Evaluating capture methods for urban white-tailed deer

M. Nils Peterson, Roel R. Lopez, Philip A. Frank, Markus J. Peterson, and Nova J. Silvy

Abstract Wildlife management involving public participation is becoming commonplace. Given that successful management of natural resources increasingly depends on securing public cooperation, wildlife capture methods deemed unethical by the public should be avoided if possible. When evaluating the ethical use of wildlife capture techniques, the public sees animals as individuals while the wildlife profession focuses on populations and communities. Problems may arise when these differing perceptions of wildlife dictate different capture techniques. The capture of urban white-tailed deer (*Odocoileus virginianus*) on private lands both typifies and magnifies the dissonance between wildlife managers and the public rooted in their different constructs of nature. We analyzed capture techniques from 1) a literature review of white-tailed deer capture and 2) our own experiences working with the endangered Key deer (*O. v. clavium*) to determine the most suitable methods for minimizing problems associated with the differing social perspectives of wildlife. Many historical studies used drugs to immobilize, tranquilize, or sedate deer after physical capture and were characterized by high (>5%) mortality. Some studies also focused on demonstrating statistical differences in mortality between capture methods rather than decreasing mortality. Drop nets, drive nets, hand capture, net guns, dart guns, and box traps all were used by some researchers with mortality approaching 0. Modified drop nets and drive nets are appropriate methods for urban deer capture because they are passive, silent, fast, yield low mortality and injury rates, and are not associated by the public with weapons. Urban wildlife capture techniques with these attributes demonstrate respect for the public's individualistic view of wildlife and can be combined with education to generate support for research and management in urban areas.

Key words animal welfare, capture myopathy, deer capture, ethics, Florida, Key deer, *Odocoileus virginianus clavium*, urban deer, white-tailed deer

An emerging trend toward public participation in wildlife management has led to advocacy of public participation in many forms, including co-management (Chase et al. 2000) and community-based conservation (Western and Wright 1994, Wondolleck and Yaffee 2000, Brick et al. 2001). Securing the cooperation of diverse groups of people is essential to wildlife management (Peterson et al. 2002). Indeed, Riley et al. (2002:591) claimed that stakeholder participation is 1 of 2 key precepts that capture "the essence of wildlife management." However, stakeholder involvement is more than a trendy idea purporting to pacify interest groups through collaboration, consensus building, and ownership of the process. Urban sprawl, suburban development, and increasing incidences of controversy involving urban wildlife render public participation a condition inherent to wildlife management (Decker and

Address for M. Nils Peterson, Roel R. Lopez, Markus J. Peterson, and Nova J. Silvy: Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA; present address for Peterson: Department of Fisheries and Wildlife, Michigan State University, 13 Natural Resources Building, East Lansing, Michigan, 48824, USA; e-mail: peter529@msu.edu. Address for Philip A. Frank: United States Fish and Wildlife Service, National Key Deer Refuge, Big Pine Key, FL 33043, USA.

Gavin 1987, Conover et al. 1995). Riley et al. (2002:586) argued that this would require the wildlife profession to "reexamine its purpose to emphasize fundamental anthropocentric objectives." If this is a call to re-examine techniques, management goals, and policy in light of stakeholder perspectives, rather than a challenge to nonhuman-centered ethics, we concur. Urban wildlife management will lead this movement by necessity if for no other reason. The ongoing transition toward public participation in wildlife management likely will require a re-evaluation of the ethical basis for research within the wildlife profession as well as how research is perceived by various publics. If this re-evaluation is not self-imposed, various watchdog groups or community activists will impose it externally as they become more intimately involved in the management process (Farnsworth and Rosovsky 1993).

The public and the wildlife management profession tend toward fundamentally different perceptions of wildlife. Traditional wildlife management is rooted in Leopold's (1949) Land Ethic, and finds value in biological integrity (Callicott 1980). Accordingly, Leopold had, and many in the wildlife profession still have, no qualms about hunting, eating meat, or inadvertently killing animals while capturing wildlife. From a population or community perspective, the value of information garnered from research involving collection of animals or capture-related mortality outweighs the individual animal costs (Farnsworth and Rosovsky 1993). Further, the likelihood that these activities improve our ability to protect and restore ecological integrity makes them morally right according to the land ethic (Callicott 1980) and scientific construction of nature (Rolston 1981). Although the wildlife profession is by no means monolithic in this perspective, an emphasis on biotic populations and communities undoubtedly exists.

The public's view of wildlife management issues takes a more Kantian (Kant 1873) approach in which moral obligations are inherent within individuals. Kant suggested that cruel treatment of individual animals was wrong primarily because it evoked depravity in the abuser. Schweitzer (1950) placed individual animals on even stronger ethical footing by arguing for an equal reverence for life, whether human or nonhuman. Most members of the public support animal welfare and compassionate treatment of animals for these reasons, but a significant portion also supports animal rights. Singer's (1975) book, *Animal Liberation*, provided a philosophical rationale for extending rights from individual humans to individual animals (Muth and Jamison 2000). The contemporary animal-rights movement is an attempt to broaden the list of species whose individual members are due moral consideration to some arbitrary point of sentience (Regan and Singer 1976, Singer 1975). Clearly, both animal-welfare and animal-rights advocates are more likely to focus on individual animals and their plight than on an entire biotic community. Although the logic of perceiving wildlife in this fashion is questionable (Callicott 1980, 1987), it is psychologically appealing (Rolston 1981, Kellert 1986).

Either viewpoint may be legitimately defended. Research involving urban wildlife in general, and urban endangered species in particular, compounds problems caused by these different social constructions of wildlife. Visibility, charisma, ubiquity in urban environments, and a relatively high ranking on a sentience scale make the white-tailed deer (*Odocoileus virginianus*) an excellent test-case regarding how wildlife professionals approach urban wildlife capture in the age of public participation (McAninch 1995, Messmer et al. 1997, Chase et al. 2000). These issues are further magnified when the management of an urban and endangered species such as the Florida Key deer (*O. v. clavium*) is considered (Peterson et al. 2002).

Key-deer management provides an ideal case study for evaluating capture methods for urban deer according to the aforementioned social constructions of wildlife. In this paper, we evaluate capture methods for urban deer using both published accounts of white-tailed deer capture and our personal experiences with capturing Key deer. We use capture-related mortality as an evaluative factor, because from an individualistic viewpoint, killing an individual is the ultimate wrong in wildlife capture. Individualists may quibble over how much discomfort capture must cause an animal before it is wrong, but killing the animal during capture is wrong by definition. We include our personal observations of deer capture on Big Pine Key, Florida, because a myriad of factors including perceived stress to the animal, time taken by the capture event, passivity of the capture device, public education, researcher behavior, and the nature of the workup process influence public perceptions. Efficiency in terms of worker-hours becomes less important in urban environments where individual animals are endowed by much of the public with

rights. Thus, trading deer lives for lower labor costs is morally repugnant to those with an individualistic viewpoint. Grossly inefficient capture methods purporting to cause low capture mortality still may be rejected, but are rare precisely because of the population-community perspective heretofore in vogue.

