Capture and chemical anesthesia of Amur (Siberian) tigers

John M. Goodrich, Linda L. Kerley, Bart O. Schleyer, Dale G. Miquelle, Kathy S. Quigley, Yevgeny N. Smirnov, Igor G. Nikolaev, Howard B. Quigley, and Maurice G. Hornocker

Abstract In 1992, we began a research program on the ecology of endangered Amur (or Siberian) tigers (*Panthera tigris altaica*) to develop a database from which conservation plans could be developed. Radiotelemetry was a necessary part of our program because tigers are cryptic, secretive, and difficult to observe; hence, we developed techniques to capture them, equip them with radiocollars, and collect tissue and blood samples. We captured 19 tigers 23 times in 12,287 trap nights during 1992–1998, using Aldrich foot snares. Most (65%, $n=23$) tigers were caught at mark trees, but snares set at kills were most effective (1 capture/47 trap nights, $n=6$ captures). The snared foot was swollen in all cases ($n=18$; data on swelling were not recorded for all captures). We observed no other detectable injuries (e.g., lacerations) in 68% of 22 captures, but in the remaining captures, we observed minor lacerations in 23% of the cases, moderate injuries in 4.5%, and severe injuries in 4.5% (2 fractured metatarsals). To change radiocollars, we recaptured 8 tigers 12 times in 19 attempts from a helicopter (Russian MI-8). Tigers sustained no notable injuries because of capture from helicopter. We anesthetized tigers with a mixture of ketamine hydrochloride ($\bar{x}=10.8 \pm 3.4$ mg/kg, $n=33$) and xylazine hydrochloride ($\bar{x}=0.81\pm0.24$ mg/kg, $n=23$).

Key words Amur tiger, capture techniques, carnivore, foot-hold snare, helicopter, ketamine, *Panthera tigris altaica*, xylazine

Capturing and anesthetizing wild animals is an integral part of many wildlife research projects, particularly those involving cryptic, secretive animals inhabiting dense habitats where visibility is poor. Safe and effective techniques are essential, especially for endangered species. In developing a field research program on Amur (or Siberian) tigers (*Panthera tigris altaica*), we required safe capture and anesthesia techniques to equip animals with radiocollars and collect genetic samples (Miquelle et al. 1996, Miquelle et al. 1999).

Traditional capture techniques for tigers were unsuitable for our research needs. Amur tiger cubs have been captured using dogs, but this sometimes required killing the mother (Abramov 1958, Matyushkin 1966, Smirnov and Miquelle 1999) and was not feasible for capturing adults. Problem tigers have been captured in baited box traps, but these traps were ineffective for capturing tigers away from human habitations (unpublished data), too unwieldy for use in remote areas, and often resulted in injuries such as broken teeth, as have

Address for John M. Goodrich, Linda L. Kerley, Bart O. Schleyer, Dale G. Miquelle, Kathy S. Quigley, Howard B. Quigley, and Maurice G. Hornocker: Hornocker Wildlife Institute/Wildlife Conservation Society, 2023 Stadium Drive, Suite 7, Bozeman, MT 59719, USA; e-mail for Goodrich: tiger372@yahoo.com. Address for Yevgeny N. Smirnov: Sikhote-Alin State Biosphere Zapovednik, Terney, Prymorye Krai, Russia 692150. Address for Igor G. Nikolaev: Institute of Biology and Pedology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok-22, Russia 690022.

occurred with other felids (Rabinowitz 1986). Free-range darting—at bait sites, on drives, or by stalking (e.g., Smith et al. 1983, Stander and Morkel 1991, Stander et al. 1996)—would be difficult because Amur tigers occur at low densities (0.6 tigers/100 km², Smirnov and Miquelle 1999), making encounters unlikely. While Smith et al. (1983) relied on CI-744 (Telazol®, Parke-Davis Company, Detroit, Mich.), which was concentrated enough to be delivered in a single dart, this drug is no longer recommended for tigers because many captive tigers displayed symptoms of central nervous system disease 2 to 4 days after immobilization with Telazol (Tilson et al. 1994). We used an immobilizing agent requiring large volumes and multiple darts, making free-range darting difficult.

