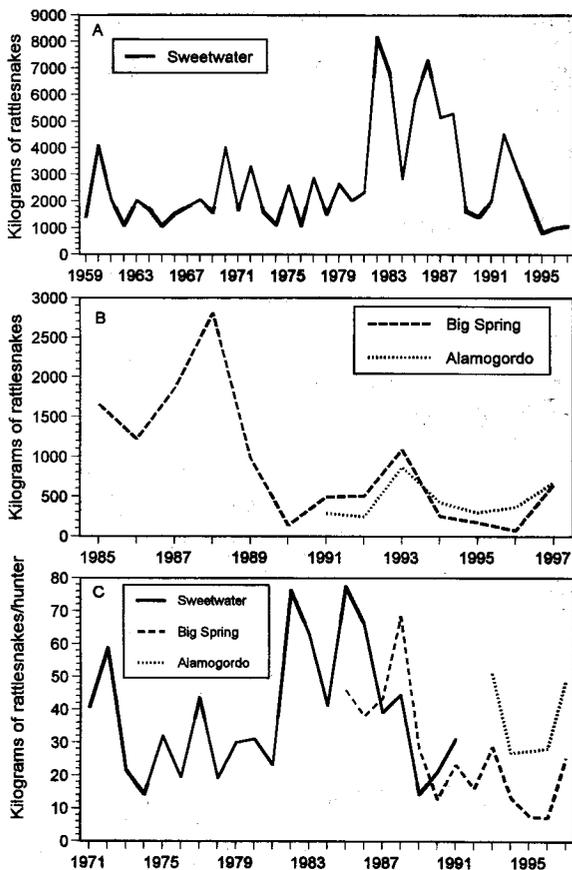


Figure 2. Kilograms of western diamondback rattlesnakes brought to roundups in Sweetwater, Texas, 1959–97 (A); Big Spring, Texas, 1985–97, and Alamogordo, New Mexico, 1991–97 (B); and kilograms of western diamondback rattlesnakes/hunter for all 3 roundups (C).

roundup in Sweetwater varied greatly from 1959 to 1997, ranging from 832.80 kg to 8,158.31 kg without a clear long-term trend (Figure 2). Although numbers of rattlesnakes in a given year at Sweetwater were sometimes very large, the annual rate of take for the entire 39-year time series varied around a long-run mean close to 0.0 ( $n=38$ ,  $\bar{x} = -0.007 \pm 0.204$ ,  $SD=0.642$ , Figure 3). Mean rate of take was positive from 1959 to 1981 ( $n=22$ ,  $\bar{x} = 0.023 \pm 0.272$ ,  $SD=0.650$ ) and has been negative since the peak harvest in 1982 (1982–97,  $n=16$ ,  $\bar{x} = -0.048$ ,  $SD=0.650$ ). Fluctuations in numbers of snakes brought to the Sweetwater roundup resulted in lack of convergence to a precise estimate of the mean rate of take, despite availability of long-term data. Confidence limits around the rates remained very broad, even when we included all years ( $\bar{x} = -0.007 \pm 0.204$ , Figure 3).

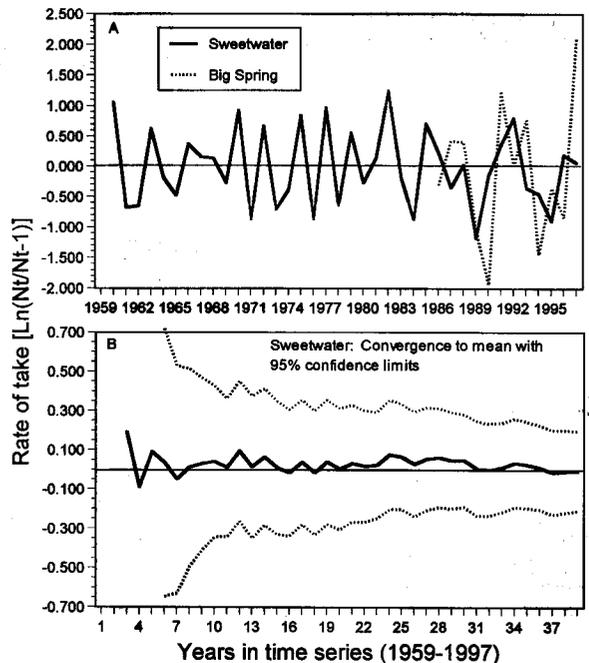


Figure 3. Annual rates of take (kg) of western diamondback rattlesnakes at Sweetwater, Texas, and Big Spring, Texas, since 1959 (A) and convergence time to long-run rate of take over the 39-year time series at Sweetwater, Texas (B).

### Variation in body size and sex ratios of hunted western diamondback rattlesnakes

**Geographic variation in size.** There were significant differences in mean SVL ( $F_{2,479}=9.87$ ,  $P<0.001$ ) and mass ( $F_{2,47}=22.33$ ,  $P<0.001$ ) of male western diamondback rattlesnakes sampled at the 3 roundups in 1993. Multiple comparison tests showed that male western diamondbacks from Alamogordo and Freer were similar in mass ( $P>0.05$ ) and SVL ( $P>0.05$ ) and longer ( $P<0.05$ ) and heavier ( $P<0.05$ ) than males from Big Spring. The largest western diamondbacks we observed were at Freer; several individuals were  $>1.8$  m total length. There also was significant variation among mean SVL ( $F_{2,199}=8.43$ ,  $P<0.001$ ) and mass ( $F_{2,197}=13.74$ ,  $P<0.001$ ) of females among the roundups. Females from Alamogordo were significantly shorter ( $P<0.05$ ) and weighed less ( $P<0.05$ ) than those from Freer. Females from Alamogordo and Big Spring were similar in SVL ( $P>0.05$ ) and mass ( $P>0.05$ , Table 2).

Summarizing, western diamondback rattlesnakes were heavier and longer, on average, in southern Texas (Freer) and New Mexico than in northern Texas (Big Spring). The sample of western diamondbacks from Alamogordo in 1993 was intermediate in

Table 2. Morphological characteristics and sex ratios of western diamondback rattlesnakes from roundups in Texas and New Mexico. Values are means with standard deviations in parentheses.