Thus, we evaluated a coterie of reasonably efficient capture methods for use in urban environments. More specifically, we 1) used field notes (1998–2002) to determine how residents, whose willing participation determined our research success, viewed Key deer and our capture methods, 2) compared capture mortality among different methods used to capture white-tailed deer in both urban and less human-influenced settings based on our experience with Key-deer capture and published accounts, and 3) suggested methods for urban deer capture based on their respective mortality rates and public perceptions of urban wildlife.

Study area

Florida Key deer, an endangered subspecies of white-tailed deer, are endemic to the Florida Keys on the southern end of peninsular Florida (Hardin et al. 1984). Key deer occupy 20–25 islands within the boundaries of the National Key Deer Refuge (NKDR) in Monroe County, with approximately 75% of the overall deer population (≈500) on Big Pine (2,548 ha) and No Name (461 ha) keys (Lopez 2001, Lopez et al. 2003). Approximately 5,000 people share these 2 keys with Key deer (Lopez 2001). All data presented in this paper were collected on Big Pine and No Name keys.

A curious doe watches researchers radiocollar its fawn in the Port Pine Heights subdivision. Photo by W. Peterson.

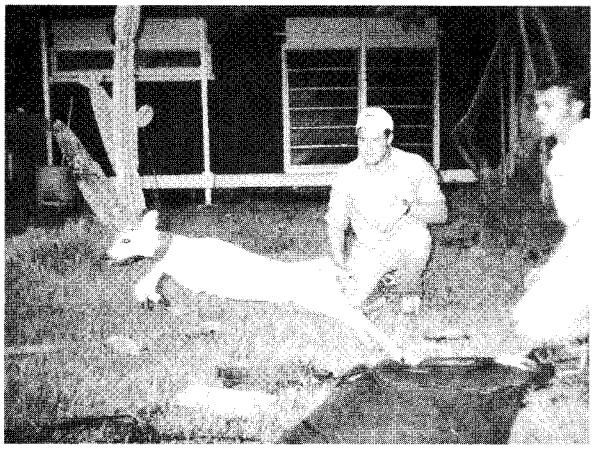
The NKDR and residential areas created a patchwork of urban and natural landscapes on these keys (Lopez 2001). Typically, island areas near sea level (maritime zones) were comprised of red mangrove (*Rhisophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*) forests. With increasing elevation, maritime zones transition into hammock (e.g., gumbo limbo [*Bursera simarub*], Jamaican dogwood [*Piscidia piscipula*]) and pineland (e.g., slash pine [*Pinus elliottii*], saw palmetto [*Serenoa repens*]) upland forests intolerant of salt water (Dickson 1955).

Methods

Key-deer capture

Key deer were captured and fitted with mortality-sensitive radiocollars (150–152 MHz, 100–110 g for plastic neck collars, 10–20 g for antler transmitters and elastic collars, Advanced Telemetry Systems, Isanti, Minn.) as part of other studies conducted January 1998–December 2000 (Lopez 2001, Lopez et al. 2003), and May–August 2002.

We captured deer using portable drive nets (Silvy et al. 1975), free-standing tension-release drop nets (Lopez et al. 1998), hand capture (Silvy 1975), net gun (DelGiudice et al. 2001), and dart gun. No more than 3 deer were captured at once using drop nets or drive nets. During net-gun captures, we approached deer on foot rather than by helicopter. We captured adult deer using immobilizing drugs delivered with a Dan-inject® dart gun (Wildlife Pharmaceuticals, Inc., Fort Collins, Colo.), with shots at ranges of ≤15 m to the gluteal muscle. We immobilized deer with a combination of ≈5.1 mg



A fawn is released in the Eden Pines subdivision. Photo by B. Porter.

ketamine hydrochloride and 1.1 mg xylazine hydrochloride per kg body mass via intramuscular injection. When using this procedure, we held deer 24 hours at the NKDR deer facility to allow the drugs to dissipate before release.

With the exception of darted deer, we used physical restraint to hold all animals for 5–15 minutes. After capture we blindfolded and physically restrained deer with rope to minimize struggling. We handled deer on a stretcher, and for each deer captured we recorded sex, age, capture location, weight, radio frequency, injuries sustained during capture, and body condition prior to release.

We monitored radiocollared deer 6–7 times per week at random intervals via either homing or triangulation (Lopez et al. 2003). We immediately followed mortality signals by walk-ins to determine cause of death from evidence at recovery sites. We necropsied all carcasses using procedures described by Nettles (1981), or we submitted carcasses for necropsy to the Southeastern Cooperative Wildlife Disease Study, University of Georgia–Athens. Since clinical signs of exertional myopathy progress within a few days of capture and rarely take as long as a month to appear (Basson and Hofmeyr 1973, Williams and Thorne 1996), we evaluated all mortalities occurring within 2 weeks of release for capture-related causes. We monitored all deer until radio failure.

During capture activities, we explained both the method and purpose of the capture to bystanders. We often demonstrated how telemetry equipment could locate a recently captured deer after it was released. Those who insisted on participating by encroaching on the handling area were enlisted to watch for vehicle traffic that might endanger the deer upon release. We also attended meetings of local organizations to inform the public about the study.

We used field notes taken during capture activities (1998–2002) to determine how the public viewed Key deer. Our notes reflected the perspectives of landowners living near/on suitable habitat patches whom we asked for access, and spectators who offered their opinions without solicitation. We used the 5 steps of thematic analysis (Peterson et al. 1994): 1) searching for themes in each transcript, 2) developing each theme, 3) determining the significance of each theme, 4) searching for oppositions among themes and thematic hierarchies, and 5) comparing thematic hierarchies and themes to analyze field notes.