We report on the successful initial capture of tigers using Aldrich foot snares and a mixture of ketamine hydrochloride and xylazine hydrochloride. We also report on the capture of free-ranging tigers by darting from a helicopter. We used Aldrich foot snares because snares have been used successfully on other large carnivores such as grizzly bears (*Ursus arctos*) and pumas (*Puma concolor*; e.g., Jonkel 1993, Logan et al. 1999), and because tiger use of kills, travel corridors, and scent marking trees is predictable (Matyushkin 1977, Smith et al. 1989), making them susceptible to capture. However, because tigers on our study area moved over very large, remote, and rugged areas, foot snares were not effective to recapture animals to change radiocollars. Thus, we recaptured tigers from a helicopter.

Study area

We captured tigers in and near the Sikhote-Alin State Biosphere Zapovednik, near the village of Terney, Primorye Krai, in the Russian Far East (44°46'N, 135°48'E). Sikhote-Alin Zapovednik is closed to the public and access is generally limited to Sikhote-Alin Zapovednik staff and visiting scientists. Sikhote-Alin Zapovednik is bordered by the Sea of Japan to the east and bisected by the Sikhote-Alin Mountains, which parallel the coastline and are characterized by low, rolling hills near the coast and steep slopes and broad creek and river valleys farther inland. Elevations reach nearly 1,600 m on the Zapovednik, but most peaks are <1,200 m. We captured animals only on the east side of the Sikhote-Alin, where dominant plant communities included oak (*Quercus mongolica*) forests near the coast, mixed conifer–deciduous forest inland, and Korean

Siberian Tiger Project biologist ascending on a cable to a waiting helicopter after successfully recollaring a study tiger.

pine (*Pinus koraiensis*), larch (*Larix komarovii*), and birch (*Betula* spp.) at higher elevations.

Sikhote-Alin Zapovednik occurs in the coastal region of the Far Eastern Temperate climate zone. Climate was characterized by marked seasonal differences with dry, cold winters ($\bar{x} = -14$°C, January, in Terney) with frequent strong winds and $\bar{x} = 1,190$ mm snow in Terney; summers were moderately hot and wet ($\bar{x} = 15$°C, July in Terney), and most of the average annual precipitation of 788 mm falls in summer (Sikhote-Alin Zapovednik unpublished records).

Larger mammal species that we could have incidentally captured in snares or that could harm tigers in snares included moose (*Alces alces*), elk (*Cervus elaphus*), wild boar (*Sus scrofus*), sika deer (*Cervus nippon*), roe deer (*Capreolus capreolus*), wolves (*Canis lupus*), brown bears (*Ursus arctos*), Asiatic black bears (*U. thibetanus*), and lynx (*Lynx lynx*). Of these, elk, wild boar, and both bear species were common, whereas moose and wolves were rare.

Methods

Ground captures

From 1992 to 1998 we captured tigers in standard Aldrich leg-hold snares (e.g., Jonkel 1993) set primarily on trails and at mark trees (Smith et al. 1989) frequented by tigers; we also set snares at tiger kills, at live bait (domestic goats and pigs), meat, and at a cassette player that played the distress call of a pig or goat. We used the latter in combination with live bait and in attempts to recapture tigers to change their radiocollars or to capture the

cubs of radiocollared tigers. We set snares on trails and mark trees, usually as a trap line in a specific area, for 1 to 3 months, whereas we used other sets opportunistically (e.g., whenever we found the kill of an unmarked tiger). Although we began trapping with 4-mm-diameter snare cables, by spring 1992 we switched to 6-mm-diameter cable to reduce stress at the capture point and to better secure large bears that might be incidentally captured. Trap lines consisted of 20 to 35 snares maintained by 2 to 3 people and checked daily between 0800 and 1000 hours. We tallied number of trap nights for each type of set to determine effectiveness of various trapping methods.