Locality	Year	Sex ratio (M:F)	Female		Male		Hunting method	
			N	SVL (cm)	Mass (g)	SVL (cm)		Mass (g)
<b>Alamogordo</b>								
	1993	2.0	197	91.8 (10.11)	594.2 (256.05)	106.6 (19.57)	10,34.3 (649.41)	Dens in April; some road cruising.
	1994	2.5	192	92.6 (8.06)	556.9 (161.69)	101.2 (13.98)	947.1 (422.90)	
	1995	3.0	204	88.7 (11.10)	487.7 (275.45)	106.2 (20.47)	897.7 (528.3)	
	1996	3.5	167	87.0 (7.98)	387.6 (112.09)	108.1 (20.41)	923.8 (622.72)	
	1997	1.7	332	90.2 (11.01)	540.8 (211.17)	103.9 (17.40)	825.8 (481.64)	
<b>Sweetwater</b>								
	1994	1.6	553	92.1	472.7	101.8	653.2	Dens in March; some road cruising.
	1995	2.4	422	98.1	522.6	110.2	843.7	
	1996	2.4	501	101.6	608.8	116.2	952.5	
	1997	3.6	362	101.1	635.0	114.0	902.6	
<b>Big Spring</b>								
	1993	1.7	211	90.8 (8.3)	565.2 (193.38)	98.2 (12.27)	642.6 (246.78)	Dens in March; some road cruising.
<b>Freer</b>								
	1993	3.7	286	99.2 (18.45)	841.8 (482.98)	107.6 (22.89)	1,112.8 (774.44)	Road cruising in late spring.

<sup>a</sup> Standard deviations were not reported for the Sweetwater Tex. samples (Del Monte and Miller 1997).

size because males were relatively large with respect to the Big Spring population and females were smaller than the Freer population.

**Temporal variation in size.** Mass of rattlesnakes at Sweetwater averaged 447.5 g, without an evident trend from 1959 to 1973 (Figure 4). Mean mass of rattlesnakes measured at Big Spring (presumably the same population as at Sweetwater) in 1993 was within the range of variation of the historical data ( $n = 211$ ,  $\bar{x} = 570.9$  g,  $SD = 266.38$  g, Figure 4), as was the sample measured in 1994 at Sweetwater (580 g,  $SD$  not reported). Curiously, snake mass at Sweetwater increased dramatically during 1995-97, averaging 750 g, 850 g, and 840 g/rattlesnake respectively (4-year mean 1994-97 = 755 g,  $SD =$

125.03) The increase in body size occurred in both sexes (Table 2).

Annual variation in body size of western diamondbacks at Alamogordo was somewhat different for males and females. There was significant variation in mass of males by year ( $F_{4,753} = 3.15$ ,  $P < 0.014$ ). Multiple comparison tests distinguished subgroups of means 1993-96 and 1994-1997 ( $P < 0.05$ ). There also was significant variation in mass of females by year ( $F_{4,332} = 6.20$ ,  $P < 0.001$ ). Female mass was least in 1996 and distinct from all other years ( $P < 0.05$ ). Means in 1993, 1994, and 1997 were indistinguishable ( $P > 0.05$ ), as were means from 1994, 1997, and 1995 ( $P > 0.05$ ). However, those subgroups were statistically distinguishable ( $P < 0.05$ ). We failed to reject the null hypotheses that average SVL of males ( $F_{4,755} = 2.00$ ,  $P < 0.095$ ) and females ( $F_{4,333} = 2.36$ ,  $P < 0.054$ ) varied significantly during 1993-97, although the probability values indicated annual variation in SVL may be important.

**Sex ratios.** Rattlesnake collections are typically biased toward males (Klauber 1972), presumably because behavioral differences between sexes result in greater encounter rates for males. Not surprisingly, significantly more males than females were brought to all roundups in all years ( $\chi^2 > 14.1$  in all samples,  $df = 1$ ,  $P < 0.001$  in all samples). Sex ratios differed significantly among the 3 roundups ( $\chi^2 = 15.2$ ,  $df = 2$ ,  $P < 0.001$ ). The sample from Freer was much more male-biased (78% males) than the

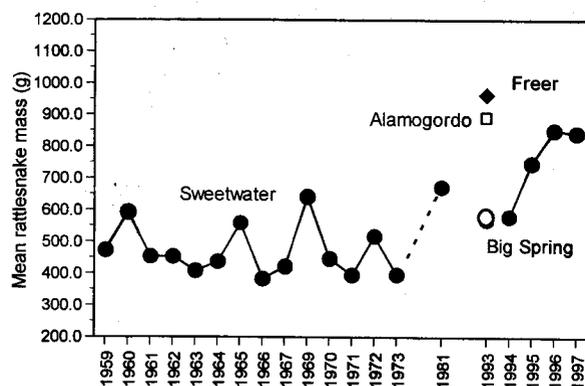


Figure 4. Average mass of rattlesnakes at Sweetwater, Texas, for years when data were available. Also plotted are means from Big Spring, Texas; Freer, Texas; and Alamogordo, New Mexico in 1993.

samples from Big Spring (63%) and Alamogordo (67%). There also were significant differences in sex ratio at Alamogordo from 1993 to 1997 ( $\chi^2=18.0$ ,  $df=4$ ,  $P<0.001$ ), ranging from 62% males in 1997 to 78% males in 1996. Sex ratios differed significantly at Sweetwater from 1994 to 1997 ( $\chi^2=32.3$ ,  $df=3$ ,  $P<0.001$ ) becoming increasingly male biased since 1994 (Table 2).

### Hunting patterns for western diamondbacks

Small numbers of hunters contributed rattlesnakes to the roundups in Alamogordo and Big Spring, and many hunters contributed snakes to the same roundups annually. Hunters worked alone, together, and sometimes switched teams. In our analyses, a team consisted of unique combinations of one or more hunters selling rattlesnakes. During 1991 and 1993–97, 35 individual hunters participated in the Alamogordo roundup, with 10–17 teams participating in a given year (Table 1). These teams sold 74 lots of snakes, or hunter bags, to the Alamogordo roundup. Twenty teams sold snakes to the roundup only once, whereas 6 participated in 2 years, 2 in 3 years, 3 in 4 years, 2 in 5 years, and 2 teams participated in all 6 of our sample years. At Big Spring during 1985–97, 243 individual hunters contributed 367 hunter bags. Number of teams in a given year varied from 11 to 43. One hundred and eighty-five teams participated in only one roundup, whereas 28 brought snakes in 2 different years, 10 in 3, 13 in 4, 2 in 5, 3 in 6, 1 in 7 and 1 in 8 different years. During the years when we knew the number of teams at Sweetwater (1971–91), 41–131 teams brought rattlesnakes to the roundup in a given year (Table 1).