Retrospective analysis

We reviewed published literature on the capture of both urban and other white-tailed deer using the ISI Science Citation Index Expanded (1966–2002), and paper indexes for *The Journal of Wildlife Management* and the *Wildlife Society Bulletin*. We also evaluated additional studies cited in articles found using the aforementioned approaches. Studies with <10 deer captures per method were omitted. We noted capture method, number of deer captured; mortality observed; presence or absence of post-capture monitoring; whether tranquilizers, sedatives, or chemical immobilizing agents were used post-capture; and any unusual handling or transporting methods. We summarized trapping data and evaluated each method by capture-related mortality. Because differences in handling procedures, different post-capture monitoring periods, and the common practice of sedating deer caught using nets or box traps could confound statistical tests, we compared capture methods using box-and-whisker plots.

Results

Key deer

Capture, mortality, and injury. We captured 282 Key deer (128 males, 154 females) in our study using 5 techniques (Table 1). We observed no mortalities during capture activities, but one adult female caught with a drop net died 2 weeks post-capture when struck by a motor vehicle. Necropsy results did not suggest any capture-related problems. No serious injuries (e.g., lacerations, broken bones) were noted during capture activities. Two adult females limped and one female fawn had an abrasion on its tail after capture with the drop net. Two male fawns captured with a drive net and one hand-captured female fawn suffered minor abrasions.

Public perception. Field notes reflected interactions with approximately 300 spectators. Two dominant themes regarding public perception of Key deer and thus Key-deer capture emerged during thematic analysis. The public demonstrated an individualistic view of Key deer in every recorded interaction, while an anthropomorphic (ascribing human characteristics to nonhuman entities) perspective was evident in repeated interactions with a smaller portion of the community ($n \approx 20$). The individualistic perspective toward deer was demonstrated by the "underground" medical care of deer mentioned by 14 different spectators. The "deer

Table 1. Summary of capture methods used for white-tailed deer, 1954–2002.

Category Capture method	Number captured	Mortality (%)	Post-capture monitoring	Chemical immobilization[a]	Reference
Passive, staffed					
Hand capture	40	0.0	Yes	No	This study
Drive net	144	2.1	Yes	No	Silvy et al. 1975
Drive net	28	3.6	No	No	DeYoung 1988
Drive net	430	1.4	Yes	No	Sullivan et al. 1991
Drive net	69	0.0	Yes	No	This study
Drop net	292	0.3	No	No	Ramsey 1968
Drop net	175	6.9	Yes	0.5 mg/kg xylazine	Conner et al. 1987
Drop net	164	0.0	Yes	No	This study
Passive, unstaffed					
Box trap (Stephenson)	47	0.0	No	No[b]	Hawkins et al. 1967
Box trap (Cohick)	92	7.6	Yes	No	Peery 1968
Box trap (Stephenson)	2,035	2.1	No	No	Palmer et al. 1980
Box trap (Stephenson)	367	3.3	Yes	1 mg/kg ketamine 1 mg/kg xylazine	Haulton et al. 2001
Clover trap	115	0.9	No	No	Clover 1954
Clover trap	254	4.7	Yes	No	Fuller 1990
Clover trap	115	5.2	Yes	No	Beringer et al. 1996
Clover trap	167	7.2	Yes	00-400 mg ketamine[c] 50 mg xylazine	DelGiudice 2001
Clover Trap	29	20.7	Yes	1 mg/kg ketamine 1 mg/kg xylazine	Haulton et al. 2001
Corral Trap	302	13.9	No	No[d]	Hawkins et al. 1967
Explosives mandatory					
Rocket-cannon net	33	6.1[e]	No	No	Hawkins et al. 1968
Rocket-cannon net	17	23.5	No	50-100 mg promazine	Palmer et al. 1980
Rocket-cannon net	300	10.3	Yes	No	Beringer et al. 1996
Rocket-cannon net	132	4.6	Yes	1 mg/kg ketamine 1 mg/kg xylazine	Haulton et al. 2001
Net Gun	42	2.4	No	No	DeYoung 1988
Net Gun	63	1.6[f]	Yes	300-400 mg ketamine[c] 50 mg xylazine	DelGiudice 2001
Net Gun	2	0	Yes	No	This study
Chemical immobilization					
Crossbow	83	15.7	No	nicotine alkaloids	Hawkins et al. 1967
Dart Gun	75	20.0	No	nicotine alkaloids	Hawkins et al. 1967
Dart Gun	44	13.6	No	≈9 mg succinylcholine chloride	Palmer et al. 1980
Dart Gun	23	0.0	Yes	200 mg ketamine[g] 70 mg xylazine	DeNicola and Swihart 1997
Dart Gun	31	0.0	Yes	280 mg ketamine 225 mg xylazine	Kilpatrick et al. 1997
Dart Gun	51	2.0	Yes	≈13.3 mg/kg ketamine ≈2.7 mg/kg xylazine	Haulton et al. 2001
Dart Gun	7	0.0	Yes	≈5.5 mg/kg ketamine ≈1.1 mg/kg xylazine	This study
Longbow	63	33.3	No	nicotine alkaloids	Hawkins et al. 1967
Oral Sedative	36	22.2	No	valium	Hawkins et al. 1967

[a] This category includes neuromuscular blocking drugs, general anesthetics, and/or tranquilizers/sedatives used after capture with nonchemical techniques.

[b] Used nicotine alkaloid injection on 1 adult male.

[c] Used 50 mg xylazine and 200 mg ketamine for fawns.

[d] Used nicotine alkaloid injections on adult males with 26.8% mortality.

[e] Both deer held >1.5 hours before release.

[f] This doe found tangled in a barbed wire fence.

[g] Used 35 mg xylazine and 100 mg ketamine for deer weighing <45 kg.

lady" was a somewhat mythical figure, possibly derived from multiple people, who dispensed medical advice to locals attempting to rehabilitate injured deer. "Dave" told us how he used an ointment prescribed by the deer lady to heal an older buck with a brain abscess; another resident described using the ointment to treat a doe with a festering wound on her abdomen caused by a pellet gun (M. N. Peterson, field notes, 23 May 2002). "John" fed a buck for over a year while it was incapable of foraging on its own and continues to care for a doe that was partially incapacitated by an improperly healed leg fracture (M. N. Peterson, field notes, 3 Jul 2000). Similarly, only 3 months into the study, the *Miami Herald* reported, "One of them [collared deer] has been spotted entangled in the bushes hanging feet off the ground" (Lynch 1998). The article also cited comments from locals such as, "It literally brings tears to my eyes to think they're going to put collars on them (deer)."

