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Evolution of ungulate capture techniques in California

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When a great need, the right people, and the right tools come together, history is sometimes made. From the late 1970s through the late 1980s that happened in California. At that time there was a need to capture elk, then deer and pronghorn, then bighorn sheep—the "big game species"—in previously unprecedented numbers. The need focused primarily on translocation to re-establish populations in areas of historic range and to consolidate gains in lands available for wildlife conservation. These efforts also advanced wild ungulate research and management. The tools were helicopters, dart guns and new drugs, various ways to physically capture wildlife including net guns, and other advances in capture technology. The right people were a small group of California Department Fish and Game employees, contract pilots, graduate students, and a host of other agency personnel, friends and volunteers. The history they made lives on in the mountains, savannahs, deserts, and grasslands of California as a wildlife legacy of more elk, deer, pronghorn and bighorn that, with

continued conservation, will pass from generation to generation of future Californians.

Key words: *Antilocapra americana*, bighorn sheep, capture methods, *Cervus elaphus*, chemical immobilization, drive-net, drugs, elk, helicopter, history, mule deer, net gun, *Odocoileus hemionus*, *Ovis canadensis*, pronghorn, trapping, ungulate

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Market hunting of California's wildlife from the mid-19th through the early-20th centuries in part explains why big game species, with the exception of mule deer (*Odocoileus hemionus*), were present in only small numbers in California as recently as the mid-1970s. Add habitat loss and the pervasive impacts of disease to unregulated take (market hunting or poaching), and populations of most ungulates (a term for species that walk on their hooved toes) had declined substantially from their historical levels. Prior to 1849, when gold was discovered in central California, development was limited primarily to small agricultural endeavors, the Spanish mission system, and a few coastal, towns. Although elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), pronghorn (*Antilocapra americana*), and mule deer were used as sources of meat at that time, their numbers and the extent of their ranges were little diminished. During the 30–40 years following the discovery of gold at Sutter's Mill, however, hundreds of thousands of Americans flooded into the Golden State in search of fortune, and all those mouths needed to be fed. With only small herds of cattle on the range, game was the major source of red meat for many years, and the once abundant wild ungulates of California were slaughtered indiscriminately.

Historical Distribution and Early Declines of Ungulates

At the time of the gold rush, tule elk (*C. elaphus nannodes*), which were endemic to California, roamed in large numbers in riparian areas of the San Joaquin and Sacramento valleys and the oak-grassland savannas of the western foothills of the Sierra Nevada (McCullough 1969). Roosevelt elk (*C. e. roosevelti*) were present in the Siskiyou Mountains and in the northern coastal areas of the state (Harper et al. 1967). Rocky Mountain elk (*C. e. nelsoni*) occupied northeastern California (Doney et al. 1916, McAllister 1919). Various subspecies of mule deer (including the black-tailed deer, *O. h. columbianus*) occupied the Cascade Range, the coast ranges and peninsular ranges, the western foothills of the Sierra Nevada, and the high deserts east of the Sierra Nevada crest (Wallmo 1981; but, see Longhurst et al. 1976). Large herds of pronghorn roamed the alkali grasslands of the interior valleys of California, the Great Basin Desert of the eastern and northeastern parts of California, and the Mojave and Sonoran deserts (Nelson 1925). Bighorn sheep were abundant at higher elevations in the Siskiyou and Cascade mountains, including Mount Shasta (Doney et al. 1916). Bighorn sheep were also present in extreme northeastern California near the borders with Oregon and Nevada (Buechner 1960), the Sierra Nevada (Jones 1950), in the transverse and peninsular ranges of southern California (Weaver 1968, Weaver and Mensch 1970, Weaver et al. 1972, Freel 1984), and in essentially all of the island-like mountain ranges of the Mojave, Sonoran, and Great Basin deserts (Cowan 1940, Wehausen et al. 1987, Berger 1990, Wehausen 1999).

By the late 1880s tule elk were nearly extinct, despite the fact the California Legislature had passed a law in 1852 that provided for a closed season of six months in 12 counties, and that was extended to the entire state in 1854 (California Department of Fish and Game 1928, as cited by McCullough 1969). In 1872 protection was extended to 8 months of the year, and in 1878 the Legislature established a moratorium on the take of any female elk for four additional years. Rancher Henry Miller, who owned the vast Miller-Lux ranches of the southern San Joaquin Valley, was a strong advocate for protecting tule elk and cooperated with elk preservation programs (Pavey 2014). In 1932, one ranch near the town of McKittrick, Kern County, became the Tupman State Tule Elk Reserve (Burtch 1934). Eventually, tule elk that inhabited the Miller-Lux ranches were the source of the successful introduction to the Owens Valley (Dow 1934, Moffitt 1934), and those last few animals became the progenitors of all tule elk inhabiting California today (McCullough 1969, McCullough et al. 1996).

Similarly, pronghorn were slaughtered and completely exterminated from the interior of California and all of southern California. By the early 1940s, remnant herds remained only in Modoc and Lassen counties in the far northeastern part of the state (McLean 1944, CDFG 2004). The same 1872 law that protected elk also prohibited the take of pronghorn for eight months each year, and the subsequent 1878 legislation established a four-year moratorium on the take of pronghorn (Bleich 2006).

Mule deer and black-tailed deer are more dispersed, more secretive, and sometimes solitary or occur in small groups. This made them more difficult to slaughter in large numbers and they better survived the first 50 years of post-gold rush development in California than did elk or pronghorn. The same laws that protected pronghorn and elk for eight months of the year also extended to female deer. When compared to earlier periods, mule deer actually increased in numbers during the 1920s–1950s (Longhurst et al. 1976), when their predators (wolf [*Canis lupus*] and grizzly bear [*Ursus arctos*]) had been exterminated, or severely suppressed by bounty hunting (mountain lion [*Puma concolor*]).

Bighorn sheep were an important source of camp meat for desert prospectors in the 1800s and provided trophies for big game hunters in California, including Theodore Roosevelt. Even more importantly, herds of domestic sheep that were grazed in the Sierra Nevada, the Cascade and Siskiyou mountains, and in parts of the Mojave and Sonoran deserts, brought diseases that were devastating to bighorn sheep. To this day these diseases limit the potential for bighorn population recovery (Wild Sheep Working Group 2012, Brewer et al. 2014). In response to the near extinction of bighorn sheep, legislative actions in 1872 and 1878 that protected elk, pronghorn, and female mule deer also extended protection to bighorn sheep. In 1883, a moratorium on the harvest of bighorn sheep was extended indefinitely, and in 1933 that species became California's first fully protected mammal (Bleich 2005a, 2005b). Bighorn sheep inhabiting the peninsular ranges (*O. c. nelsoni*) subsequently were listed as threatened by the California Fish and Game Commission (FGC), and as an endangered distinct population segment by the U.S. Fish and Wildlife Service (Torres and Bleich 1999). Similarly, bighorn sheep occupying the Sierra Nevada (*O. c. sierrae*) initially were listed as threatened (eventually upgraded to endangered) by the FGC (Bleich and Torres 1999), and as an endangered taxon by the U.S. Fish and Wildlife Service in 2000 (Bleich 2006). Federal recovery plans were completed for bighorn sheep inhabiting the peninsular ranges and the Sierra Nevada in 2000 and 2007, respectively.

Initial Restoration Efforts

Several early efforts were made to move tule elk to other locations in the first half of the 20th Century. In 1904 a small number of elk was moved to Sequoia National Park (Merriam 1921; Figure 1), and in 1921 others were released in Yosemite National Park (McCullough et al. 1996). Both locations were beautiful, but not ecologically suitable, and those elk failed to thrive. Several additional translocations occurred from 1904 to about 1933 (McCullough et al. 1996) but, so far as is known, only those translocated in 1922 to Cache Creek in Yolo and Colusa counties have contributed to the current population (McCullough et al. 1996). A small group of tule elk was moved to the Owens Valley after the "water wars" deprived the Owens Valley of most of its irrigation water and drove farmers out of the bottom lands by allocating most of the flow in the Owens River to the city of Los Angeles. Previously tule elk had not occurred east of the Sierra Nevada (McCullough 1969).

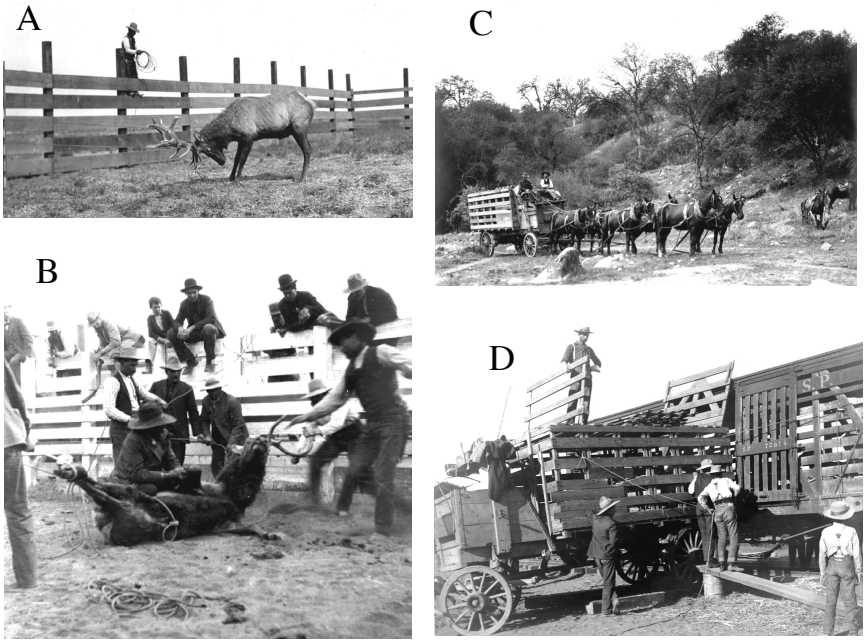

Figure 1.—An early effort to conserve large mammals involved the capture and translocation to Sequoia National Park on the western slope of the Sierra Nevada, California. In 1904, tule elk were driven into a winged corral trap on the Miller and Lux ranch near Buttonwillow, Kern County, California by approximately 35 horsemen (Merriam 1921, Pavey 2014). This effort involved several complex steps, all of which remain in place today, although the methodology has evolved substantially. (A) Bull elk were physically restrained inside the corral with ropes. (B) Antlers were then removed with a saw, a standard practice that is still used. (C) Elk were transported from Buttonwillow to a railroad siding in horse-drawn wagons. (D) The animals were then loaded into railcars and moved to the park. Photographs are by John Rowley and C. Hart Merriam, courtesy of the Museum of Vertebrate Zoology at the University of California, Berkeley, and the California Academy of Sciences.