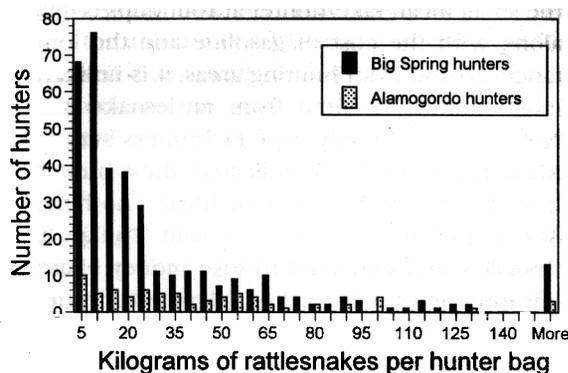


Figure 5. Distribution of kilograms of western diamondback rattlesnakes collected by individual hunters or teams at Alamogordo, New Mexico, 1991 and 1993–97, and Big Spring, Texas, 1985–97.

There was great variability in the take/team, with most selling relatively small numbers of snakes (Figure 5). The median number of kg/team sold at Alamogordo over the 6 years for which we have data was 33.06 kg ( $n=74$  hunter bags,  $\bar{x}=45.37$ ,  $mode=23.93$ ,  $range=0.91-409.59$ ,  $SD=57.22$ ). The distribution of hunter bags was even more skewed toward small amounts at Big Spring. Half of the 367 hunter bags from 1985–97 were 15.2 kg (all years combined 1985–97,  $n=367$  hunter bags,  $\bar{x}=32.57$  kg,  $mode=2.27$  kg;  $range=0.5-390.5$  kg,  $SD=53.81$  kg). It is noteworthy that a very few hunters or hunting teams contributed most snakes. In Alamogordo, the 2 most productive teams in a given year accounted for 37–85% of total take. In Big Spring, where about twice as many teams participated, the 2 most productive teams contributed 25–64% of the total take in a given year (Table 1).

**Hunter effort.** During the 21-year period, 1971–91, for which data on hunting effort at Sweetwater were reported, number of teams increased an average rate of  $0.023 \pm 0.125$  ( $n=20$ ,  $SD=0.267$ ), whereas rate of take/team was slightly negative ( $n=20$ ,  $\bar{x}=-0.014 \pm 0.299$ ,  $SD=0.639$ ). At Big Spring, both rate in number of teams and kilograms/team were negative with broad 95% confidence limits,  $-0.027 \pm 0.336$  and  $-0.050 \pm 0.379$ , respectively (rate for hunters:  $n=12$ ,  $SD=0.593$ ; rate for kg/hunter:  $n=12$ ,  $SD=0.670$ ). The rates in number of hunters and kilograms/hunter at Alamogordo during 1993–97 were  $-0.049 \pm 0.232$ , whereas the rate for kilograms/team was  $-0.012 \pm 0.478$ . (rate for number of hunters:  $n=4$ ,  $SD=0.237$ ; rate for kilograms/team:  $n=4$ ,  $SD=0.488$ ).

Peak years in take of western diamondbacks at all 3 roundups corresponded to similar peaks in hunter effort. At Sweetwater, when hunters brought 8,158 kg of rattlesnakes to the roundup in 1982 and 6,827 kg in 1983, the kilograms/team were 2.5 and 2.1 times above the mean of 30.42 kg/team during 1971–81 ( $n=11$ ,  $SD=13.181$ , Figure 2). Other peak years for hunter effort at Sweetwater were 1985 and 1986, when 77.4 and 66.3 kg/team, respectively, were brought to the Sweetwater roundup, resulting in a similar increase in hunter effort of 2.6 and 2.2 times the average take/team of 30.15 kg ( $n=5$ ,  $SD=12.485$ ) during subsequent years, 1987–91. Peak years in the take at Alamogordo were 870.56 kg in 1993 and 684.13 kg in 1997. These peaks corresponded to increases in the kilograms/team of 1.9 and 1.8 times the average 27.58 kg/team during non-peak years

(1994-96:  $n=3$ ,  $SD=0.725$ ). At Big Spring, there was a single peak in the take of western diamondbacks in 1988 (2,811.4 kg) that corresponded to a 2.5-fold increase in kilograms/team over the average 27.6 kg/team during non-peak and non-low years (1988, 1995, and 1996 were excluded from the time series to estimate a baseline hunter effort;  $n=10$ ;  $\bar{x}=27.61$ ;  $SD=11.88$ ). Two years of low take at Big Spring, 182.3 kg in 1995 and 78.9 kg in 1996, were accompanied by relatively few kilograms/team, 7.9 kg/team in 1995 and 7.2 kg/team in 1996, corresponding to only 0.25 and 0.23 times the average kilograms/team during non-peak and non-low years (Figure 2).

### *Take of other rattlesnake species*

Harvest data are less precise for other exploited rattlesnake species, but trends are apparent. As with western diamondbacks, few hunters had disproportionate impacts on the take of other species. The shocking decline of timber rattlesnakes in New York, New Jersey, Connecticut, and Massachusetts was attributed to a single rattlesnake poacher operating in the area for 30 years (Brown 1993, Brown et al. 1994). Approximately 50,000 eastern diamondbacks from Florida and Georgia were traded by one individual over a 28-year period. Recent harvests of eastern diamondbacks were characterized by most hunters contributing one or 2 snakes.

Yearly take of eastern diamondback rattlesnakes at 3 roundups in Georgia and one in Alabama is approximately 1,000-1,600 (Enge 1993, Berish 1998). Enge (1993) reported 13,006 eastern diamondbacks taken from Florida, Georgia, and Alabama in 1990 and 8,870 in 1991. The large difference in take between the 2 years is indicative of the large fluctuations seen in the take of western diamondback rattlesnakes. The trade in prairie rattlesnakes is associated almost entirely with the Sharon Springs, Kansas, Rattlesnake Roundup and is < 300 snakes/year (Fitch 1998). Sex ratios of harvested eastern diamondback, timber, and prairie rattlesnakes were all male-biased (Berish 1998, Fitch 1998). We observed < 12 blacktail rattlesnakes in the yearly harvest in New Mexico, and we presume the trade in this species is small.

### *The rattlesnake trade in North America*

The rattlesnake trade has characteristics of a typical wildlife exploitation system but is unique because of its links to the social phenomenon of rattlesnake roundups and snake shows. There are many part-time hunters and very few professional

Table 3. Wholesale prices for parts of western diamondback rattlesnakes based on interviews with 2 dealers in 1994 and 1997. Live snakes were bought for \$8.82-\$11.02/kg.