Although the anthropocentric theme was less dominant, those who saw Key deer from this perspective significantly influenced our ability to capture deer because they typically fed and watered deer. Eight property owners tracked genealogy of "their" deer, and references to individual deer according to their family position (e.g., grandma, grandpa, momma, baby) was common. When one of these residents discovered our intention to capture several pregnant does on his property, he assured us that they were not actually pregnant. To ease our concerns, he palpated each of them while they foraged on and around his avocado tree, nodding and saying "She's already dropped" after rubbing their bellies (M. N. Peterson, field notes, 11 Jun 2002). Bleating fawns elicited responses from spectators of "The baby didn't do anything to you" and "Why are you doing this to him" (M. N. Peterson, field notes, 9 Jun 2002). In reference to several other fawns, "Anne" said, "They're my little babies, and they know if they come by here they can get a little extra nourishment" (M. N. Peterson, field notes, 15 Jul 2000).

Published accounts

Only 16 articles we reviewed provided both capture-related mortality and had ≥10 white-tailed deer captures using a single technique. Several studies evaluated multiple methods including (Table 1) box traps ($n=4$), drop nets ($n=2$), drive nets ($n=3$), corral traps ($n=1$), Clover traps ($n=5$), cannon nets ($n=1$), rocket nets ($n=3$), net guns ($n=2$), oral

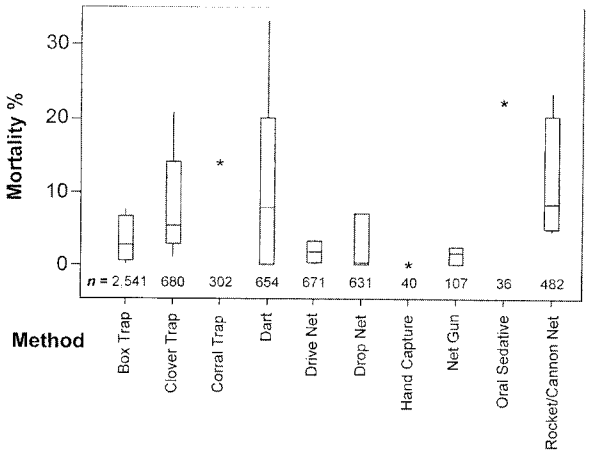


Figure 1. Box-and-whisker plots (boxes shown medians and quartiles, whiskers show ranges) of mortality (%) by white-tailed deer capture method. Asterisks represent one study per method.

tranquilizers ($n=1$), and darting ($n=6$). Mortality associated with box traps, drop nets, Clover traps, rocket nets, and darting was highly variable (0.0–33.3%), both within and between methods (Figure 1). High deer mortality (13.9 and 22.2%, respectively) occurred during the only studies using corral traps and oral sedatives (Hawkins et al. 1967). Conversely, mortality associated with drive nets and net guns was 0–3.6%. Studies using chemical immobilizing agents, tranquilizers, or sedatives after deer where captured with other techniques typically resulted in higher mortality than those using only physical restraint post-capture (Figure 2).

Box and Clover traps. Mortality associated with the use of box traps varied from 0.0–7.6% (Table 1). The study reporting 7.6% mortality, however,

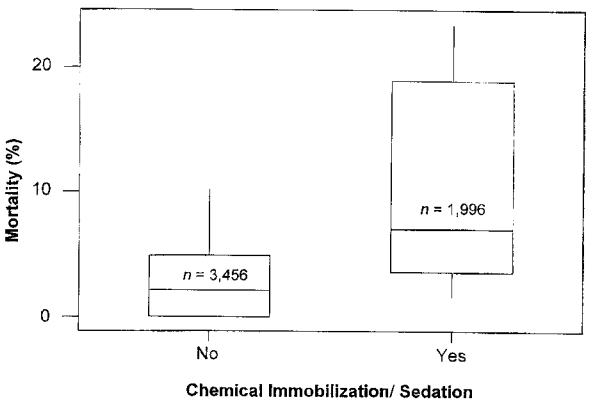


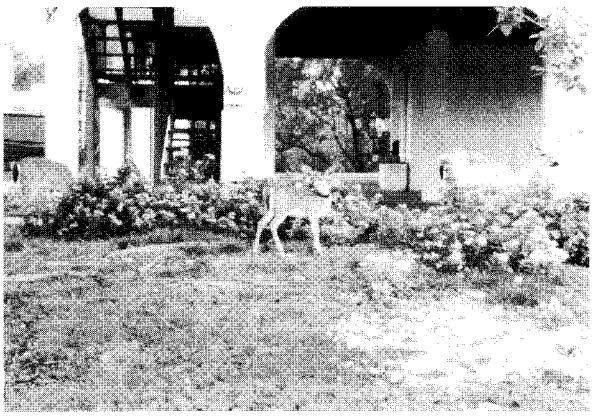
Figure 2. Box-and-whisker plots (boxes show medians and quartiles, whiskers show ranges) comparing white-tailed deer capture mortality (%) between studies not using neuromuscular blocking drugs, general anesthetics, or tranquilizers/sedatives, and studies using them after capture with a nonchemical-related method.

involved transporting or holding deer overnight prior to release (Peery 1968). If the aforementioned study was not considered, 3.3% was the highest mortality reported for this method (Table 1; Haulton et al. 2001). These deer were immobilized with ketamine hydrochloride and xylazine hydrochloride via intramuscular injection, so the mortality rate attributed to box traps might have been a function of chemical immobilization as well. Studies not using chemical immobilization in conjunction with box traps (Hawkins et al. 1967, Palmer et al. 1980) had lower mortality (Table 1), but neither monitored deer post-capture for exertional myopathy-related deaths.

Clover traps also had variable mortality (Figure 1). Clover (1954) reported 0.9% mortality, but did not monitor deer post-capture (Table 1). Fuller (1990) and Beringer et al. (1996) reported 4.7 and 5.2% mortality, respectively, and monitored deer post-capture (Table 1). Beringer et al. (1996) might have increased Clover trap-related mortality by leaving some deer in traps for up to 24 hours. The highest levels of capture-related mortality occurred in studies using drugs to immobilize deer after capture in Clover traps (DelGiudice et al. 2001, Haulton et al. 2001). For example, Haulton et al. (2001) chemically immobilized captured deer with a 1:1 mixture of ketamine hydrochloride and xylazine hydrochloride via intramuscular injection at 1 mg of the mixture per kg body mass and reported 20.7% capture-related mortality (Table 1). All documented mortalities were fawns.

Drop nets. Although we did not experience mortality using the modified drop net (Lopez et al. 1998; Table 1), Conner et al. (1987) reported 6.9% mortality using a slightly larger nonfree-standing drop net followed by an intramuscular dose of xylazine (Table 1). Again, the dangers inherent to the drop net might have been combined with use of sedatives. Further, larger net size, capture of larger groups, and the assumption that 6 animals (50% of their mortality) with unknown fates actually were capture-related mortalities might have artificially inflated their mortality estimate. Although Ramsey (1968) did not monitor deer post-capture, his 0.3% mortality (Table 1) suggested that dropping on larger groups of deer ($\bar{x}$ = 10; maximum = 23) did not necessarily result in high mortality.