This translocation was successful, and several hundred elk occupied the Owens Valley by the 1970s (Blankenship et al. 1986, CDFW 2014a). The population was kept in check by hunting, poaching, and accidents for many years.

Remnant herds of pronghorn in the far northeastern counties had recovered sufficiently by 1942 to allow limited drawing hunts, in large part to keep numbers from increasing to the point that their grazing created problems with ranchers. These hunts were held sporadically until 1964, and annually thereafter (CDFG 2004). Beginning in 1986, Roosevelt elk were hunted in very small numbers in northwestern California (CDFW 2014b). Limited opportunity hunts for Rocky Mountain elk were held from 1969 to 1972, closed from 1973 to 1986, and then resumed in 1987 (CDFW 2014b). Since hunts for both subspecies were all in northern California, their management was carried out largely by personnel in Region 1, the northern California administrative region of the California Department of Fish and Game (CDFG).

By the mid 1970s, only mule deer were an important "big game" animal in most of California, and the Wildlife Management Division (WMD; currently the Wildlife Branch) of CDFG offered few other big game hunting opportunities. Despite a period of intense research on big game species from the 1940s to the early 1960s, during the 1970s CDFG devoted little additional research or management effort to them. That situation changed with legislation in 1976 that mandated individual management plans for each deer herd in California; the law also established a deer plan coordinator in WMD. Following the field investigations described by Weaver (1972), another staff position in WMD was split among bighorn sheep, black bear, and mountain lion. Management authority for bighorn sheep had been with the Legislature since the late 19th Century and bighorn sheep remained a low priority for biologists in Region 5, the southern California administrative region of CDFG, where small herds remained in many of the desert mountain ranges.

In the late 1970s tule elk occurred in only two free-ranging populations (Owens Valley and Cache Creek), and two captive populations (Tupman and the San Luis Wildlife Refuge—a population started from Tupman and zoo animals in 1974). Poaching and predation seemed to keep the Cache Creek herd from growing too quickly, and there was a lot of land into which they could expand. The Owens Valley was never historic elk habitat, but early pioneers had painstakingly developed much of that area into farm and orchard land through irrigation. As the numbers of introduced tule elk increased to >400 animals (Figure 2) in six distinct herds from north of Bishop to south of Lone Pine in Inyo County, conflicts with the remaining agricultural operators and elk-vehicle collisions on U.S. Highway 395 resulted in pressure to cull animals or to allow hunting. The Friends of the Tule Elk, allied with other preservationist groups, favored translocation over culling or hunting as a management tool. They argued that approximately 500,000 tule elk once occupied the Sacramento and San Joaquin valleys, adjacent oak grasslands, and coast ranges, and that there were a number of potential locations where additional tule elk herds could be established.

For several years the opposing politics—groups wanting to increase hunting to limit the numbers of elk in the Owens Valley, and anti-hunting groups who opposed that—played out in local meetings, as well as in the California Legislature and the Governor's office. Efforts by CDFG to accommodate both sides ultimately opened the door for the large-scale capture and translocation efforts that would facilitate restocking of tule elk and other species of large mammals in suitable habitat throughout California (Clark 1978).

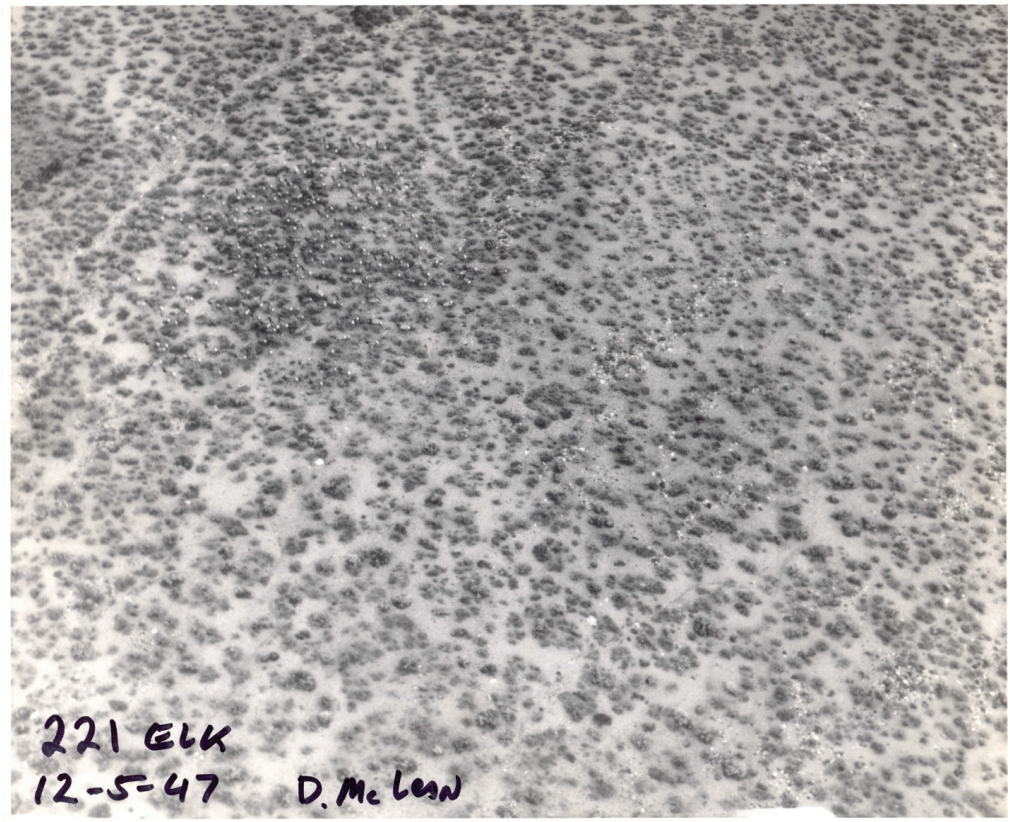

Figure 2.—During the 1940s, tule elk increased substantially in the Owens Valley, Inyo County, California. Using data from annual aerial counts, the population was managed by carefully controlled recreational hunting (photo by Donald McLean, 5 December 1947).

Compromise legislation mandated that hunting of tule elk in California could resume, but only when there were more than 2,000 animals statewide, or it was determined that no further habitat, either on public or private land (Clark 1978, Bleich and Koch 1992), was available to support them. That legislation also mandated a maximum of 490 elk in the Owens Valley (Blankenship et al. 1986). Elk had to be captured and moved in fairly large numbers to comply with these laws; it was clear that ground darting and the use of the currently available types of drugs would not be an option, and also that CDFG personnel would play a central role in the capture, relocation and restoration of California's tule elk herds.

Technological Advances

Early attempts to capture mule deer and bighorn sheep were inefficient, and generally resulted in the capture of individuals rather than groups of animals. Among these methods were leg-hold traps (Frakes 1910, Hornaday 1922), foot snares (Ashcraft 1957, DeForge 1980), and a drop-gate corral trap (Turner 1971). The successful restoration of large mammal herds in California would require efficient, large-scale capture efforts and necessitate large investments of personnel and funds (Clark 1978, Bleich 1990), and would be possible through close interagency cooperation (Keay et al. 1987, Bleich et al. 1991). Efforts to capture and translocate large mammals to historical ranges were highly successful, though, because of several technological advances, including improvements to rotary-winged aircraft, net guns, drug delivery systems, and pharmacological agents.

Helicopters.—The first commercial helicopter license was granted for the Bell model 47B in 1946, and the performance of the Bell H-13 (the military version of the Bell 47D) in the Korean war as a medical evacuation vehicle greatly advanced the technology. Limited use was made of the various Bell model 47 "whirlybirds" for herding game animals in Africa and the USA in the 1960s.

The initial use of helicopters for wildlife-related activities in California occurred in the 1950s (Dick 1979), but routine use of those aircraft by CDFG did not really begin until the late 1960s (Bleich 1983). The gasoline-fueled piston engines of the Bell 47B and similar Hiller models (12E and 12E-4) limited the ability to hover for long periods, work at higher elevations and in hot weather, or to maneuver quickly at the low levels above ground necessary for precise herding or approaches. The Vietnam War era U.S. Army light observation helicopter (LOH) competition from 1962 to 1965 resulted in the design of two totally new turbine-powered aircraft that became the Hughes 500 and the Bell Jet Ranger series. Hughes won the competition, but Bell put its design into commercial production, thereby beating Hughes into the marketplace by several years. The performance characteristics of the turbine-powered LOHs available at the onset of aerial wildlife captures in North America have been detailed elsewhere (Jessup 1982).