We set snares using techniques similar to those described by Jonkel (1993) for grizzly bears and anchored the snares to trees ≥20 cm diameter at breast height. To reduce risk of injury, we minimized the distance an animal could lunge against the snare cable by making the length of the tail between the snare swivel and the anchor tree as short as possible (usually about 25 cm). When we needed to set snares >25 cm from the anchor tree, we clamped an automobile hood spring to the cable to absorb some of the shock of an animal lunging against the snare. Also to reduce risk of injury, we did not set snares at sites with low tree limbs from which an animal could hang itself, where water in which an animal might drown was within reach, or near steep embankments or cliffs, and we set snares far enough apart so that we could not capture an animal in 2 snares (Jonkel 1993, Logan et al. 1999). To prevent cold damage to the captured foot, we avoided setting snares during periods of snow cover or when temperatures were less than –10°C. However, kills of unmarked tigers were found in winter through snow tracking and the presence of crows (*Corvus* spp.), ravens (*C. corax*), and eagles (*Haliaeetus* spp.). We sometimes set snares on these kills and used a variety of methods to prevent a tiger from being in a snare for more than a few hours, including closing snares at night and checking them frequently during the day, opening snares a few hours before dawn, and using trap-site transmitters (Jonkel 1993) so the animal could be anesthetized shortly after capture, even at night.

Three people approached to dart snared tigers. All 3 were equipped with pepper spray, one with a dart gun or blow gun, and one with a shotgun. We tried to minimize stress to the tiger by approaching slowly and quietly, slowing or stopping our approach when a tiger became excited, avoiding eye contact, and by remaining partially hidden by vegetation. We usually fired all drug darts upon our first approach from 10 to 15 m away; however, if a tiger was extremely excited, we fired the first dart and backed off until the animal calmed down. We approached to fire the remaining darts after about 10 minutes, when the tiger had partially succumbed to anesthesia. After delivering the estimated anesthetizing dose, we backed off 10 m to 20 m and waited 5 to 10 minutes before approaching to handle the tiger. We determined whether a tiger was safe to handle by observing its response to noise and by tapping it with a long stick from a safe distance. We then removed the snare from the captured foot and reattached the snare to the other front foot for safety. Throughout handling, we monitored temperature and respiration and kept the tiger's eyes covered and lubricated. We protected tigers from hyperthermia in summer by cooling them with water and from hypothermia in winter

John Goodrich fitting a sedated Siberian tiger with a radiocollar in the Russian Far East.

Measuring the footpad of a sedated Siberian tiger.

by wrapping them in a thermally reflective blanket. We equipped each tiger with a radiocollar; collected blood, tissue, and hair samples for genetic analysis; and weighed, measured, sexed, and aged each tiger.

We routinely examined all snared tigers for any visible signs of capture-related injuries. We described and treated injuries and subjectively categorized swelling of the snared foot as low, medium, or high and other injuries as minor, moderate, severe. To determine whether snare captures affected subsequent movements, we compared daily movements (mean [±SD] distance moved between locations taken 12 to 36 hours apart) of tigers for up to 5 days following capture to those of tigers that had not been captured recently (i.e., ANOVA and Scheffe test [Zar 1996]).

Helicopter captures

We recaptured tigers every 24 to 30 months to change radiocollars, usually by darting from a Russian-built MI-8 helicopter. We conducted helicopter captures in winter and early spring when leafless deciduous trees allowed greatest visibility, snow cover impeded movements of tigers, and frozen lakes, creeks, and rivers minimized the chances of accidental drowning of an anesthetized tiger.

The capture crew consisted of 4 to 5 people, each with specific tasks outlined prior to takeoff. One person was responsible for locating the tiger via radiotelemetry using 2 "H" antennas, one mounted on either side of the helicopter at a 45° angle to the ground and parallel to the direction of flight, and for picking up the crew after a successful capture. One person sat at the sliding side door to dart the tiger and another reloaded the dart gun after each shot. The fourth person coordinated the

team and communicated among members of the group and the flight crew. A fifth person, when available, tried to maintain visual contact with the tiger and helped to determine whether darts hit and injected after each shot. We were sometimes able to determine whether darts injected by observing the position of the syringe plunger through binoculars.