Drive nets. Several types of nets and different driving techniques (e.g., Silvy et al. 1975, Sullivan et al. 1991) have been used with consistently low mortality (Figure 1). Sullivan et al. (1991) and DeYoung (1988) used large fixed nets and hazed deer by helicopter for up to 9 minutes before capture. We drove deer on foot when using drive nets. Silvy et al. (1975) developed their drive net for urban use, so the lack of mortality in our study may reflect experience gained in the first study. For instance, Silvy (1975) reported 0% mortality in 83 drive-net captures after publication of the aforementioned study (Silvy et al. 1975). Because Silvy et al. (1975) found that injuries were reduced if deer hit the net at lower speeds, we attempted to "startle" deer into the net after slowly pushing them toward it, rather than driving them at full speed into the net.



Key deer forage in the Port Pine Heights subdivision. Photo by N. Peterson.

Cannon nets and rocket nets. Palmer et al. (1980) reported the highest mortality using rocket nets, but only 1 person stayed at the net and tranquilized captured deer with promazine hydrochloride. Again, risk of mortality from tranquilization and the capture method cannot be separately determined. Additionally, handling time was presumably longer in their study than for the others in which several field assistants were on site and tranquilizers were not used (Table 1). Although Hawkins et al. (1968) reported 6.1% mortality, both animals that died had been held >1.5 hours before release (Table 1). Beringer et al. (1996) and Haulton et al. (2001), however, still reported 10.3 and 4.5% mortality (Table 1), respectively, so even under more ideal conditions, mortality did not approach 0.

Darting. Chemical immobilization using darts had the highest variability in capture-related mortality (Figure 1). This could be due at least partly to improvements in this methodology and drugs over time (Table 1). Both the longbow and crossbow were abandoned as darting tools after being involved in studies with high mortality (Table 1). Further, federal

regulations now require an attending veterinarian for chemical immobilization (Code of Federal Regulations 9, Uniform Rules of Practice for the Department of Agriculture). Thus, the 4 most recent studies (Table 1), approaching 0.0% capture-related mortality, were conducted under laws that required experience with these drugs, if not the technique. Moreover, it seems clear that both legal and moral constraints now require practitioners of this technique to be experienced (Pond and O'Gara 1996).

Discussion

Key-deer capture

In our study of Key deer, positive public relations were critical because we needed to 1) trap deer, 2) track deer, and 3) locate mortalities on private property throughout the study. In urban settings, trapping and monitoring activities must occur primarily on private property. Significant opposition existed between those with individualistic and anthropomorphic views regarding management because those who saw Key deer as individuals but not human opposed giving deer equal status with themselves (Peterson et al. 2002). This opposition did not exist, however, when it came to evaluation of capture methods. Both groups were critical of apparent discomfort to deer caused by capture. They also opposed methods appearing to be violent, regardless of their other merits. Thus, to ensure future access, our capture techniques could not injure or kill individual animals even if major improvements in efficiency could be realized. The public's individualistic and often anthropomorphic view of Key deer motivated us to choose techniques for each specific capture context based upon the goals of no mortality or injury, passivity, efficiency, and rapid immobilization.

We attempted to tailor methods to minimize negative effects on individual deer by considering age class. For example, we exclusively captured fawns with drive nets because they allowed us to target one individual at a time (Table 1). This prevented fawns from being injured by struggling adults. In urban areas we trapped most adult deer using a drop net or by hand. Two handlers were available to immediately immobilize each animal, and 3 to handle it prior to release. Residents were not exposed to a deer "rodeo" because animals were quickly immobilized (<1 minute) and processed (5–15 minutes) using these methods. We handled deer on a stretcher, and materials were clean and organized. When a deer struggled excessively or demonstrated signs of stress, we reduced holding time by omitting steps such as taking blood or fecal samples.

The free-standing tension-release drop net was the most useful method for capturing urban deer on Big Pine Key. It was passive and silent, caused no mortality or serious injury, and the weight of the net partially restrained deer on impact. Further, its free-standing design worked on paved surfaces and could be used on private residences without driving posts into people's yards. The drive net was a valuable tool for catching fawns, which would not respond to bait under the drop net, and "net-shy" deer familiar with the drop net. In the most developed areas, barriers such as fences, buildings, vehicles, and canals made the drive net more effective. Slowly pushing deer toward the net before startling them, and leaving some slack in the net, allowed soft captures. Deer running at full speed were the only ones that sustained abrasions or were flipped, jolted, or twisted enough by the impact with the net to upset spectators. We received some negative feedback when using drive nets because this approach required chasing or at least startling deer. For example, one resident would not allow us to attempt to capture pregnant or older deer with a drive net. In fact, some residents suggested hand capture when faced with the possibility of seeing their favorite deer driven headlong into a net. In one instance, when a couple saw us unrolling the drive net, they approached us and said, "You don't need that. They'll eat right out of your hand" (M. N. Peterson, field notes, 4 Jun 2002). They then demonstrated how the doe could be enticed by a piece of raw potato, and gave us a piece to catch "their" deer with. By hand-capturing "tame" deer, time to physical immobilization was less than required for any other methods and deer had almost no chance of injuring themselves. Although "grabbing" deer may be impractical in many settings, hand capture should be considered where possible in urban settings. When urban deer are accustomed to hand feeding, the method is efficient. It can be dangerous to biologists, however, particularly when attempted on bucks during the rut (Les Pulley, NKDR, personal communication). With 3 handlers we hand-captured and immobilized males up to 45 kg and females up to 38 kg, including males in rut, without difficulty or injury to handlers.

The net gun could not be used because citizens perceived it as a weapon and explosives were frowned upon in suburban neighborhoods. United States Fish and Wildlife Service (USFWS) biologists used a net gun (White Line, Pachmayr GunWorks,

Los Angeles 15, CA, Patent # D191, 449) exclusively for Key-deer capture prior to our study with moderate success (Tom Wilmers, NKDR, personal communication). They had difficulty catching deer when they stalked them by foot. Hazing deer with helicopters or shooting out of vehicles in residential areas did not seem prudent and was not attempted. Further, when the net gun was used, citizens often called the law-enforcement offices complaining of gunfire (Les Pulley, NKDR, personal communication), so this technique required coordination with local law-enforcement personnel.