The increased power, maneuverability, and stability of turbine-powered helicopters greatly enhanced the use of chemical immobilization to capture the larger ungulates (moose [*Alces alces*], caribou [*Rangifer tarandus*], elk, bighorn sheep) in North America, but darting agile deer in dense brush or forests or swift pronghorn was problematic. But helicopters proved very effective at herding pronghorn into wing traps (O'Gara et al. 2004) and later for herding deer into standing drive nets (Thomas and Novak 1991). As capture operations grew more complex and sophisticated, animals caught in remote locations were flown to central processing sites for examination, treatment, marking, loading, and transport. Later, in some CDFG capture operations, multiple helicopters were used, with one serving as the capture ship and another as a "hook ship" to transport captured animals to a central processing area. In some instances, the second helicopter was also used to transport animals to remote holding areas prior to release. In one operation during 1983, a capture ship, a "hook ship", and two U.S. Navy UH-1 aircraft—into which multiple specially constructed animal transport boxes could be placed—worked simultaneously to capture, transport, and release bighorn sheep in the Eagle Crags, an area on the China Lake Naval Weapons Center, San Bernardino County, from which they had been extirpated. Helicopters also aided in delivering medical treatment. During 1987–1988, desert bighorn sheep were remotely vaccinated by shooting

them in the rump with a small, dissolvable "biobullet" containing a vaccine, just as bighorn had been previously treated for scabies with biobullets containing a parasiticide in New Mexico (Jessup et al. 1991a, Jessup 1993; Figure 3).

Figure 3.—A Hughes 500 flown by Mel Cain was used in 1987 and 1988 to remotely inject bighorn sheep with a vaccine against parainfluenza-III virus. Small bioabsorbable bullets, manufactured by BallistiVet delivered the vaccine "on-the-run" in the Santa Rosa Mountains and Anza Borrego Desert State Park, California (photo courtesy of Dave Jessup).

At about the same time that commercial LOHs became common in the 1970s, the need to capture large wild animals in greater numbers increased, and the drugs and other methods required to do so were being developed (Clark 1982a). In California, these advances were spurred by increases in conservation and wildlife management needs and expectations, along with commensurate funding. All that was then needed was to combine improved methods of delivery and capture drugs, the right group of people to employ them, and a helicopter and a pilot with "the right stuff."

Chemical capture and handling techniques.—It is difficult and dangerous (some might argue crazy) to handle large, wild animals without some form of anesthesia. Efforts by CDFG personnel to capture elk in the early 1970s with the paralytic drug succinylcholine chloride resulted in several well publicized mortalities and undermined public confidence and political support for CDFG. Then Director G. Ray Arnett decreed that darting equipment and drugs belonging to CDFG would be centralized in the Wildlife Investigations Laboratory (WIL), a unit of WMD in Sacramento, to be used under supervision and training provided by WIL. Although cheap, readily available, and effective and quick when dosed correctly, succinylcholine left animals paralyzed but completely aware of their surroundings and

sensitive to pain and stress. It also had a very low safety margin (10% too little was ineffective, 10% too much and the animal could suffocate from paralysis of respiratory muscles). Additionally, it was chemically unstable—breaking down with time so that dosage effects were inconsistent—and came to be regarded as inappropriate and inhumane.

From the 1950s to the 1970s, anesthesia of humans and animals was based largely on injectable (primarily intravenous) barbiturates or inhaled volatile gas anesthetics, both usually supplemented with tranquilizers. The use of narcotic drugs was generally limited to pain relief and sedation because they had serious side effects, like respiratory depression, and were generally long-acting and not reversible. These drugs, and their various combinations, had very limited application to free-ranging wild animals. For example, to achieve optimum effect, barbiturates have to be administered intravenously (not very feasible with a wild struggling animal), gases need to be precisely delivered via a controlled airway, and tranquilizers alone are not powerful enough to immobilize free-ranging elk, mule deer, pronghorn, or bighorn sheep.

The goal was also to transport free-ranging ungulates to a new location involving >12 hours of travel, so drugs could help reduce the stress and fear of confinement and risk of injury. By the 1970s, the utility of drugs to aid in the capture of truly wild animals was in its infancy and their efficacy was mostly an illusion fostered by the television program *Wild Kingdom*. The methods available for capturing free-ranging wild ungulates, including darting with drugs, were primitive and mortality rates associated with capture often exceeded 10%.

Several new classes of drugs were developed in the 1960s and early 1970s that would eventually prove useful in wildlife anesthesia. These included psychotomimetic drugs (phencyclidine and ketamine) that separated the conscious brain from the portions of the brain that govern vital functions like heart beat and respiration; powerful (but reversible) narcotics like etorphine and fentanyl; and alpha adrenergic sedative-tranquilizers like xylazine. Charged with developing safe and reliable drug combinations for use on elk and other species, CDFG personnel had successfully darted elk on refuges and in zoos from the ground with a combination of the narcotic etorphine and the tranquilizer acetylpromazine. The dilute form of those drugs required the use of large darts (5–7 cc), but the combination was fairly effective and was reversible (Clark 1978). A narcotic antagonist, diprenorphine, could subsequently be given and the elk would start breathing deeply and were able to stand and walk within minutes. Etorphine is 600–1,000× more potent than morphine—it could (and had) killed people that were accidentally injected and, as a Schedule II narcotic drug, had legally restricted availability. Additionally, it remained to be determined if the combination would work on wild elk that were highly excited after being chased from the air, and in the rough volcanic terrain of the Owens Valley. It also had to be determined whether it could be delivered accurately and safely by dart gun from a helicopter. During a few fateful days in the fall of 1977, author Bill Clark and Don Landells—the first helicopter pilot in California with "the right stuff" (and who had >20,000 hours of helicopter flight time)—would meet to decide if all the pieces were in place to capture and relocate tule elk (but more on that later).

The net gun.—Although it is not the primary subject of this review, many improvements and refinements were made in net gunning, both during the 1980s and subsequently. Net gunning as a method for wild ungulate capture had its origin with New Zealand's red deer capture industry. Tim Wallis, one of the premier New Zealand pilots and net gun capture practitioners, visited Sacramento in 1982 and met with Dave Jessup and Bill Clark. Mel Cain, another New Zealander, loaned Don Landells—a pioneer in the helicopter

industry (deJesus 2012) and the owner of Landells Aviation—a helicopter-skid-mounted net gun built on a .303 Enfield receiver (Figure 4). Corey Gray developed the Coda net gun, which became the primary model licensed for sale and use in North America. Dave Jessup and Jim DeForge of Bighorn Institute were the first to capture bighorn with a net gun in California using the first Coda model, which had a triangular net.

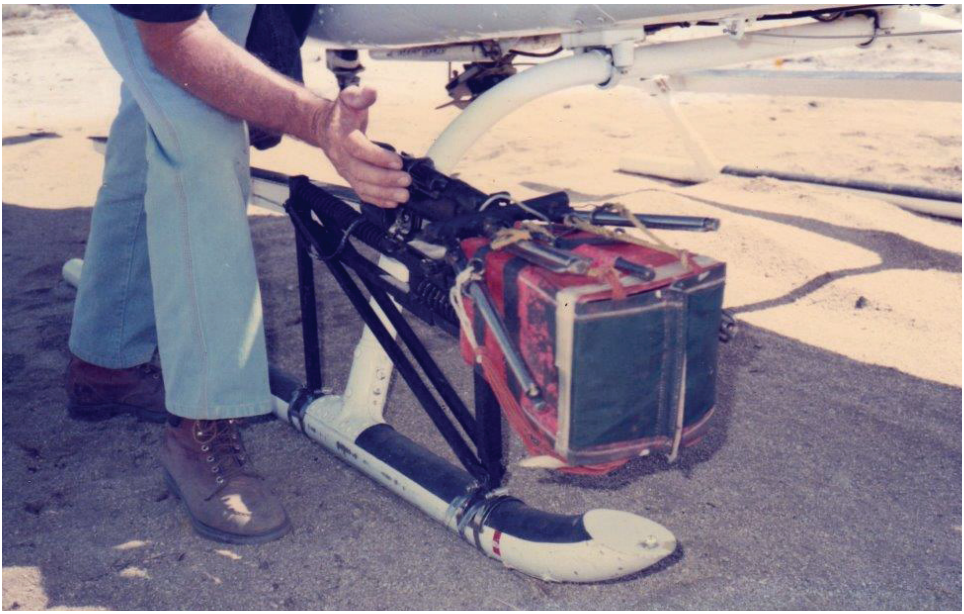

Figure 4.—The skid-mounted net gun loaned by Mel Cain to Don Landells and used to capture bighorn sheep. It was a hand-held model, but Don Landells constructed the external mount to secure it to the right skid of the Jet Ranger helicopter so that the pilot could "aim" the net gun at the target animal and then fire it. Note the recoil-absorbing spring located immediately behind the canister and below the Enfield receiver (photo by Charlie Jenner).

Author Dave Jessup and Rick Clark, a contract veterinarian, working under the supervision of Dick Weaver, made the early transition to net gunning for bighorn sheep capture operations (Jessup 1988, Jessup et al. 1988b). During a number of efforts from 1985 to 1987, up to 20 bighorn were captured by net gunning in three-day, or "long weekend" operations with a pilot, fuel truck driver, and a support crew of 3 or 4 individuals. During an operation in 1986, Don Landells and Bureau of Land Management wildlife biologist Jim Bicket died in a helicopter crash (Bleich 1987a, 1987b); Dick Weaver was very seriously injured in that same accident. After Don's death, and for the subsequent decade-and-a-half, author Steve deJesus and Brian Novak, both highly skilled pilots with Landells Aviation, took over the flying. Steve became the primary pilot for most capture efforts involving bighorn sheep, deer, and elk, most of it net-gunning. Brian also participated in net-gun captures, and became especially skilled at hazing mule deer into drive nets.