Part of the Snake	Approximate wholesale value
Raw skin	\$8.82-\$11.02/linear foot
Fresh frozen meat	\$13.23-\$26.46/kg, depending on size
Gall bladders	\$1.00 each
Heads	\$0.50-\$1.00 each
Rattles	\$0.50 each
Baby rattlesnakes	\$1.00-\$10.00 each
Fat for snake oil	Unknown
Entrails for manufacture of catfish bait	Unknown

hunters. A few middlemen make a living reselling rattlesnakes to industry-level processors or processing them and selling snake parts wholesale. In 1997, we were aware of 5 commercial rattlesnake dealers in Texas.

The market for rattlesnake skins drives the magnitude of the trade, but additional profit from parts, especially the meat, should not be understated. In 1994, the wholesale value of a 0.5-kg western diamondback (approx. 1 m total length) was \$12.00 for the raw skin versus \$21.00 for the entire animal (Table 3). Prices paid to hunters from 1980 to 1991 at 2 Texas rattlesnake roundups varied from \$5.51/kg to \$18.74/kg ( $\bar{x}=\$8.60$ ,  $SD=\$3.66$ , Adams et al. 1991). Average price paid to hunters at Alamogordo during 1991 and 1993-97 was \$8.82/kg (range = \$6.61-\$11.02). At Alamogordo, half of the hunters grossed < \$319.25 ( $n=74$  hunter bags,  $\bar{x}=\$412.77$ , mode = \$42.50, range = \$7.50-\$3,612,  $SD=\$528.98$ ). Considering the high variance, the skewed distribution of hunter bags, and the small mean take/hunter at roundups (Figure 5), along with the cost of gasoline and the long distances to and from hunting areas, it is unlikely that most hunters profited from rattlesnake hunting. Not surprisingly, only 4 of 11 hunters surveyed at Alamogordo in 1993 indicated they hunted rattlesnakes for profit. One individual who hunted in 3 counties in New Mexico sold 26 kg of rattlesnakes and expected to lose money. Based on our interviews with snake traders, when prices for live rattlesnakes fell below \$8.82/kg, few hunters were motivated to collect. Interestingly, there are strong feedbacks between demand, wholesale value, and hunter price, even though few hunters hunt for profit.

At most roundups, hunters pay a registration fee, which is a form of commercialization of the rattlesnake resource. Roundup organizers and snake buyers deal with each other over prices for live snakes and logistical details concerning rattlesnakes as merchandise. Some of the take of western diamondbacks and eastern diamondbacks at most roundups is sold to the public as food, skins, or curios, but most is destined for the commercial trade. Prairie rattlesnakes from the Sharon Springs roundup are used as food and to make products or released. Skins of blacktail rattlesnakes, pygmy rattlesnakes (*Sistrurus miliarius*), cottonmouths (*Agkistrodon piscivorus*), and copperheads (*Agkistrodon contortrix*) occasionally appear as curios, but are not known in the commercial trade for skins and meat. In some cases, roundups are intermediate in the trade chain—snakes are bought there for resale to a dealer, often with prearranged price contracts (e.g., Sweetwater and Alamogordo). In other cases, 1 or 2 traders buy rattlesnakes from the public at a roundup (e.g., Freer and the roundups for eastern diamondbacks) and their activities are coordinated with roundup organizers.

*Magnitude of the trade.* It is difficult to quantify the rattlesnake trade because it is not monitored officially by any agency. Commercial rattlesnake traders are reluctant to discuss specifics of the trade and apparently know only the magnitude of their own businesses. Adams et al. (1994) pointed out that estimates of the yearly take of western diamondback rattlesnakes in Texas were compromised because dealers did not provide records, the public take was undocumented, and only 4 roundup organizers kept records of the poundage of snakes purchased. The same constraints apply to the rattlesnake trade nationwide.

Rattlesnake take was relatively low until 1982, when the amount of rattlesnakes entering the trade increased dramatically in response to high demand for exotic reptile skins. The same peak in trade occurred in *Tupinambis* and *Varanus* lizards (Fitzgerald 1994b). Prices for rattlesnakes skyrocketed. Hunters and dealers recalled prices as great as \$19.84/kg for live rattlesnakes, and one dealer claimed to have processed more than 454 kg of western diamondbacks weekly from March to August during the 1980s. Take of rattlesnakes in 1986 and 1987 was estimated at between 400,000 and 500,000 by Barker (1988). Although this unsubstantiated figure was published in a newspaper and no explanation was given of how it was cal-

culated, that number has been perpetuated in technical and popular literature on rattlesnake roundups (Williams 1990, Warwick et al. 1991, Pisani and Fitch 1993, Reber and Reber 1994). It is impossible to know exactly how many snakes were traded in the mid-1980s, but the annual take since 1991 is undoubtedly much less.

Western diamondbacks are traded by weight and not by number. To create high, low, and average estimates of total numbers of western diamondbacks traded at some roundups, we converted mass to numbers of rattlesnakes by dividing total kg of rattlesnakes by mean snake mass and the upper and lower 95% confidence intervals of the mean. Number of western diamondback rattlesnakes sold at the roundup in Alamogordo 1991–97 ranged from 381 to  $982 \pm 7-11\%$ . Using the distribution of weights of western diamondbacks measured at Big Spring in 1993 ( $n=211$ ,  $\bar{x}=574.71$  g,  $SD=264.69$ ), we estimated the range in annual number of snakes traded there from 1985 to 1997 as  $137-4,892$  snakes  $\pm 6\%$ . Using data for the years available, we estimated that numbers of snakes at Sweetwater from 1959 to 1997 varied between 1,114 and 15,640 (Kilmon and Shelton 1981, Weir 1992, Del Monte and Miller 1997). Average weights of rattlesnakes at Sweetwater were not available for most years; standard deviations were not reported.

Based on interviews with 6 rattlesnake traders in 1991, Adams et al. (1994) estimated that 15% of western diamondbacks entering the trade originated from roundups. Our interviews in 1993 with 3 of those dealers and in 1997 with 2 dealers corroborated this estimate. Using the mean of 832.72 g/snake ( $n=503$ ,  $SD=628.867$ ) measured at Freer and Big Spring in 1993, divided into the 8,820 kg of western diamondbacks from 16 active Texas roundups in 1991, we estimated that total take in Texas in 1991 was  $70,527 \pm 6\%$ . Our estimate was less than the 112,620 reported by Adams et al. (1991) because they were unable to account for the large size of southern Texas western diamondbacks. Pisani and Fitch (1993) reported takes of 1,500 to 3,000 western diamondbacks at each of Oklahoma's 5 roundups and guessed that the total annual harvest of western diamondbacks in Oklahoma was 10,000. One dealer active in Oklahoma in 1997 estimated the total take at 6,000/year since 1995.