For each capture attempt, we loaded 12 3-ml Telinject (Telinject® USA, Inc., Saugus, Calif.) darts with the appropriate anesthetizing agent prior to takeoff. Once a tiger was located, we determined whether the site was suitable for a capture attempt. Conifer stands reduced visibility, making captures impossible, and we avoided areas with cliffs (from which a partially anesthetized tiger might fall) and areas near open water (in which an anesthetized tiger might drown). If we deemed an area suitable for capture, we established visual contact with the tiger and attempted to dart it when it stopped moving. If a tiger was not fully anesthetized after receiving the necessary darts (i.e., usually 2 to 4), the helicopter backed off a few hundred meters to reduce stress on the animal, thereby facilitating induction. Because it was usually impossible to land the helicopter in forested areas, once a tiger was anesthetized, members of a 3- to 4-member team were individually lowered on a winch cable 50–300 m from the tiger. Protocol for approaching an anesthetized tiger was similar to that for snared tigers, including attaching the tiger to a tree with a snare as a safety precaution.

To estimate chase times, we noted time of first visual contact, time of each dart, and time the animal succumbed to anesthesia. To compare physical stress on tigers captured from helicopter versus those captured in snares, we compared mean (±SD) temperature and respiration (*t*-test).

Chemical anesthesia

We anesthetized tigers with a mixture of ketamine hydrochloride (Aveco Co., Inc., Fort Dodge, Ia. and Wildlife Pharmaceuticals, Fort Collins, Colo.) and xylazine hydrochloride (Mobay Corporation, Shawnee, Kans.) mixed at 200 mg/ml and 100 mg/ml, respectively, and administered at an intended dosage rate of 6.6 mg/kg and 0.67 mg/kg, respectively (Seal et al. 1987, Clark et al. 1992, Quigley 1992, Kreeger 1996). We shot drug darts from a Telinject rifle, or occasionally from a blow gun, and always delivered the entire dose of xylazine in the first dart. In some cases, darts failed

to inject and we were unaware of this until the tiger was anesthetized. When the dart containing xylazine did not inject, the tiger was anesthetized with ketamine only. We evaluated depth of anesthesia by monitoring respiration and body movements in response to sound and touch and maintained anesthesia with ketamine at an intended dosage rate of 3.3 mg/kg injected intramuscularly.

For each capture, we noted time each dose was administered and time of initial signs of recovery, but time of full recovery was unattainable for safety reasons. We compared actual mean dosage rates (±SD) between helicopter captures and ground captures and actual mean dosage rates with those recommended for captive tigers in published literature (*t*-test). We expected that dosage rates for helicopter captures would be greater than for snare captures because of increased excitement levels and time of delivery of anesthetizing agents for helicopter captures. We also expected that dosage rates of ketamine would be greater in wild tigers than in captive tigers due to increased excitement levels. Use of xylazine should result in a lesser ketamine dosage rate (Seal et al. 1987, Tilson et al. 1994). To examine this effect of xylazine, we compared mean dosage rate of ketamine between tigers that were anesthetized with ketamine only and those that were anesthetized with both drugs. We made no comparisons of xylazine dosage rate because a full dose of xylazine was delivered in the first dart and subsequent doses were not given (Quigley 1992), thus xylazine dosage rate varied little among captures. We administered diazepam (Elkins-Sinn, Cherry Hill, N.J.) intravenously in response to seizures at an intended dosage rate of 0.05 to 0.1 mg/kg (Quigley 1992). When tigers were still sufficiently anesthetized following han-

dling, we administered yohimbine (0.07 mg/kg) before leaving, but because we left immediately we were unable to observe its effects.