Improvements in technology, pilot skills, gunner skills, and the experience gained while working with net gunning bighorn sheep were quickly applied to deer and pronghorn and the net gun became a favored capture method (Figure 5). Eventually net gunning was

used for elk, and even feral donkeys in the Sonoran Desert (Marshal et al. 2008, 2012), although bigger and heavier nets were needed. Bob Teagle, a technician at WIL, became the lead person for net-gunning in the 1990s. Baiting deer and elk into traps and bighorn sheep under drop nets, as well as ground darting and other methods were, nevertheless, still used.

Figure 5.—(A) During the mid-1980s the net gun became the primary tool used to capture large mammals, particularly elk, mule deer, and bighorn sheep. Note the distance between the target animal and the aircraft, the orientation of the aircraft, and the position of the gun relative to the target animal (photo by Mike Kock). (B) Net gun operations sometimes resulted in bighorn sheep being captured in very steep terrain. Wildlife veterinarian Rick Clark, who worked extensively with bighorn sheep during the 1980s, processes this animal in the field. Note the eye cover used to decrease visual stimuli and calm the animal, a canteen of water to cool it, and all field equipment, drugs and supplies that are contained in a vest and backpack (photo by Mike Kock).

A Period of Intensive Capture and Restoration

Starting with elk, 1977–1978.—The job of determining whether elk in the Owens Valley could be successfully darted from a helicopter and relocated to start new herds was assigned to Bill Clark. In September 1977, Bill and Don Landells spent a day making aerial approaches on elk with a dart gun in various Owens Valley locations. They worked with Banky Curtis and Tom Blankenship, Region 5 Unit Managers in Inyo County, who had spent several years studying tule elk and were the CDFG experts on the ground. They decided that it was indeed possible to dart elk, immobilize them, pick them up and move them by truck or helicopter cargo sling, place them in a shipping crate, and then load them into horse trailers, after the immobilizing drug was reversed (Clark 1978). Bill reported this to Red Hunt, the Chief of WMD. Although it may seem like "the rest is history", it still had to be done, not just considered possible.

As the supervisor of WIL, Brian Hunter was involved in early elk darting efforts and in the first 1977 elk capture, but he soon moved on to different positions in WMD. Patti Perkins, a technician at the time, did the "lions share" of the planning, packing and managing equipment, and also handling the vital record keeping that made it possible to learn from each change in procedures. Later, Karen Jones would assume those responsibilities and become the key to organization of the biomedical teams. Other critically important staff in the early years included Ken Moore, whose capability as a field biologist and ability to fix aging state vehicles and to rewire old and borrowed (and highly modified) horse trailers made him indispensable, and Bill Grenfell, who was a steadying influence and would take on virtually any task to help ensure success. Dave Jessup was the principal veterinarian for elk capture efforts for many years, and worked to improve drug combinations, monitoring of vital signs, treatments of injuries and stress, tranquilization during transport, and prevention of disease after release. Numerous veterinarians and veterinary students came along for the experience, fun and excitement. Many other individuals played important roles in those early years, and personnel were recruited from various administrative regions within CDFG to help and to learn.

In the fall of 1977—and again in 1978—three field operations of about one week each were mounted to capture tule elk in the Owens Valley and move them to historic habitats (Clark 1978; Figure 6). All animals captured on any one day generally had to be put on the road to arrive at their destination the next morning because wild elk couldn't be kept from killing themselves or each other in closely confined trailers much longer than that. Three small horse trailers were modified to prevent easy escape; internal swinging dividers were added to facilitate loading and separation of animals, as were darkened openings that channeled in air and vented heat. Because CDFG was not yet fully committed to the elk capture and translocation program, no investment was made in professional-quality trailers or vehicles. This subsequently resulted in injuries and stress to both the elk and their captors.

Capture days began at "zero dark thirty" and each brought many new lessons. Gas-pressure dart guns were not reliable because ambient temperatures were highly variable and CO_2 cartridges were quickly exhausted. When .22 caliber blank cartridge-powered dart guns were used, the darts struck too hard; darts had to be pushed halfway down the barrel so the increased volume of the gas expansion chamber would slow the dart and keep it from embedding in the elk. On really cold mornings, drugs could freeze in the dart, so they were kept in cigar tubes (to contain the potentially lethal drugs) in a pouch inside the shooter's

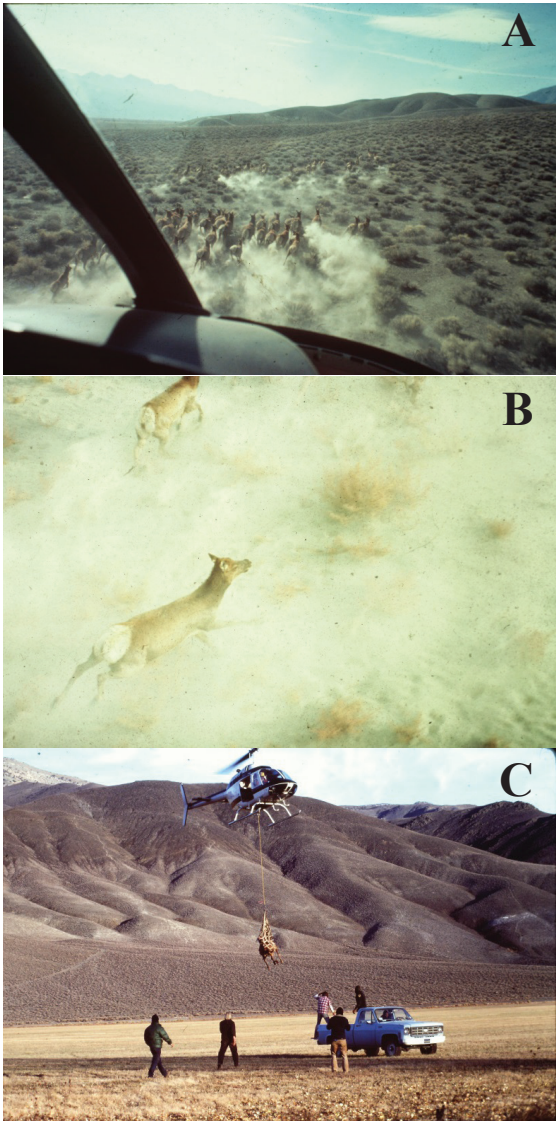

Figure 6.—(A) Beginning in 1978, free-ranging elk in the Owens Valley were captured with the use of a low-flying helicopter. (B) Individuals were darted with a narcotic-tranquilizer combination, and hobbled and blind-folded once immobile. (C) Each animal was then transported to a base camp where they were medically assessed, treated, marked, sampled, and loaded into trailers after the narcotic was reversed. These actions helped reduce the Owens Valley population and start new populations in areas of historic tule elk habitat in western and central California (photos by Dave Dick).

jacket. As the gunner leaned further and further out the back seat of the helicopter, and eventually stood on the skids, to improve accuracy, it became clear seat belts did not provide adequate restraint, even with the addition of duct tape to ensure that buckles would not pop open. A safety harness was quickly made from belts and leather hobbles until more professional safety harnesses were developed.

Dilute drugs meant large darts, and darts larger than 5 cc were too heavy and aerodynamically unstable. Sometimes after being darted, elk did not go completely down, likely a result of the combination of excitement, low dosage rates, dilute drugs, slow absorption, or poor dart placement. Some elk would stand stupefied but, if a person approached them slowly—bent over and walking elk-like, holding a brown and white eye cover that looked like an animal's rump patch—it was possible to walk up to a drugged—but still standing—animal, place the cover over its eyes, and gently get it to lie down so it could be hobbled and further restrained (Figure 7). Initially, war surplus Army chest bandages were used as eye covers and secured with gauze. Reducing or eliminating visual stimuli and keeping voices and foreign sounds to a minimum helped animals relax. As operations evolved cut-off pant legs were used as a quicker form of eye cover, and then custom made spandex eye covers with Velcro straps. These simple improvements in eye covers proved to be even more useful when handling deer, pronghorn and bighorn sheep. We