Yearly take of eastern diamondbacks at 3 roundups in Georgia and 1 in Alabama is approximately 1,000–1,600 (N.C.S. News 1993a, Jones

1995), and total take of eastern diamondbacks is probably around 10,000/year. As with western diamondbacks, about 15% of the total take of eastern diamondbacks originates from roundups (Berish 1992, Enge 1993). Trade in prairie rattlesnakes is apparently associated entirely with the Sharon Springs roundup and is <325 snakes/year. Though prairie rattlesnakes are common in New Mexico, <50 appear at the Alamogordo roundup annually and we saw few at roundups in Texas.

Because estimates remain imprecise, it is difficult to conclude that during the 1990s the total yearly trade in all species of rattlesnakes combined could be >125,000/year. Probably >85% of the total take of all species is composed of western diamondbacks from Texas, Oklahoma, and New Mexico and >75% is from Texas.

The market for curios, meat, and gall bladders is important because these products account for a large portion of the value of a rattlesnake (Table 3). Curios, hats, bolo ties, and hatbands are sold in airports and in numerous strip-mall stores and mail-order catalogs. Based on wholesale prices and price lists, the curio market forms a significant part of the trade in rattlesnakes. A rattlesnake-skin cap cost more than \$30.00 in 1997 and a mounted rattlesnake more than \$100.00. Rattlesnake meat is expensive, and United States Department of Agriculture-inspected meat is available at restaurants. Rattlesnake gall bladders are used for oriental medicine nationally and internationally. It is unknown how many snakes are needed to satisfy the demand for rattlesnake parts independent of the skin market, and we were unable to quantify demand for the international market.

### Size restrictions: modeling results

The model produced interesting results relating to the possible economic impact of establishing size restrictions for harvests of western diamondbacks. As the minimum size limit was increased in successive simulations, the average price paid to hunters changed very little up to the minimum allowed SVL of 75 cm. However, when hunters were restricted to taking rattlesnakes >90 cm SVL, the price received for the average snake increased substantially (Figure 6). The model showed that hunters made 19% more on average when harvesting rattlesnakes >90 cm SVL, compared to harvests without size restrictions. This result occurred because of the SVL-mass relationship of western diamondbacks (Figure 6). After western diamondbacks reach 90

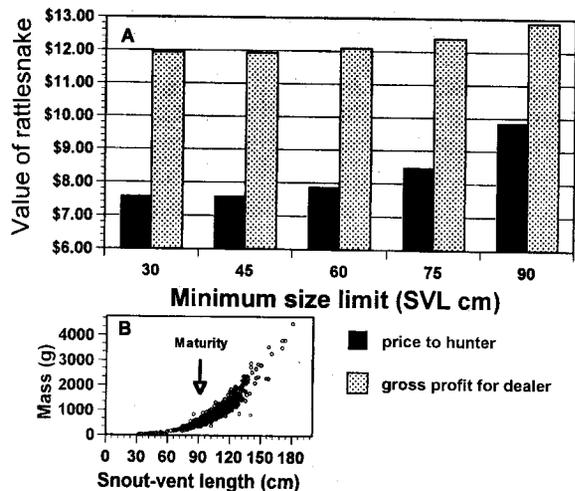


Figure 6. Results of a simulation model showing economic effects of imposing minimum size limits on hypothetical harvests of 2,000 western diamondback rattlesnakes. Bars represent the average price paid to hunters and gross profit for a hypothetical wholesale dealer (A). The relationship between mass and SVL shows that rattlesnakes gain weight rapidly when >90 cm SVL, demonstrating why hunters would make more when their take was restricted to rattlesnakes >90 cm SVL (B).

cm SVL, they gain weight more rapidly than length. Because hunters were paid by the weight of snakes they collected, they earned much more per snake when they collected only large ones.

The gross profit realized by traders did not decrease with changes in the minimum size restrictions (Figure 6). Harvests restricted to >90 cm SVL resulted in a 6% gain in gross profit compared to unrestricted harvests. This result occurred because the increase in wholesale value outpaced the hunter's gain and, importantly, because there was no cost for increasing hunter effort to obtain 2,000 snakes.

Examining the size distribution of harvested western diamondbacks provided an understanding of the potential impacts of size restrictions on their harvest. In a sample of 1,599 harvested western diamondbacks, only 6.6% were <75 cm SVL. In contrast, 41.9% of the sample was <90 cm SVL and 47.8% of all females ( $n=467$ ) were <90 cm SVL. Apparently, limiting the harvest to individuals >90 cm SVL could substantially reduce total take, assuming no response in hunter effort. Additionally, reducing the take of females <90 cm SVL should have positive effects on population growth, as most females are sexually mature at 90 cm SVL (Fitch and Pisani 1993). Raising the minimum size to 115 cm SVL would protect almost all females, as only 3.4% of female *C. atrox* were >115 cm SVL. A size limit

of 115 cm SVL also would greatly reduce total take; only 21.8% of our sample was >115 cm SVL.

Limiting both the maximum and minimum sizes of harvested snakes, as in a slot-size management strategy, is appealing because the largest females produce the largest litters. However, the fact that western diamondbacks are sexually dimorphic and sexing requires individual examination complicates slot-size management strategies. If size distribution of harvested western diamondbacks in our sample were truncated to >90 and <105 cm SVL, for example, 62.1% of the females would fall within this range but only 36.3% of males. Hence, a slot-size strategy would protect more males than females and the total harvest would be reduced by >50%.



Figure 7. Overcrowding in pits is a common example of mistreatment of rattlesnakes. Improper holding and transport were the primary causes of injury to rattlesnakes at roundups. Photo by Lee A. Fitzgerald.

### *Ethical and educational issues*

**Treatment of live rattlesnakes.** The management of exploited rattlesnakes is complicated by issues of hunting methods and treatment of live snakes. How long rattlesnakes are kept alive depends on how long it takes a hunter to contact a trader and whether the hunter holds rattlesnakes to compete in a roundup. During our study, most rattlesnakes were kept alive <3 weeks. Rattlesnakes were not stockpiled for long periods, in contrast to reports that people stockpiled snakes for up to 2 years and that organizers stockpiled large numbers of rattlesnakes and transported them to roundups to maximize the number on display (Barker 1988, Reber and Reber 1994).