Residents also viewed dart guns as weapons. In one instance where we attempted to use a dart gun to capture an injured deer, nearly a dozen distraught tourists gathered around, asking, "Why are you going to shoot it?" and "Are you going to kill it?" (M. N. Peterson, field notes, 25 Jul 2002). Moreover, dense natural vegetation made darted deer difficult to find (Silvy et al. 1975), and the prospect of drugged deer wandering across roads and into yards deterred us from using this technique in urban areas.

Darts equipped with radiotransmitters alleviated the problem of finding deer (Kilpatrick et al. 1997), but barbed darts required surgical removal. Fourteen percent of the deer Kilpatrick et al. (1997) darted were not found, and one dart (3%) was not found. Presumably, these urban deer might have wandered throughout the residential area for several days with a barbed dart hanging from their sides. In the one instance in which NKDR biologists attempted to use this technique, the darted buck did not go down and carried the dart in its side while foraging in urban areas for nearly one week. Numerous complaints were made to refuge personnel (Helana Cichon, NKDR, personal communication). The buck eventually was captured with a drop net. Further, one unrecovered dart, depending on the chemical agent used, could represent an unacceptable risk to human safety in urban areas. In our study, 3% would equate to 9 darts potentially containing dangerous drugs lying around residential areas of Big Pine Key.

Human safety issues precluded the use of cannon nets or rocket nets in close proximity to residences. Human proximity also made Clover traps and box traps less practical because trapped deer could be exposed to people and pets until we removed them from traps.

Capture-related mortality

From our experiences with Key deer and published accounts of white-tailed deer capture elsewhere, it appears that several factors other than the capture technique itself influence capture-related mortality (Figure 1). Handling time, workers per animal, experience with the method in question, combining drugs with other methods (Figure 2), study-area attributes, environmental conditions, physical condition of individuals targeted, and monitoring probably all influence observed mortality. Researchers can control most of these variables, and Haulton et al. (2001) listed recommendations for controlling the problems associated with many of these factors. Although they described how darting and chemical immobilization should be conducted, they did not address whether chemical agents should be used routinely after capture using techniques not involving drugs.

We maintain that acceptance of anesthetizing, chemical immobilization, or tranquilization as an apparent requisite to deer capture by nonchemical methods is too pervasive in wildlife research. For example, Henderson et al. (2000:904) cited Conner et al. (1987) to support their claim that using chemical immobilization would "minimize capture myopathy." Not only did Conner et al. (1987) not use chemical immobilization (they sedated deer with xylazine hydrochloride), they made no attempt to demonstrate any link between sedating deer and reduced capture-related myopathy. In fact, Conner et al. (1987) provided no rationale for using these pharmaceuticals.

There is little evidence that anesthetizing, chemically immobilizing, or tranquilizing white-tailed deer after capture with nonchemical techniques reduces capture-related mortality. If anything can be inferred from existing studies, researchers who used these drugs after they captured deer using other techniques reported higher mortality than those who did not (Figure 2). Arguments for chemically immobilizing or tranquilizing deer to reduce stress after capture are suspect. First, stress is rather difficult to quantify for wildlife (Callicott 1980). Further, because some commonly used agents, such as xylazine, are primarily sedatives, they do not eliminate pain. Similarly, anesthetics do not act immediately, so one must assume that darted deer still feel pain and are under stress until anesthesia is achieved.

Deer often can be handled and released in less time (5–10 minutes) than it takes for an anesthetic to take effect (this study, Sullivan et al. 1991). High mortality (20.7%) associated with chemical immobilization of fawns (Haulton et al. 2001) suggests

that even experienced technicians should question chemically immobilizing fawns unless surgical procedures or other study parameters require doing so. Finally, we must ask: what is the purpose of chemically immobilizing a deer that already is physically immobilized? We suggest following the lead of the medical community in using chemical immobilization only when absolutely necessary. For example, anesthetics might be warranted in studies requiring surgery and certain studies where handling time greatly exceeds induction time, but probably are not required for most other purposes.

Because of the public focus on individual deer, hazing with helicopters, drop nets armed with explosives, and capture-related injury and mortality were not as acceptable to those perceiving wildlife individualistically or anthropomorphically as to wildlife management professionals. Drop nets, drive nets, hand capture, net guns, and dart guns (Table 1) all can be used to capture deer with associated mortality approaching 0. The first 3 methods, however, are more appropriate for urban areas where time to immobilization, human safety, noise, and public perception are critical factors.

Conclusions and implications

Although previous management activities associated with Florida Key deer met with public resistance (Peterson et al. 2002), community members did not oppose our radiotelemetry study once it began. Demonstrating respect for individual deer by using capture techniques that yielded low mortality and injury rates and quick immobilization indirectly demonstrated respect for individualistic and anthropocentric viewpoints in the community. This was instrumental to the positive public response to our research. These attributes should be sought in any capture technique used in wildlife research where participation by publics espousing individualistic or anthropocentric social constructions for nature is likely. In some ways, the case of Key deer might be perceived as new or unique, but the way Big Pine Key residents viewed wildlife was neither (Berris 1987).

In urban environments, the modified drop net (Lopez et al. 1998), drive net (Silvy et al. 1975), and hand capture might be the most appropriate tools for capturing deer. Although these methods sometimes are more labor-intensive, they result in nearly 0% mortality and are perceived favorably by the public. Any increased labor costs should be weighed against future costs to the wildlife profession created by using methods more likely to kill or seriously injure individual white-tailed deer in full public view. If the public experiences the dramatic death of a fawn, for example, an urban white-tailed deer study with even 1.0% mortality could negatively impact future wildlife research in the area for years to come. Conversely, studies of urban deer that require capture can improve public perception of wildlife research if they are tailored to demonstrate respect for individual deer and public perceptions of the deer.

The aforementioned attributes are mandated in part by public involvement, but we must remember that deer capture conducted in rural areas essentially becomes public when published in scientific journals or elsewhere. Undoubtedly, techniques involving helicopters, dart guns, or cannon and rocket nets are more acceptable in rural environments, but techniques resulting in high mortality or injury rates are not. Since several deer capture techniques can be used with nearly no mortality (Figure 1), this should beg the question of whether we can justify deer capture resulting in >1% mortality to a public that values animals as individuals. Perhaps we can, but in such circumstances the justification should be explicitly stated.