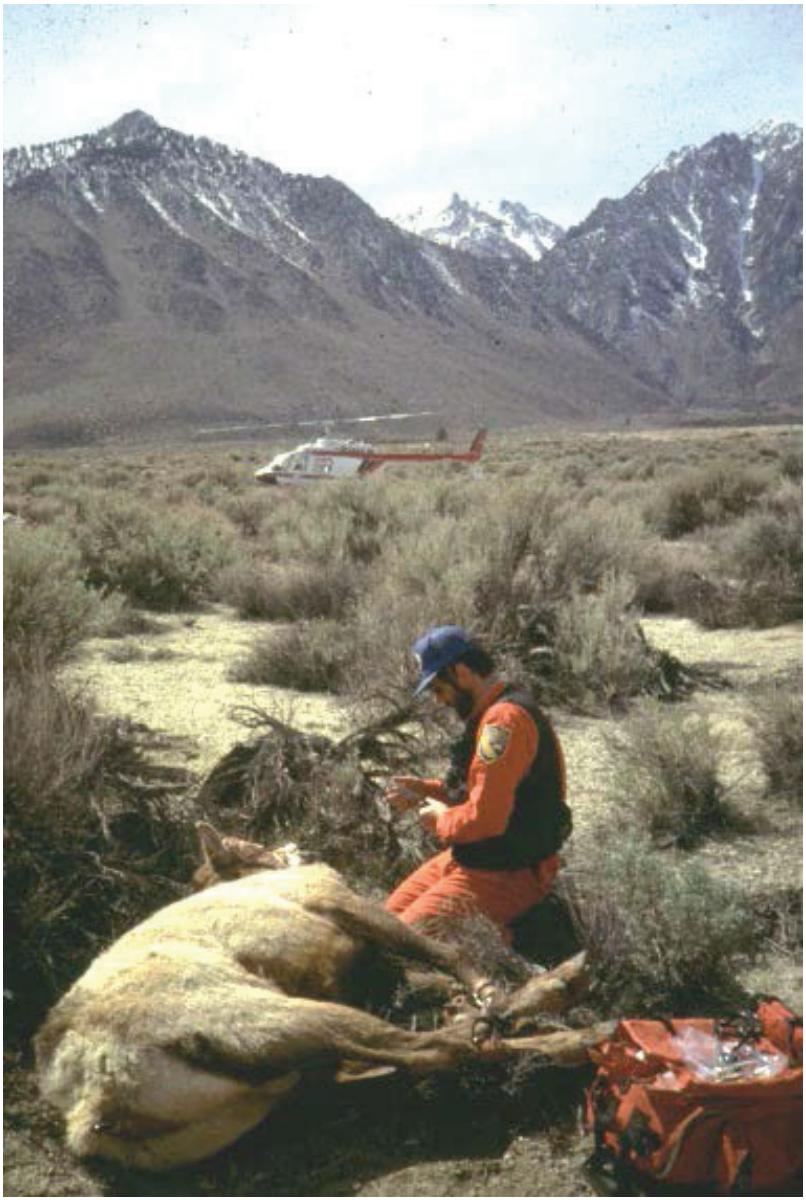

Figure 7.—Don Koch, the CDFG Elk Coordinator at the time—and who later would be appointed Director of the California Department of Fish and Game—processes a female tule elk that had been immobilized with carfentanil and xylazine, and fits her with a radio collar. The carfentanil and xylazine were reversed with naltrexone and yohimbine (respectively) and the elk released on site to supply information on habitat utilization in the Owens Valley, Inyo County, California (photo courtesy Dave Jessup).

learned that when releasing bighorn in the wild their eyes needed to adjust to sunlight for a few seconds or they would stumble and fall on steep terrain. Use of eye covers, along with leather hobbles to bind the feet together in case they startled, made handling lightly anesthetized wild ungulates safer and more effective. Anything that could be done to reduce sensory stimulation and fear helped the process.

After a couple of elk choked and died when being transported out of a remote area in a cargo net, litters were built from the heavy, steel frames of a fish hatchery raceway screen from which the screen had been removed and replaced with netting; Don Landells then designed and fabricated several light-weight litters that could be transported between the skids of the helicopter, and then by long-line below the aircraft after they were loaded with animals (Figure 8). Litters allowed elk and other species to be transported from a capture site to a central processing area without any possibility of pressure on the throat, and also made it much easier to carry the heavy animals from place to place while they were

Figure 8.—(A) Authors Bill Clark (R) and Vern Bleich discuss the transport of bighorn sheep strapped to litters used to move animals following capture in Cattle Canyon in the San Gabriel Mountains, Los Angeles County, California, in 1985. These animals were captured with a drop-net and sedated with xylazine, which was reversed upon their delivery minutes later to a central processing area. Note the heavy steel transport litter in the foreground, and the lightweight, aluminum transport litter in the background, which was designed and fabricated by Don Landells to transport individual tule elk from capture sites to a central processing area, and later proved invaluable for transporting multiple bighorn sheep. (B) A secondary benefit of the "Landells Litter" was the ability to stow it between the skids helicopter and to move multiple crates containing bighorn sheep into remote, mountainous areas prior to release. In this 1985 photograph, helicopter pilot Brian Novak delivers three crates containing bighorn sheep to San Rafael Peak, Ventura County, California, to restore them to an area from which they had been extirpated (photos © B. Moose Peterson).

unconscious. The litters fabricated by Don Landells were of great value in other ways: they could be carried between the skids immediately below the helicopter fuselage, and during translocations up to three crates containing bighorn sheep could be moved into remote areas for release. Ultimately, mesh bags were developed that were more portable than litters and provided better positioning and support and no risk of choking during aerial transport.

It was quickly discovered that elk chased for more than 5 minutes would get too hot and could die if darted. Monitoring body temperature (at that time with a glass, large-animal rectal thermometer) and other vital signs was a critically important task. Despite efforts to cool animals that included dousing them with cold water and alcohol baths at base camp, and even dunking them in canals or icy streams, some animals died of hyperthermia. Besides limiting chase time, we learned that pulling the helicopter back immediately from a darted elk allowed it to rejoin the herd and relax while the drugs took effect, generally providing better all-around results. By wetting hot animals in the field, we learned that they cooled down considerably while they were flown to a base camp.

By organizing everything so elk could be processed very quickly we could reverse them sooner, which restored normal respiration and optimized cooling and recovery. While age, sex and other information and observations were recorded, vital signs (temperature, respiration and heart rate) were taken, ear tags and some radio collars for follow-up studies were attached, prophylactic (antibiotics, vaccinations, and stress relieving) medications were administered, and blood samples were drawn. The latter eventually provided an extensive health history for most of California's elk herds, and allowed California elk to be recognized as free of brucellosis and not subject to quarantine and testing. Routine blood sample collection and testing became standard protocols for other species, as each capture event was seen as a unique opportunity to look at the health of individuals and populations. Every day, and every trip, brought new lessons and knowledge, and adjustments were made "on-the-spot" as the need was realized. Following each capture season personnel spent weeks going over data and laboratory results. These sessions would help us understand what worked and what didn't, and how we could improve.

The high body temperatures and slow response to drugs experienced in 1977 led to modification of the drug combination. The sedative xylazine was substituted for the less potent tranquilizer, acepromazine. Doing so allowed more narcotic to be used, and resulted in more rapid "down times." The xylazine also helped keep elk drowsy in the transport trailers. Diazepam (Valium) was often given to elk in trailers as it both calmed and relaxed muscles, but didn't result in animals laying down and getting trampled as could happen with acepromazine. In the 1980s a new, extremely potent narcotic (carfentanil) was tested. It allowed much smaller darts (1 or 2 cc) to be used and also afforded much more rapid immobilization (Jessup et al. 1985a).

In 1977, and again in 1978, trailers full of elk arrived at Grizzly Island Wildlife Management Area, Concord Naval Weapons station, Point Reyes National Seashore, the Hewlett-Packard Ranch in Santa Clara County, and several places in Potter Valley, Mendocino County. But, even though elk could be successfully and selectively captured from the various elk herds of the Owens Valley, the costs were high and the numbers removed barely kept the total below the maximum allowed. Another method had to be found to remove more elk more quickly and less expensively.

Game changer.—In the spring of 1979 Bill Clark and Dave Jessup stood on a hill just east of Highway 395, about 50 km south of Bishop and just north of the Tinnemaha

Reservoir, and looked at what seemed to be a perfect place to build a large corral trap. There were many elk trails from the alfalfa fields to the north leading into the wooded riparian area along the reservoir, and it was at the edge of a hill separating it from Highway 395. A year later, after several weeks spent building long fences—also referred to as wings—to funnel animals into a central corral, and covering the wings with brush and disguising the corral with burlap, the great experiment in mass elk capture was ready. Don Landells used his helicopter to haze 66 elk into the trap and they were captured, processed, loaded, and shipped in a single day (Figure 9). A new page had been turned and although chemical immobilization was still in use—all bulls had to be darted to remove their antlers—CDFG was moving more and more toward larger capture operations and physical capture techniques.

The ability to herd elk into corral traps and remove them in larger numbers changed everything. It made the capture and removal of substantial numbers of elk from the Owens Valley feasible, and allowed control of the overall size of the population in a more cost-effective manner. Repeated several times in the Owens Valley, corral trapping was also used to capture and remove elk on occasion from Grizzly Island—where the first translocated herds had quickly outstripped the available forage and begun to consume toxic plants (Jessup et al. 1986a). Baiting elk into corral traps and loading them through chutes also worked to