Overcrowding of rattlesnakes in pits at roundups was evident (Figure 7). Of approximately 7,500 live rattlesnakes we observed at roundups, 250 (3.3%) were crushed. We observed visible external injuries on 3.7% of western diamondbacks examined ( $n=1,609$ ), and 4.3% were underweight. We found few internal injuries, and most wounds occurred during capture and transport.

Live rattlesnakes destined for the commercial trade were displayed and used for public entertainment in snake shows at roundups. Documented human behavior toward rattlesnakes at public events that we observed included general harassment, inducing rattlesnakes to strike balloons and attendants' boots, and performing various daredevil tricks with rattlesnakes (Reinert 1990, Warwick et al. 1991, Weir 1992, Thomas and Adams 1993). A controversial activity at some roundups is killing snakes by decapitation and butchering them in public, sometimes by beauty-pageant contestants or

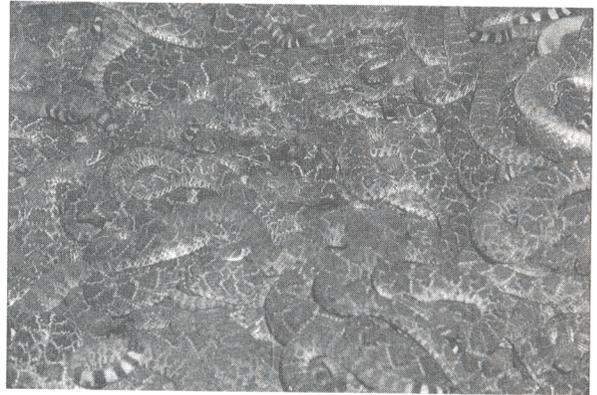
celebrities (Warwick et al. 1991, Fitch 1998, MacGregor 1998). We are not aware of any other instance in North America wildlife is killed as entertainment for spectators.

**Spectator education issues.** We interviewed spectators at Alamogordo in 1993 to learn their reasons for attending the roundup and to evaluate the educational impact of snake shows. Sixty-six of 93 spectators (71%) were attending their first rattlesnake roundup. Forty-three (46%) stated that their reason for going was curiosity, 25 (27%) were on a weekend outing, and 19 (20%) went to learn about snakes. Only 48% of the respondents said the presence of rattlesnakes is why they attended. Sixty-six of 93 (71%) spectators believed the roundup had minimal effects on rattlesnake populations or controlled population size, whereas 12 spectators (13%) considered the roundup a threat to rattlesnake populations.

We asked spectators 11 true-false questions about rattlesnake natural history (Table 4). Of the 93 respondents, 48 did not attend the educational snake show and 45 were interviewed after they attended. The show attendees scored an average of 6.00 correct answers ( $n=45$ ,  $SD=2.39$ ); those who did not attend scored an average of 5.23 correct answers ( $n=48$ ,  $SD=2.28$ ). These differences were not statistically significant according to a 1-tailed  $T$ -test ( $t=-1.5904$ ,  $P<0.06$ ), and the mean difference between the 2 groups was less than one correct answer. Thus, according to their test scores, spectators left the roundup with similar levels of knowledge about rattlesnakes whether or not they attended the education show.

### Overview of state regulations and monitoring of rattlesnake commercialization

**Regulations.** In Texas, rattlesnake hunters must possess a hunting license. A nongame collecting permit is required to sell rattlesnakes and to possess >25 live specimens or >10 specimens of the same species. A dealer's permit is required to buy rattlesnakes for resale. Venomous snakes are excluded from nongame regulations in Georgia. A hunting license is not required for residents of New Mexico or Alabama (Levell 1995). In Florida, rattlesnake parts may be possessed and sold without a permit. A venomous reptile permit is required to possess live rattlesnakes, and a separate permit is required to sell them. Organized venomous reptile hunts must be registered with the Florida Fish and Wildlife Conservation Commission, but there currently are none (D. Cook, Florida Fish and Wildlife Conservation Commission, personal communication). Rattlesnake hunting is regulated in Kansas (Levell 1995), where only the prairie rattlesnake may be commercially harvested and individuals may sell them only during licensed events. A Commercial Prairie Rattlesnake Harvest permit is required to hold a rattlesnake harvest event (e.g., roundup). A harvest event may last a maximum of 30 days and must be held from 1 April to 15 June. A permit also is required for individual hunters and is valid only during organized events. In 1995, bag limits and possession limits were 10/day and 20 in possession (Levell 1995). Rattlesnakes not used and those under 45.72 cm must be released after the roundup. A Commercial Rattlesnake Dealer permit also is required. In Oklahoma, a hunting license is



Close-up of rattlesnakes in roundup pit.

required, and western diamondbacks, prairie and timber rattlesnakes, and western massasaugas (*Sistrurus catenatus*) may be collected in unlimited numbers from 1 March through 30 June. Rattlesnakes harvested in Oklahoma may be sold only during open season to licensed commercial or noncommercial breeders. Collecting rattlesnakes via gasoline is illegal in Oklahoma (Levell 1995). In Pennsylvania, it is against the law to commercialize timber rattlesnakes, and individuals need a special license to hunt or possess snakes (Reinert 1990, Brown 1993). The 1999 possession limit for timber rattlesnakes was one. Hunters are urged to release snakes where they were collected.

**Monitoring.** The trend among wildlife agencies is to work with roundup organizers and volunteer herpetologists to collect information from harvested rattlesnakes, a convenient arrangement because of the special skills needed to work with live pit-vipers. In Pennsylvania, the organizing club is

Table 4. Results of a true-false survey about rattlesnake natural history given to 93 spectators at the 1993 Alamogordo roundup. The questions were used with permission from Adams et al. (1991) to allow comparisons between studies.

True-false statement	Attending show (n=45)		Not attending show (n=48)	
	Correct	Incorrect	Correct	Incorrect
Rattlesnakes lay eggs (F)	9	36	8	40
Rattlesnakes swallow their young (F)	28	17	25	23
Rattlesnakes are venomous with fangs removed (T)	18	27	18	30
Baby rattlesnake bite is more dangerous than adult (F)	15	30	12	36
Fewer people die from snake bites than from hunting (T)	32	13	37	11
Rattlesnakes see prey when they strike (F)	28	17	30	18
Rattlesnakes inject venom with every bite (F)	32	13	27	21
Livestock losses due to snake bite is a major problem (F)	33	12	37	11
Rattlesnake age is determined by number of rattles (F)	21	24	17	31
Rattlesnakes cannot close their eyes when asleep (T)	18	27	16	32
Rattlesnakes can strike greater than their body length (F)	34	11	29	19

responsible for registering hunters, collecting license fees, and providing monitoring data to the Pennsylvania Fish Commission. An encouraging collaboration began in 1994 in Texas, where the Sweetwater Jaycees measure a sample of rattlesnakes at the Sweetwater roundup according to protocols set by the Texas Parks and Wildlife Department (Del Monte and Miller 1997). The take and condition of prairie rattlesnakes at the roundup in Sharon Springs, Kansas, has been monitored by volunteer herpetologists since 1992 (H. Fitch, University of Kansas, personal communication). Florida Fish and Wildlife Conservation Commission personnel have developed working relationships with commercial dealers and have estimated volume of trade and obtained natural history information from snake carcasses (Berish 1998, Eng 1993).