Improvements in capture techniques discovered during studies with other objectives certainly are valuable to the wildlife community, but should be published with the caveat that evaluating mortality and stress associated with techniques was not the primary motivating factor behind the research. We assumed that statements about tooth extraction, tagging, weighing, and collaring indicate that other research objectives, such as population age structure, health, and density estimates, were implicit in reviewed studies. However, the belief that wildlife biologists, let alone the public, will understand that these deer were captured for other purposes is probably an unfounded assumption. A statement such as "To obtain animals for an ecological study using radiotelemetry, it was necessary to develop a safe but productive capture technique" would be ideal (Silvy et al. 1975). Our argument is not directed toward physiological research but rather at the circular logic inherent in the idea that deer should be captured to determine how much capture hurts them. The constant need for demographic information on wildlife populations provides ample opportunity to evaluate innovations in capture techniques. Studies conducted solely to determine the levels of mortality, stress, or other animal suffering

caused by research techniques should cease.

Although white-tailed deer capture techniques have evolved to the point where researchers have several ways to capture deer with nearly no injury or mortality, the situation may be different for other species. Methods known to be dangerous, however, should not be tested merely to provide comparisons with new methods. Statistical differences among mortality associated with various capture methods are not as important to the public, or the scientific community, as 0 mortality. We are aware that chance events will preclude this possibility in some studies, but this should be the goal, not demonstrating statistical differences. The wildlife profession is answerable to an ethic generated by society at large even if we do not espouse it in its entirety. We should regulate ourselves regarding research techniques and goals before others regulate us. Although population-community and individualistic paradigms cannot be reconciled in all research situations (Callicott 1980), they should be carefully balanced, particularly where urban wildlife capture is concerned.

Acknowledgments. We thank Texas A&M University (TAMU) student interns who assisted in the collection of field data, and 2 anonymous reviewers and C. Nilon for constructive criticism and for sage guidance for making this manuscript palatable for a broad audience. Special thanks are extended to the staff of the NKDR, Monroe County, Florida. The TAMU System, Rob and Bessie Welder Wildlife Foundation, and USFWS provided funding. Key-deer capture and handling protocols were reviewed, approved, and permitted under USFWS Special Use Permit No. 97-14 and TAMU Animal Use Permit No. 2002-139. Human research protocol was reviewed and approved by the TAMU Independent Review Board Permit No. E2000-221. The Welder Wildlife Foundation, Contribution No. 602, supported this project.

Literature cited

Basson, P.A., and J. M. Hoefmeyr. 1973. Mortalities associated with wildlife capture operations. Pages 151–160 *in* E. Young, editor. The capture and care of wild animals. Human and Rousseau Publishers, Cape Town, South Africa.

Beringer, J. L., P. Hanson, W. Wilding, J. Fischer, and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. Journal of Wildlife Management 60:373–380.

Berris, C. R. 1987. Interactions of elk and residential development: planning, design, and attitudinal considerations. Landscape Journal 6:31–41.

Brick, P., D. Snow, and S. Van de Wetering, editors. 2001. Across the great divide: explorations in collaborative conservation in the American west. Island Press, Washington, D.C., USA.

Callicott, J. B. 1987. Companion to a *Sand County Almanac*. University of Wisconsin, Madison, USA.

Callicott, J. B. 1980. Animal liberation: a triangular affair. Environmental Ethics 2:311–338.

Chase, L. C., T. M. Schusler, and D. J. Decker. 2000. Innovations in stakeholder involvement: what's the next step? Wildlife Society Bulletin 28:208–217.

Clover, M. R. 1954. A portable deer trap and catch-net. California Fish and Game Journal 40:367–373.

Conner, M. C., E. C. Soutiere, and R. A. Lancia. 1987. Drop netting deer: cost and incidence of capture myopathy. Wildlife Society Bulletin 15:434–438.

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23:407–414.

Decker, D. J., and T. A. Gavin. 1987. Public attitudes towards a suburban deer herd. Wildlife Society Bulletin 16:53–75.

DelGiudice, G. D., B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer captured by Clover trap and net-gun. Wildlife Society Bulletin 29:1147–1157.

DeNicola, A. J., and R. K. Swihart. 1997. Capture-induced stress in white-tailed deer. Wildlife Society Bulletin 25:500–503.

DeYoung, C. A. 1988. Comparison of net-gun and drive-net capture for white-tailed deer. Wildlife Society Bulletin 16:318–320.

Dickson, J. D., III. 1955. An ecological study of Key deer. Florida Game and Fresh Water Fish Commission Technical Bulletin 3, Tallahassee, USA.

Farnsworth, E. J., and J. Rosovsky. 1993. The ethics of ecological field experimentation. Conservation Biology 7:463–472.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110.

Hardin, J. W., W. D. Klimstra, and N. J. Silvy. 1984. Florida Keys. Pages 381–390 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Haulton, S. M., W. F. Porter, and B. A. Rudolph. 2001. Evaluating 4 methods to capture white-tailed deer. Wildlife Society Bulletin 29:255–264.

Hawkins, R. E., D. C. Autry, and W. D. Klimstra. 1967. Comparison of methods used to capture white-tailed deer. Journal of Wildlife Management 31:460–464.

Hawkins, R. E., L. D. Martoglio, and G. G. Montgomery. 1968. Cannon netting deer. Journal of Wildlife Management 32:191–195.

Henderson, D. W., R. J. Warren, J. A. Cromwell, and R. J. Hamilton. 2000. Responses of urban deer to a 50% reduction in local herd density. Wildlife Society Bulletin 28:902–910.

Kant, I. 1873. Foundation of the metaphysics of morals. T. K. Abbott, translator, 1949. Bobbs-Merrill Co., New York, New York, USA.

Kellert, S. R. 1986. Social and perceptual factors in preservation of animal species. Pages 50–73 *in* B. G. Norton, editor. The preservation of species. Princeton University Press, Princeton, New Jersey, USA.

Kilpatrick, H. J., S. M. Spohr, and A. J. DeNicola. 1997. Darting urban deer: techniques and technology. Wildlife Society Bulletin 25:542–546.

Leopold, A. 1949. A sand county almanac and sketches here and there. Oxford University Press, London, United Kingdom.

Lopez, R. R. 2001. Population ecology of the Florida Key deer. Dissertation, Texas A&M University, College Station, USA.

Lopez, R. R., N. J. Silvy, J. D. Sebesta, S. D. Higgs, and M. Salazar. 1998. A portable drop net for capturing urban deer. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 52: 206–209.

Lopez, R. R., M. E. Viera, N. J. Silvy, P. A. Frank, S. W. Whisenant, and D. A. Jones. 2003. Survival, mortality, and life expectancy of Florida Key deer. Journal of Wildlife Management 67: 34–45.

Lynch, M. 1998. Researchers watch over Key deer: first study since 1968 keeps tab on herd. Miami Herald. 22 March 1998; section B: 1.