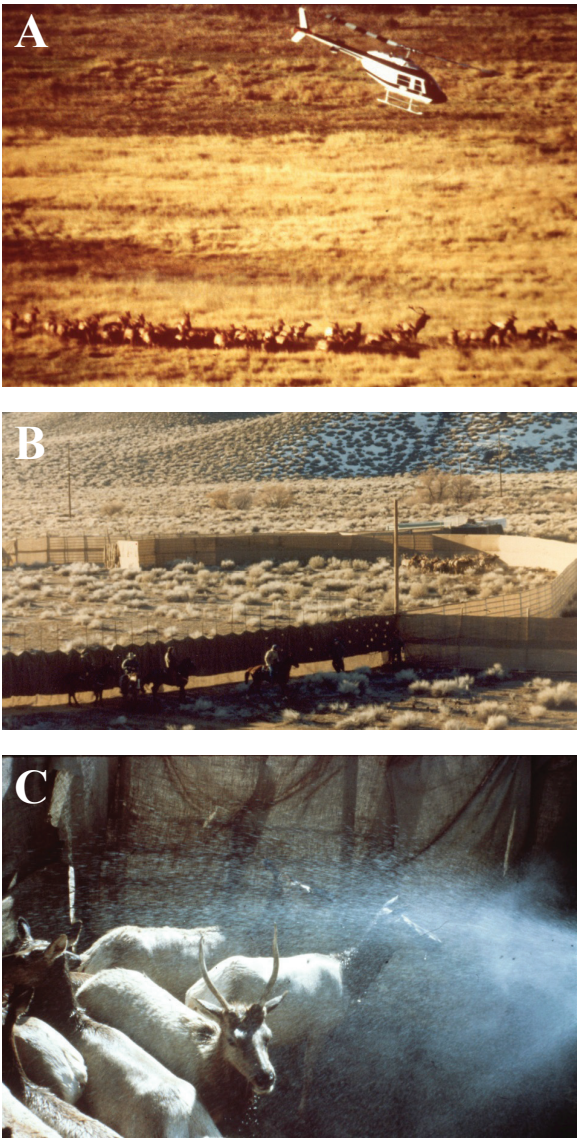

Figure 9.—(A) Don Landells herds tule elk toward a corral trap equipped with long "wings" just north of Tinnemaha Reservoir, Inyo County, California, in 1979. This was the first mass capture of tule elk in the Owens Valley and 66 elk were captured, processed, loaded, and shipped in one day. Photo by Dave Dick. (B) Tule elk in a corral trap, Owens Valley, Inyo County, California, 1981. Horsemen helped herd these animals into the trap and then a sliding curtain was closed to prevent their escape. The western "wing" of the trap extends northward from the powerpole immediately to the right of the horsemen (photo by Jeanne Clark). (C) Elk captured in corral traps frequently were hyperthermic. Trucks with thousands of gallons of water provided by personnel from the Mount Whitney Fish Hatchery were used to help cool the elk following long drives (photo by Dave Jessup).

reduce the herd at Tupman Tule Elk Reserve State Park and at Concord Naval Weapons Station. Roosevelt elk were baited into corral traps at Gold Bluffs Beach and at Prairie Creek State Park in Humboldt County. All of those elk served as founders of new herds on public lands, as well as on private ranches where limited elk hunts could now be planned (Bleich and Koch 1992).

Between 1977 and 1988 a total of 813 tule elk, including 422 from the Owens Valley, were captured and translocated to 18 sites in California to start new herds (Jessup 1988, Jessup et al. 1988a). After the legislative mandates were reached, hunting was reinstated in 1989 as a tool to manage tule elk populations in the Owens Valley and elsewhere. Over the same 12 years, 130 elk were captured and translocated from Tupman Tule Elk Reserve State Park, which by then had essentially turned into an elk feedlot. Eighty-four others were removed from San Luis National Wildlife Refuge and used to restock other suitable, but vacant, areas of California. One hundred and twenty four were removed from Grizzly Island Wildlife Management Area, a herd that was founded in 1977 as a result of the early translocation efforts. Tule elk, a distinct subspecies endemic to California, were successfully restored to some of their historic range, and Californians had another big game species that could be sustainably harvested (McCullough et al. 1996). Today, revenues from elk hunting pay for much of the costs of elk management. Elk hunting and viewing provide excellent outdoor recreational opportunities that previously were extremely limited or non-existent before intensive capture and translocation operations were implemented and new herds were started.

Advances in deer capture.—Prior to 1977 there were only a few ways deer were captured in California: foot snares (Ashcraft 1957), by attracting them to bait in panel traps (Figure 10) or Clover traps (Clover 1954, 1956; McCullough 1975) and physically restraining them (Figure 11), or by darting them with drugs—usually from a vehicle. Each of these methods was very time consuming, physical handling was dangerous and resulted in many injuries to workers and animals, and these methods yielded, at most, only one or two animals per day; nevertheless, those methods continue to be useful in some situations (Pierce et al. 2000).

New drug combinations were developed that were more effective and allowed darts to be reduced in size, increasing accuracy and reducing injuries to targeted animals. CDFG personnel were on the forefront of developments in wildlife pharmacology for a decade and a half, and pioneered use of carfentanil and its reversal, first naloxone and then naltrexone (Jessup et al. 1984, 1985a). Several non-narcotic drug combinations also were developed. By freeze-drying ketamine and reconstituting it with xylazine, a safe and non-narcotic combination was developed. This combination was partially reversible with the drug yohimbine, and could be used to dart deer (Jessup et al. 1983). This combination was eventually replaced with another partially reversible combination of Telazol and xylazine. In a different ratio of ketamine to xylazine the combination would prove useful on a very wide variety of carnivores and omnivores. Xylazine could also be used to sedate deer in Clover traps, thereby reducing the likelihood of physical trauma or injury to both deer and handler, then reversed with yohimbine (Jessup et al. 1985b). In the 1980s and 1990s, medetomadine would largely replace xylazine and atipamezole would replace yohimbine.

The knowledge gained as a result of all of this work was presented in CDFG-sponsored courses for biologists and veterinarians that were developed and taught by WIL personnel, and published in leading biology and veterinary journals. Additionally, CDFG

Figure 10.—This panel trap baited with alfalfa hay was used to capture mule deer from the Devil's Garden area, Modoc County, California, in 1948. Forty mule deer from that area were translocated to the Providence Mountains in the eastern Mojave Desert, San Bernardino County, California (Longhurst et al. 1952, Cronin and Bleich 1995; photo courtesy of Vern Bleich).

Figure 11.—A substantial improvement over panel traps occurred with the development of the Clover trap in the 1950s, particularly those designed to be collapsed on the animal— usually a mule deer— inside the trap. Deer so captured could be more easily handled and even sedated with xylazine and, after marking and processing, reversed with yohimbine, as demonstrated by Martha Schauss, Henry Coletto, and Walt Smith (photo by Mike Oliver).

biologists or wardens working in field settings were required to be certified in animal restraint techniques every five years. These standards were adopted by adjacent states (Oregon, Washington and Nevada) and eventually became widely accepted across the USA and Canada.

In 1982 CDFG began using drive nets, a method that had been pioneered earlier in New Mexico (Beasom et al. 1980). The first nets used by CDFG were borrowed from the New Mexico Game and Fish Department, and when they proved effective for mass capture of deer and bighorn sheep, CDFG procured nets custom made by commercial fishing supply companies in San Pedro, California. Deer, usually from winter range concentrations, were gently herded by helicopter into sections of large-mesh gill nets ≈35-m long and ≈3-m in height and set up in various configurations using terrain features to obscure them (Thomas and Novak 1991). Although deer sometimes avoided the nets or managed to escape, it was common to catch 3 or 4 on any one drive, and 20 or more per day (Figure 12).

Figure 12.—Deer and bighorn sheep were frequently captured in standing drive nets during the 1980s and 1990s. These nets are being set to capture migratory mule deer on a winter range immediately west of Manzanar, Inyo County, California, in 1983 (photo by Dave Jessup).

In the late 1980s, helicopter pilot Brian Novak successfully herded >120 deer into drive nets over 2.5 days along the California-Nevada border, where a veterinarian and a large crew of biologists from CDFG and Nevada Division of Wildlife were waiting to restrain them. Most of those animals were tagged or radio-collared and released on site, and >80 were sampled for a variety of diseases and other health factors. Although these operations were labor intensive for a few days at a time, the era of catching one or two deer per day was over.

The purpose of most deer captures at that time was for marking and the study of migration and habitat utilization, not for translocation. An exception was an effort to remove deer from Angel Island in San Francisco Bay, where they had increased from 25 to over 200 and had devastated the forage resources. Every technique available (drop net, drive net, darting, clover traps) was used to capture deer from the island, and 201 deer were removed in an effort to reduce the population and lessen the effects of disease and malnutrition (Clark 1982b, McCullough 1983; Figure 13). The translocation of deer from the island was demanded by animal rights advocates and supported by decision-makers outside CDFG concerned about the animals' welfare; unfortunately, the deer had no experience with predators, were in generally poor nutritional condition, and were dependent upon supplemental feed; as a result, survival among the translocated animals was very poor (O'Bryan and McCullough 1985, Jessup et al. 1988a).

Baiting deer and bighorn sheep under drop nets was also used successfully (Figure 14). When deer are captured with this method, however, they panic and fiercely fight capture, creating a dangerous and stressful situation; thus, drop nets have not commonly been used to capture them. Eventually net gunning from a helicopter proved an efficient and highly selective method for capturing deer for research (Pierce et al. 2000, 2004; Bleich et al. 2005; Monteith et al. 2011, 2013). For example, skilled pilots and capture personnel have been able