## Discussion

### *The sustainability of rattlesnake exploitation*

Our results show that populations of western and eastern diamondbacks have withstood considerable hunting pressure during several decades. Regions in Texas and Oklahoma continue to produce western diamondbacks in accordance with market demand. Despite years of great take of rattlesnakes and increasing variability in the take, there was not a clear positive or negative trend in the kilograms of snakes or kilograms of snakes/team brought to the roundups we analyzed. The slow convergence of confidence limits to a broad level ( $\pm 21\%$ ) around the long-run mean take at Sweetwater indicates that very long-term data sets are necessary to evaluate trends and great variability is inherent in the rattlesnake exploitation system. Great levels of variability pose problems for population monitoring because it is difficult to distinguish trends, much less determine whether they result from management or natural fluctuations (Fitzgerald 1994a). Short-term trends in the take of western diamondbacks varied among roundups, increasing in New Mexico and decreasing in Texas. We interpreted the differences as indicating waxing and waning interest in particular roundups rather than decreased availability of rattlesnakes. There was no discernible effect on harvest in years subsequent to peak years. Though encouraging, this pattern does not mean the take of western diamondbacks is automatically sustainable. Periods of great demand have been short-term (e.g., peaks in 1981, 1985) and it is unknown how populations might

respond to extended periods of greater hunting pressure. We did not incorporate important factors, such as whether hunters expanded their geographic hunting areas, or allow for the fact that possibly 85% of all rattlesnakes are traded outside of roundups. If hunters were expanding their ranges, rate of take could remain the same even though populations were declining due to hunting.

Despite the observation that most hunters did not profit from rattlesnake hunting, hunter effort was clearly tied to market demand. At Sweetwater, where the take was largest, more hunters participated during peak harvest years. The pattern that peak years in the take resulted in increases 1.8–2.5 times the take in nonpeak years at all 3 roundups leads us to speculate that 50–80 kg/team is an upper threshold productivity that most hunters of western diamondbacks generally do not exceed, even when demand is great. Apparently, few hunters possess the skills to harvest rattlesnakes at great rates. Skilled hunters should therefore have disproportionate effects on rattlesnake populations.

The result that only a few hunters contributed the most rattlesnakes carries great implications for conservation and management. The top 2 hunters contributed 25–85% of all western diamondbacks at roundups. The low and variable number of hunting teams implies that demand for western diamondback rattlesnakes at roundups, which we presume reflected overall demand, was met by a surprisingly small number of hunters. Similar patterns of hunting were evident for eastern diamondback and timber rattlesnakes. Hence, we can make the general prediction that the effects of hunting on local rattlesnake populations, if they exist, would result from the actions of relatively few hunters, especially where den hunting is common. Because few hunters contributed most rattlesnakes, management practices aimed at restricting the take, size, or general possession of rattlesnakes would have large impacts on the overall take. Monitoring hunter effort, quantifying spatial patterns of hunting, and educating hunters are tasks made easier with a small hunter population.

Regardless of claims by proponents of rattlesnake exploitation that the same areas and dens continue to produce western diamondbacks over long periods, no data are available on the local impacts of hunting for any species except northern populations of timber rattlesnakes. The pattern in which one-third of hunters expanded their areas in New Mexico

and Texas, along with the observed use of counties by hunters at Sweetwater, indicates there may be great turnover in hunting areas. Did hunters shift their collecting areas in response to local depletions of rattlesnakes? Is the entire area where rattlesnakes are hunted expanding? These are important questions to assess local and regional impacts of rattlesnake hunting. Investigations of spatial patterns of hunting would be useful, as would field research comparing populations of rattlesnakes at control and removal dens.

Our model to investigate size restrictions did not address the effects of hunter effort on demography of western diamondback rattlesnakes. It is important to consider that though size restrictions could save significant numbers of small rattlesnakes from harvest, periods of great demand might result in increased pressure on the adult segment of populations. The tradeoffs between increasing subadult survival and decreasing adult survivorship (through increased hunter effort) are complex and have not been investigated adequately in large reptiles and never for snakes. Population models for sea turtles and exploited lizards showed that population growth in species with life histories like that of the western diamondback should be sensitive to recruitment of subadults into the adult class, but only as long as adults survive at relatively great rates (Crouse et al. 1987, Congdon and Dunham 1994, Fitzgerald et al. 1994). Effects of size limits and other strategies aimed at harvesting specific population segments of exploited rattlesnake populations are undoubtedly complex and research in this area should be a priority.

### *Effects of hunting on rattlesnake demography*

Variation in size among the western diamondback populations examined was probably the result of interactions among environmental and genetic factors. Western diamondbacks may grow larger in southern Texas because of a longer activity season. The result that western diamondbacks from Alamogordo were distinguished from Freer and Sweetwater samples largely because of sexual dimorphism in size hints that peculiarities of mating systems and sexual selection may play a role in morphological differentiation among populations. The activity season is not as long in New Mexico as in southern Texas, yet males from New Mexico were not significantly smaller than at Freer. Females at Alamogordo were similar in size to their

northern Texas counterparts. While proximate and ultimate reasons for geographic variation in body size can be clarified only through intensive population studies, it seems likely that regional differences were probably due more to natural geographic variation than to effects of hunting.

It is difficult to explain the large and rapid increase in body size of both male and female western diamondbacks at Sweetwater since 1995 (30% increase in mass since 1995, Figure 4). It is possible that hunting occurred in locations with relatively large snakes, perhaps in new areas. This hypothesis could be tested by monitoring the size of rattlesnakes in hunters' bags (kg/snake/hunter) and correlating these data with locations where snakes originated, frequency of hunting in the area, and hunting methods. We predict that previously unharvested areas should produce a catch of more males and larger snakes. Hunting primarily by cruising roads instead of seeking dens could produce a similar pattern; hence it would be important to account for hunting methods used. Regardless of the real causes of change in body size of rattlesnakes at Sweetwater, the hypotheses outlined here serve to point out that research on ecological interactions between rattlesnakes and hunters is needed to determine the extent to which demography of rattlesnakes is influenced by hunting.