McAninch, J. B. 1995. Urban deer: a manageable resource? Proceedings of the symposium of the 55th Midwest Fish and Wildlife Conference. North Central Section of The Wildlife Society, 12–14 December 1993, St. Louis, Missouri, USA.

Messmer, T. A., L. Cornicelli, D. J. Decker, and D. G. Hewitt. 1997. Stakeholder acceptance of urban deer management techniques. Wildlife Society Bulletin 25: 360–366.

Muth, R. M., and W. V. Jamison. 2000. On the destiny of deer camps and duck blinds: the rise of the animal rights movement and the future of wildlife conservation. Wildlife Society Bulletin 28: 841–851.

Nettles, V. F. 1981. Necropsy procedures. Pages 6–16 *in* W. R. Davidson, F. A. Hayes, V. F. Nettles, and F. E. Kellogg, editors. Diseases and parasites of white-tailed deer. Tall Timbers Research Station, Tallahassee, Florida, USA.

Palmer, D. T., D. A. Andrews, R. O. Winters, and J. W. Francis. 1980. Removal techniques to control an enclosed deer herd. Wildlife Society Bulletin 8: 29–33.

Peery, C. H., III. 1968. The economics of Virginia's deer transplantation program. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 22: 142–144.

Peterson, M. N., T. R. Peterson, M. J. Peterson, R. R. Lopez, and N. J. Silvy. 2002. Cultural conflict and the endangered Florida Key deer. Journal of Wildlife Management 66: 921–942.

Peterson, T. R., K. White, E. Enkerlin-Hoeflich, L. Espericueta, J. T. Flora, N. Florey, T. Loughran, and R. Stuart. 1994. Using informant directed interviews to discover risk orientation: how formative evaluations based in interpretive analysis can improve persuasive safety campaigns. Journal of Applied Communication Research 22: 199–215.

Pond, D. B., and B. W. O'Gara. 1996. Chemical immobilization of large mammals. Pages 125–139 *in* T. A. Bookhout editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Ramsey, C. W. 1968. A drop-net deer trap. Journal of Wildlife Management 32: 187–190.

Regan, T., and P. Singer, editors. 1976. Animal rights and human obligations. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Riley, S. J., D. J. Decker, L. H. Carpenter, J. F. Organ, W. F. Siemer, G. F. Mattfield, and G. Parsons. 2002. The essence of wildlife management. Wildlife Society Bulletin 30: 585–593.

Rolston, H., III. 1981. Values in nature. Environmental Ethics 3: 113–128.

Schweitzer, A. 1950. The philosophy of civilization. First American edition. C. T. Campion, translator. Macmillan, New York, New York, USA.

Silvy, N. J. 1975. Population density, movements, and habitat utilization of Key deer, *Odocoileus virginianus clavium*. Dissertation, Southern Illinois University, Carbondale, USA.

Silvy, N. J., J. W. Hardin, and W. D. Klimstra. 1975. Use of a portable net to capture free-ranging deer. Wildlife Society Bulletin 3: 27–29.

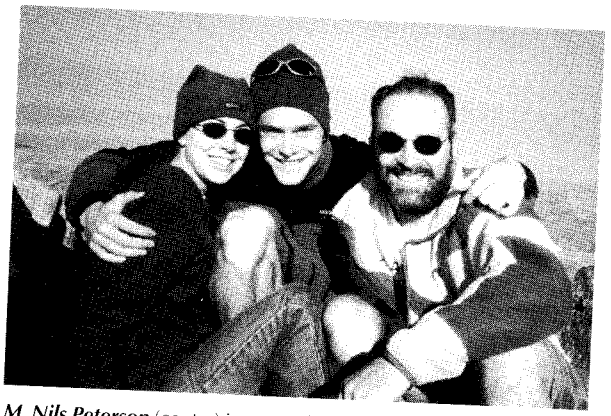
Singer, P. 1975. Animal liberation. Random House, New York, New York, USA.

Sullivan, J. B., C. A. DeYoung, S. L. Beasom, J. R. Heffelfinger, S. P. Coughlin, and M. W. Hellickson. 1991. Drive-netting deer: incidence of mortality. Wildlife Society Bulletin 19: 393–396.

Western, D., and R. M. Wright, editors. 1994. Natural connections: perspectives in community-based conservation. Island Press, Washington, D.C., USA.

Williams, E. S., and E. T. Thorne. 1996. Exertional myopathy (capture myopathy). Pages 181–193 *in* A. Fairbrother, L. N. Locke and G. L. Hoff, editors. Noninfectious diseases of wildlife. Second edition. Iowa State University Press, Ames, USA.

Wondolleck, J. M., and S. L. Yaffee. 2000. Making collaboration work: lessons from innovation in natural resource management. Island Press, Washington, D.C., USA.



M. Nils Peterson (center) is currently a Ph.D. student in the Department of Fisheries and Wildlife at Michigan State University. His research project is evaluating the effects of household dynamics on wildlife. Nils received his B.S. and M.S. degrees in wildlife and fisheries sciences from Texas A&M University. ***Roel R. Lopez*** is an assistant professor with the Department of Wildlife and Fisheries Sciences at Texas A&M University (TAMU). His previous employment was with U.S. Fish and Wildlife Service's National Key Deer Refuge. He received his B.S. in forestry from Stephen F. Austin State University and his M.S. and Ph.D. from Texas A&M University. His research focus is urban wildlife ecology, deer ecology, wildlife population dynamics, and habitat management. ***Philip A. Frank*** is the Florida Keys Project Leader, United States Fish and Wildlife Service. He is responsible for overseeing and implementing recovery actions for threatened and endangered species in the Florida Keys. He received his B.S. in biology from Indiana University, his M.S. in zoology from University of South Florida, and his Ph.D. in wildlife ecology from University of Florida. ***Markus J. Peterson*** (right) is an assistant professor in the Department of Wildlife and Fisheries Sciences at TAMU. He received his B.S. from University of Idaho, D.V.M. from Washington State University, and M.S. and Ph.D. from TAMU. Markus has a wide array of research interests ranging from ecology and management of terrestrial wildlife populations to the formation and implementation of environmental policy. ***Nova J. Silvy*** is a Regents Professor with the Department of Wildlife and Fisheries Sciences at Texas A&M University. He received his B.S. and M.S. from Kansas State University and his Ph.D. from Southern Illinois University-Carbondale. Nova served as President of The Wildlife Society in 2000-2001 and received the Aldo Leopold Award in 2003. His research focus is upland gamebird ecology.

Associate editor: *Nilon*