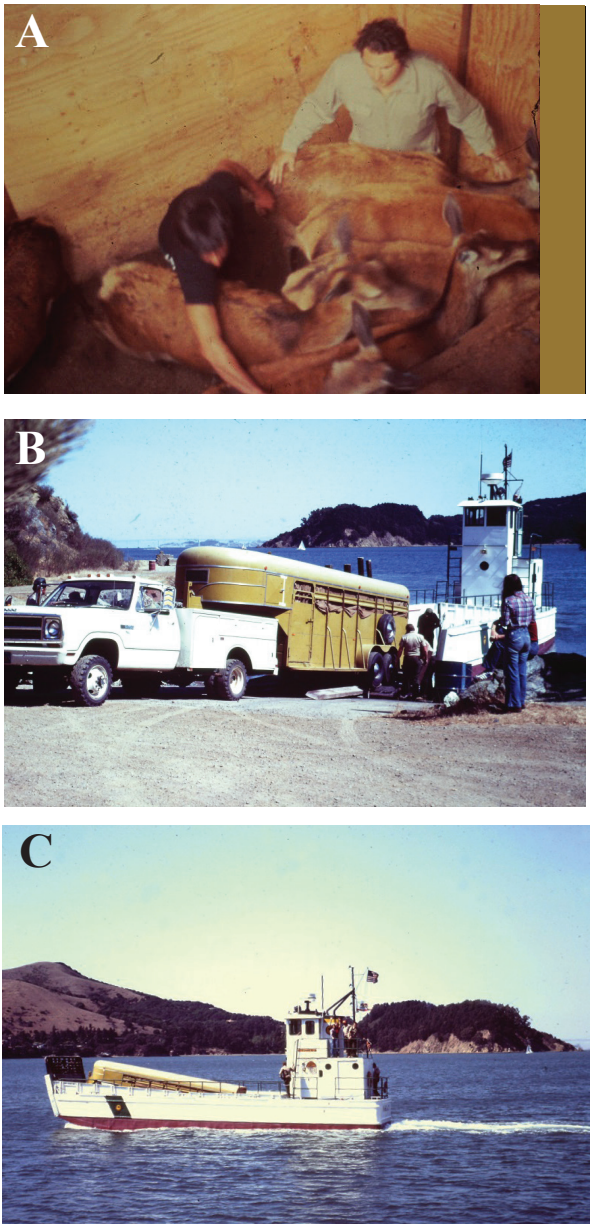

Figure 13.—Many methods were used to capture starving deer on Angel Island in 1982. (A) Deer sedated with xylazine and diazepam were gently sorted inside a darkened custom-built pen where they were held until transportation off the island could be scheduled. (B) Captive deer were then placed in specially modified trailers for transport to a boat dock. (C) The trailers were loaded on a LST for transport to the mainland in Marin County where they were off-loaded and then towed to Cow Mountain in Mendocino County, where the deer were released. More than 200 mule deer were removed from the island, which has an area of about 5 km^2 (photos by Dave Jessup)

Figure 14.—Drop nets were used very successfully to capture bighorn sheep and mule deer under the appropriate circumstances. In 1983, 1985, and 1987 volunteer Bill McIntyre (seen here in his trademark red jacket), a member of the Society for the Conservation of Bighorn Sheep, camped alone in remote areas of the San Gabriel Mountains for >2 months to facilitate three successful capture efforts. Bill's dedication ensured the successful translocation of 65 bighorn sheep to historically occupied areas in the Prairie Fork of the San Gabriel River (*n*=22) and San Rafael Peak (*n*=43), Ventura County, from the South Fork of Lytle Creek and from Cattle Canyon, respectively (photo © B. Moose Peterson).

to capture numerous marked or radio-collared individuals multiple times over periods of many years to better understand the reproductive histories and nutritional status of individual animals in Round Valley, California (Monteith et al. 2011, 2013).

Advances in pronghorn management.—By the 1970s pronghorn occurred in 6 or 7 herds in Lassen, Modoc and Shasta counties, where their numbers were controlled by carefully regulated harvests. A small number of pronghorn also existed in Mono County, the result of several translocations from 1947 to 1950 (CDFG 2004), but that interstate population was not hunted in California. In some locations in northeastern California, harvest rates did not provide sufficient control to keep pronghorn out of alfalfa fields and the choice was to remove them using lethal means or use them for restocking historically occupied geographic areas. When in a herd and being pursued, pronghorn behave much like a school of fish, grouping tightly and moving together. Other states previously had success herding them with a helicopter into very large funnel-shaped traps with long wings that led to a central corral with an opaque, flexible curtain that could be closed quickly to prevent animals from escaping after they entered the trap (O'Gara et al. 2004). California began using this method because earlier efforts to herd pronghorn with vehicles or people with bells and noisemakers were not successful.

Led by Bud Pyshora, Doug Thayer, Dave Smith, and Tim Burton, 650 pronghorn were captured for translocation from 1977 to 1988 by herding them with a helicopter into specially constructed wing traps (Jessup et al. 1988a, CDFG 2004; Figure 15). The wings

Figure 15.—Pronghorn have excellent vision, are highly excitable, and have evolved to outrun coursing predators. They can be driven with a helicopter into winged corral traps constructed with see-through netting but later covered with burlap after the pronghorn are captured so that the sides of the corral appear to be solid. Pronghorn captured in this manner generally are in large groups comprised of males, females, and young that are exhausted and physiologically stressed, as demonstrated by these animals captured in Modoc County, California, in 1979 (photo by Tim Burton).

and corral were made of a large, fairly open mesh that did not appear solid to the pronghorn. Once in the corral burlap was quickly pulled up to make the walls appear solid. It proved relatively easy to capture groups of 30-60 at a time, but very difficult to separate them into smaller groups and load them for transport. Most pronghorn captured were translocated to establish additional populations in Lassen, Los Angeles, Mono, San Luis Obispo, San Benito, and Tehama counties, or to augment an existing population near Bodie, Mono County.

Net gunning proved to be useful for capturing individual pronghorn for marking, but their speed requires that the shooter "lead" the animal more than would be the case with deer, elk, or bighorn sheep. The net gun was not, however, efficient for mass capture. The only meaningful pharmacologic contributions to the capture of pronghorn were in the area of tranquilizers that reduced stress and injury during transport. Again, conservation activities and translocations were beneficial to the residents of California through the re-establishment of pronghorn on native ranges, with a secondary benefit of enhanced public hunting opportunities.

Advances in bighorn sheep conservation.—Until 1986, when the California Legislature gave CDFG authority to again manage bighorn sheep, there was relatively little effort put into research and management of this species, and there was no hunting (Bleich 2006). Nevertheless, the first translocation of bighorn sheep in California occurred in 1971, when 8 females and 2 males were captured on a game farm in British Columbia, and released at Lava Beds National Monument, Siskiyou County (Blaisdell 1972, Weaver 1972). That

population grew to over 60 animals. In February 1980, an effort to herd these bighorn into a very large, solid corral at Lava Beds turned tragic when six of ten animals died of capture myopathy (Figure 16), and only four were translocated to the Warner Mountains, Modoc County (Sleznick 1980). But, this event indirectly resulted in the advancement of bighorn

A

Figure 16.—(A) Author Dave Jessup carries a live bighorn yearling captured at the Lava Beds National Monument enclosure located in Siskiyou County, California, in 1980. Of 10 animals captured, only four survived this tragic episode in California Department of Fish and Game's otherwise stellar history of translocating large mammals (photo by Diane Plechner). (B) Deep discussions among those leading the capture effort ensued immediately, as author Dave Jessup, project leader Dick Weaver, and author Bill Clark consider the outcome. This event led to private funding to study capture methodologies, physiology, and medical treatment, which resulted in many improvements that benefited bighorn sheep and other wild ungulates (photo by Diane Plechner).

B

sheep management and translocation techniques when the Shikar Safari Foundation—a private organization of dedicated hunter-conservationists—donated $64,000 (a large amount that the time) to fund a study of capture stress and muscle damage (myopathy) caused by various capture techniques used on bighorn sheep, the morbidity and mortality they caused, and subsequent survival.

This study of bighorn capture methods prompted by the Lava Beds sheep deaths resulted in a 4-year Western States regional investigation (wildlife agencies in Oregon, Nevada and Arizona cooperated by allowing California researchers to participate, and to collect data and samples) and the publication of a series of papers (Kock et al. 1987a, 1987b, 1987c; Jessup et al. 1988b) comparing capture methods that, even 25 years later, remain definitive contributions. Those investigators demonstrated convincingly that, under most prevailing conditions in California, net-gunning was the safest, least stressful, and most cost-efficient method for capturing free-ranging bighorn sheep in locations where they could not be attracted to bait.

Drop-netting proved to be useful in some locations where bighorn could be habituated to bait (usually fermented apple pulp, alfalfa, or salt). Drive-netting was more widely applicable, but the terrain favored by bighorn made it very difficult to set up nets, and bighorn seldom were captured in the numbers necessary to justify the effort. Darting with etorphine, and then carfentanil combinations, was tried but rejected early on, although tranquilizing sheep with low doses of xylazine or diazepam to reduce stress and facilitate transport was done quite regularly. Net-gunning became the favored method, and early captures involved the use of both skid-mounted and hand-held versions. With bighorn, as with elk and deer, various capture methods were tried, improved upon, and adjusted as needed. Each capture operation brought new knowledge and refinement of methods.

At first, the capture of bighorn sheep was primarily for translocation to historic ranges from which they had been extirpated by disease, habitat degradation, or market hunting. In 1979, ten "California" bighorn sheep (now recognized as Sierra Nevada bighorn sheep, *O. c. sierrae*), were captured using a drop-net in the central Sierra Nevada, Inyo County, and translocated to establish a new population at Wheeler Ridge in that same mountain range (Bleich 1990a). From 1979 to 1982, an additional 50 bighorn were captured in the same area and moved to three locations in the Sierra Nevada that historically had supported populations, and to the Warner Mountains, Modoc County (Bleich et al. 1990a, 1996a). Drop nets and drive nets were used, and the same helicopter pilot (Don Landells) and many of the same capture personnel that participated in elk capture work were involved. These early bighorn translocations were led by Dick Weaver of WMD, and included Tom Blankinship, author Vern Bleich, John Wehausen, the WIL crew, and many others. In 1986 and 1988 another 43 of these bighorn were captured to supplement the three recently established Sierra Nevada populations (Bleich et al. 1990a, 1996a). Unfortunately, the bighorn sheep at Lava Beds National Monument, as well as those in the Warner Mountains that largely came from the Sierra Nevada, died as a result of respiratory disease that developed following their contact with domestic sheep (Foreyt and Jessup 1982, Weaver 1983, Weaver and Clark 1988).