Though differences in sex ratios through time of harvested western diamondbacks are not conveniently explained by the effects of hunting, it is plausible there was an interaction between hunting method and activity patterns of the rattlesnakes that influenced the proportions of males taken in different geographic areas. For example, it was found that gravid female timber rattlesnakes were vulnerable while congregating around denning sites in late summer (Brown 1993). Female eastern diamondbacks also appear most vulnerable during cool months, when they predictably can be found at burrows (Berish 1992, Enge 1993). Sex ratio of harvested western diamondbacks might be influenced by hunting period and collecting method used. Sex ratios should be closer to parity while rattlesnakes are still at winter dens. At Big Spring and Sweetwater, where rattlesnakes were collected at dens in early spring (March), sex ratios were still male-biased, but less than at Freer and Alamogordo, where roundups were held in April (Table 2). This result was consistent with the prediction of greater encounter rates for males hunted later and away from dens. However, sex ratios were variable through

time, and the greater portions of males at Sweetwater in 1997 and low proportion of males in the Alamogordo sample in 1997 did not fit the pattern.

### *Life history considerations*

Each rattlesnake species has a unique life history (Klauber 1972), and it should not be surprising that different species, and even populations of single species, would respond differently to hunting pressure. A ramification for conservation of life history variation is that specific conservation measures may be indicated for rattlesnake populations that are concordant with their capacities for renewal. Greene (1997) summarized the consequences of life history for conservation of timber rattlesnakes: "Their shockingly rapid decline stems from a collision between snake behavior, human customs, and the fundamental components of population biology." In New York, 39% of timber rattlesnakes take 10 years to reach sexual maturity and 57% of mature females reproduce every third year. The reproductive life span of northern timber rattlesnakes is constrained to the point that most females in New York populations may reproduce only 2 or 3 times in their lives (Brown 1993). Though southern populations of timber rattlesnake do not exhibit a life history as extreme as timber rattlesnakes in the north, they also are predicted to be susceptible to overexploitation (Gibbons 1972).

Life history characteristics of other species of rattlesnakes increase the likelihood that their populations can withstand hunting pressure and help explain how populations of western diamondbacks may have withstood long periods of harvest driven by market demand. Western diamondback and prairie rattlesnakes reach sexual maturity in 2–4 years, and although we expect reproductive frequency to vary by population and by year, most mature females produce litters at least every other year (Tinkle 1962, Fitch 1998). Litter sizes average 9 for western diamondbacks, whereas large females can produce more than twice that number (Degenhardt et al 1996). There are fewer data for eastern diamondback rattlesnakes. This large species (up to 2.4 m total length, Klauber 1972) takes longer to reach sexual maturity (3–4 yr, Berish 1992) and produces litters with 7–29 neonates (Palmer and Braswell 1995). Eastern diamondbacks and southern populations of timber rattlesnakes do not congregate in dens, a characteristic that may make it more difficult for hunters to encounter them predictably. This prediction is supported by

the observation that most eastern diamondback and timber rattlesnakes entering the trade in Florida were killed as nuisance animals, road-killed, or found casually (Berish 1992). Clearly, the wide range of life history variation in rattlesnakes will require management programs to incorporate data from both the species and population levels.

Although not a life history characteristic per se, the geographic distributions of western diamondback, prairie, timber, and eastern diamondback rattlesnakes are vastly greater than the distribution of hunting (Ernst 1992). The existence of rattlesnakes in many areas where they are not hunted reduces the probability of regional overexploitation. Rattlesnake exploitation systems may therefore provide good models to study source-sink phenomena in exploited populations.

### *Recommendations*

Recommendations to manage hunted rattlesnakes are obvious and have been made repeatedly in peer-reviewed literature, non-reviewed literature, and reports (Speake and Mount 1973, Campbell et al 1989, Weir 1992). Trade in rattlesnakes is international, but it is currently impossible to obtain data on its extent. Management programs for exploited rattlesnakes should include licensing of commercial traders, organizers of harvest events, and hunters so that the true magnitude of trade can be measured. It is critical that we gather data on the portion of the commercial rattlesnake trade that originates outside the roundups. Recent regulations in Kansas, Oklahoma, and Texas are examples of positive steps in this direction (Levell 1995). Monitoring of harvested populations is clearly needed, with accompanying research programs on snakes, hunters, and ecological interactions between them.

Other priorities include incorporating rules for proper hunting practices and treatment of live rattlesnakes at all levels of the trade and putting an end to making a spectacle of live rattlesnakes in public. The bottom line is that making fun of wildlife and mistreating live animals do not fit into a wildlife conservation model any more than does unregulated commercialization. Most injury to rattlesnakes occurs during their collection and transport by hunters. Hunter education would drastically reduce problems of mistreatment. There are positive signs that public education at some roundups may be changing. Organizers and snake handlers at all rattlesnake roundups we visited

were enthusiastic about changing their shows and incorporating accurate information.

It is obvious that rattlesnakes have great economic and cultural value, but the importance of ensuring that they remain available from the wild seems lost on roundup organizers, traders, and most state fish and game commissions. The cornerstones of North American wildlife conservation—tightly controlling the commercial uses of wildlife (Geist 1988) and appreciating wildlife through its use—have so far not been applied to rattlesnakes. The fact that western diamondback, prairie, and eastern diamondback rattlesnakes have thus far avoided the same fate as northern populations of timber rattlesnakes is due solely to the lucky combination of their life histories, geographical ranges, and fickle fashion trends. We suggest that agencies charged with the custody of public wild resources take a positive role in influencing the fate of rattlesnakes in North America instead of leaving the prospects for their sustainable use to chance.

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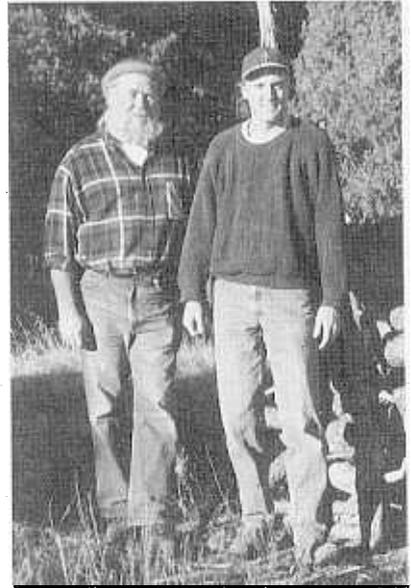
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