In 1983 CDFG was charged by the California Legislature with surveying all bighorn sheep habitat in California and, to the extent possible, capturing, marking, and sampling bighorn in every occupied mountain range (Bleich 2006). The goal was to establish a baseline of biological, ecological, genetic, and health information to optimize population management. Capture for translocation and starting new herds was also authorized. The

two most productive desert bighorn populations, those at Old Dad Peak and the Marble Mountains, were used as stock for translocating bighorn to historically occupied desert ranges. Most capture was by net-gunning, although drive nets were also employed. The San Gabriel bighorn population in Los Angeles County was also productive enough in some years to allow the translocation of animals to vacant ranges in Los Angeles and Ventura counties (Bleich et al. 1990a). In the San Gabriel Mountains, the use of the drop net baited with alfalfa hay and salt blocks was very effective.

From 1983 to 1988, primarily under the direction of author Vern Bleich, approximately 330 bighorn sheep were captured for translocation to sites in 11 mountain ranges where they had historically occurred, or at the time occurred in low numbers. Bighorn sheep were restored to ranges in Riverside, San Bernardino, Inyo, Mono, Los Angeles, and Ventura counties (Clark et al. 1988, Bleich et al. 1990a). When it was possible to transport bighorn sheep to a release site by truck and trailer, that method was used; however, when the release site was in a remote mountainous area—as were those in the Bullion Mountains and the Eagle Crags (San Bernardino Co.), the Chuckwalla Mountains (Riverside Co.), Mt. Baden-Powell (Los Angeles Co.), and San Rafael Peak (Ventura Co.)—animals were transported via helicopter into the range (Figure 8) and held in an enclosure prior to release for several hours after the last individuals had arrived. We had learned from our initial experiences at the Eagle Crags and in the Prairie Fork, where bighorn sheep were released as they arrived via helicopter, that repeated flights and releases stimulated the sheep to scatter further and further from the release site. So we developed and used the holding pen at release sites accessible only by helicopter, so that all animals could be released simultaneously (Figure 17). We also learned that there was no difference in the grouping behavior of bighorn sheep released from such an enclosure and those released simultaneously from a vehicle (Thompson et al. 2001).

Figure 17.—U.S. Forest Service Biologist the late Steve Holl (right) and author Vern Bleich release bighorn sheep from an enclosure at a remote location near San Rafael Peak, Ventura County, California in 1985. These animals had been held for several hours after the last individuals had been transported to the enclosure via helicopter. To allow the animals to disperse cohesively following the release, several weeks passed before the pen was dismantled and flown out (photo © B. Moose Peterson).

In addition to animals that were translocated, >600 other bighorn were captured for marking and sampling in remote mountain ranges, and released on site. The legislative mandate to sample and investigate disease, genetics, and ecology of bighorn resulted in a large number of scientific publications. The importance and effects of various diseases and parasites were clarified (Dunbar et al. 1985; Clark et al. 1985; Boyce et al. 1991a, 1991b; Mazet et al. 1992; Goff et al. 1993; Thomford et al. 1993; Jessup et al. 1993a). A clearer and more accurate picture of genetic relationships between bighorn populations began to emerge, and this information helped pave the way for the taxonomic reclassification of a number of populations.

By marking bighorn in many populations with radio collars, information was gleaned regarding movement patterns, critically important habitat, and previously undocumented movements among populations. Investigators posited that bighorn sheep in California existed as a metapopulation (Schwartz et al. 1986, Bleich et al. 1990b, 1996b). Subpopulations comprising the metapopulations were subsequently defined and became primary units for conservation (Torres et al. 1993, 1994). Estimates of size of the subpopulations were also refined (Torres and Bleich 1999). Combined with more accurate and meaningful demographic data, this information resulted in greater confidence in proposed management strategies, and helped justify the implementation of limited hunting of older adult males beginning in 1987 (Bleich 2006). This, in turn, began to provide much of the funding to support ongoing management of all bighorn sheep in California, including the small number of populations that were hunted as well as the numerous other non-hunted populations. Funds generated from the bighorn sheep hunting program now pay for most of the research and management efforts undertaken to conserve bighorn sheep in the Golden State.

Summary

Tremendous advances, both in the physical and chemical capture of deer, elk, pronghorn, and bighorn sheep in California took place during the 1970s and 1980s. These advances were made available internationally in a series of courses, manuals (Jessup and Clark 1980, 1982; Jessup et al. 1986b), and books (Jessup et al. 1991b), as well as numerous professional publications. Courses on wildlife capture taught by CDFG personnel throughout the western United States resulted the availability of instructional manuals with new information to hundreds of wildlife biologists throughout the Western U.S. and around the world. Under a series of sole-source contracts, Landells Aviation was employed by CDFG for more than two decades. During the 1980s, pilots Steve deJesus and Brian Novak joined the capture crews, and assumed the roles of capture pilots in 1986, following the tragic accident that killed Don Landells and BLM wildlife biologist Jim Bicket.

The many advances in capture technology that led to the restocking of big game species in California was the work of many dedicated people. Don Landells would be the first to credit all the other folks who worked so hard to conserve and care for the animals, but he gave at least as much to that effort as did any other individual. The legacies of the convergence of people, capture methods, and the conservation needs of big game species are several and substantial. Tule elk (and to a lesser extent Roosevelt elk), bighorn sheep, and pronghorn are much more widely distributed across suitable and historically occupied habitats in California than they were 35 years ago, and certainly are more numerous than

they were 100 years ago, when the first issue of *California Fish and Game* was published. Tule elk can regularly be seen along Highway 152 around the San Luis Reservoir, Point Reyes National Seashore, and other locations throughout the state. Elk at Mount Hamilton and and in the Coast Ranges move from one herd to another, and northward into eastern Alameda county. In a number of places the presence of these restored game species has changed land management policies. On the Carrizo Plain in eastern San Benito, eastern San Luis Obispo, and western Kern counties, the restoration of tule elk and pronghorn after an absence of nearly 100 years has been described as restocking an "American Serengeti." The presence of Roosevelt elk in the Marble Mountains of northern California has changed some Forest Service policies. Forest Service and other federal agency policies and priorities have been modified to accommodate the needs of bighorn sheep in many locations in the state.

Californians can anticipate that these magnificent animals will continue to thrive for many generations, provide ecosystem services, serve as umbrella species for wildlife conservation programs on publically owned lands, be seen and photographed, and in some locations can even be hunted. California Department of Fish and Wildlife and the management of these species now benefit from greater public support, and from hunting revenue that is dedicated to species management efforts. Much more is known about the animals themselves because all of the capture and relocation efforts were well documented, were usually used as an opportunity to assess the health of the species, and were often coupled with telemetry-based investigations of habitat use and basic biology. Because most of the scientific information derived was published, other scientists and wildlife management efforts elsewhere have benefitted, and many personnel gained a fuller understanding of the biological and health implications associated with wildlife capture efforts (Jessup et al. 1993b).

The efforts to improve "big game" distributions and to enhance management did not end in the 1990s, and they continue today. But after 1988 the emphasis began shifting to hunting as a tool for managing surplus populations of elk and pronghorn, rather than translocation. Further, many of the areas historically occupied by elk, pronghorn, and bighorn sheep that California's history had left empty, were getting filled. And, conflicts—as much political as biological—between agricultural interests and conservation interests began to be felt in Sacramento and elsewhere, and reduced support for restocking public lands with wildlife (Koch 1987).

Perhaps the best way to summarize this history is that for about a decade in the last quarter of the 20th Century, there was an opportunity to reestablish depleted native ungulate populations in California, and the right people and the right tools came together at the right time to accomplish that important conservation work. Because that work was undertaken with an eye toward learning from each effort, improving the constantly evolving methods (what we now call adaptive management), and the acquisition of solid scientific data and subsequent analyses, those contributions included not only the acquisition of new knowledge but pragmatic application of that knowledge, resulting in many more animals "on the mountain" in California and elsewhere.

It wasn't always easy or fun, often it was dirty, exhausting and frustrating, even heartbreaking. All of us were driven by various inner angels and demons. Nevertheless, it was real, it was important, we all worked together selflessly for the critters, and we were all as alive as we would ever feel.

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William E. (Bill) Clark passed away unexpectedly prior to completion of the manuscript; thus, any errors or omissions in this historical account are solely the responsibility of the other authors. Bill's dedication to and support of the evolution of capture methodologies were vital to many of the successes described here. Don Landells, with a sly grin, would often refer to Bill as "The Wagonmaster" after the Ward Bond character in the 1950s and 1960s TV series of the same name. Like that character, in his element Bill could command, inspire, convince, or cajole just about anyone to do what he thought needed to be done.

Don Landells lent his skills and expertise to those efforts involving the use of helicopters, and provided many years of service to the development and evaluation of capture methods and to the restoration of large mammals to historical ranges. Following Don's untimely death, Brian Novak shared capture duties with co-author Steve deJesus, and became very skilled at implementing drive-net captures.

We thank the many dedicated employees of the California Department of Fish and Game and other agencies that participated in early efforts to translocate elk, pronghorn, bighorn sheep, and mule deer; many of them volunteered their time to do so, and we suspect that they will recall participation in such events as being among the highlights of their professional careers. Among those that played important roles in the evolution of capture methods but not previously mentioned are CDFG employees Randy Imai, John Parrish, Les Coombes, Ron Thomas, Rocky Thompson. Don Pine, Jim Lidberg, Andy Pauli, and Vern Koontz, and veterinarians Bud Adams and Pat Gullett. Dozens of others, far too numerous to acknowledge individually, contributed in many meaningful ways. We thank S. Osborn and J. Clark for many helpful suggestions that resulted in a markedly improved manuscript, and J. Hobbs and J. Fischer for providing important reference material and background information. This is Professional Paper 107 from the Eastern Sierra Center for Applied Population Ecology.

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