Results

Ground captures

We captured 19 tigers 23 times in snares from 1992 to 1998: 15 at mark trees, 6 at kills, 1 at the pig distress call, and 1 on a trail. Trap night data were not available for autumn 1995. Overall capture effort was 558 trap nights/capture (*n* = 12,287 trap nights) and was least for snares set on kills (6 captures, capture effort = 47), followed by the distress call (1 capture, capture effort = 51), mark trees (14 captures, capture effort = 622), and trail sets (1 capture, capture effort = 2,730). We caught no tigers in snares set near live bait (278 trap nights), dead bait (221 trap nights), or near tiger beds (11 trap nights).

The captured foot was swollen in all cases (*n* = 18, degree of swelling was not evaluated for all captures), and this condition was low 39% of the time, medium 28%, and high 33%. Tigers sustained no other detectable injuries (e.g., lacerations) in 68% of 22 captures, minor lacerations in 23% of the cases, moderate injuries 4.5%, and severe injuries 4.5%. The moderate injury was a canine nearly rubbed through on the snare cable; the severe injury was broken second and third metatarsals associated with a severe laceration. The latter injury occurred the only time we captured a tiger by the hind leg. The wound was stitched and splinted by a surgeon, and the tiger was released the day of capture because facilities were not available to maintain the tiger in captivity while his leg healed. However, 2.5 years following his injury, he was hit by a car and a few days later recaptured and euthanized due to injuries sustained from the automobile collision and his original capture. Although the broken metatarsals had healed, he had lost 2 toes on the same foot. Of 9 tigers recaptured 6 to 31 months following their initial capture, we were able to detect evidence of injuries from previous snare captures in 2 cases: the tiger with the worn canine, which had broken, and the tiger with the fractured metatarsals.

For 17 captures, we examined data on daily movements following capture. Of the remaining 6 captures, we excluded 2 because they were captures of cubs whose movements were dependent on their mother, which also was captured; data

Linda Kerley applies lubricant to a tiger's eyes.

were not available for 4 animals. We were able to estimate daily distances moved for tigers 82%, 59%, and 41% of the time on the first, second, and third days following capture, respectively. Average daily distances moved were shorter the first (0.4±0.4 km, n=13, P<0.001) and second (1±1.2 km, n=10, P=0.007), but not the third day (2.6±0.5 km, n=7, P=0.4) after capture than average daily distance moved for animals not recently captured (4.7±3.4 km, df=3, F=11.2, P<0.001). Sample sizes were too small to test for differences on the fourth and fifth days, but of 3 tigers for which data were available, only 1 remained near the capture site. One moved 6.8 km and 10.5 km on the fourth and fifth days, respectively; the third made a kill and remained at the kill site on these 2 days. When we were unable to estimate distances moved, it was usually because tigers moved out of signal range and were probably moving normally, so the preceding test is biased toward detecting a difference.

Although we avoided snaring on trap lines when temperatures were less than −10° C, sometimes nighttime temperatures dropped unexpectedly low, and we captured 2 young female tigers in snares when nighttime temperatures dropped to −13°C on one occasion and −15°C on another. In the former, we believe that she was in the snare for 12 to16 hours based on the movements of her radiocollared mother, with whom she was traveling. Swelling of her capture foot was high and there was a 3-cm laceration between her toes, possibly a bite wound. In the latter case the capture foot was moderately swollen.

Nontarget captures included 15 brown bears, 9 Asiatic black bears, 3 elk, 2 domestic cows, one Steller's sea eagle (*H. pelagicus*), and one white-tailed eagle (*H. albicilla*). The cows and eagles were released unharmed; 1 elk died the day following capture, presumably from capture stress, and 2 elk had minor to moderate leg injuries and survived to time of release, but were not subsequently monitored. In general, bears sustained injuries similar to those of tigers, with swelling and small lacerations common, but 3 bears died because of capture. One of these died of unknown causes and 2 were shot, 1 when it attacked the capture crew and 1 when it escaped with the snare on its foot.

Helicopter captures

We recaptured 8 tigers 12 times in 19 attempts (63% success) from the helicopter, where an attempt included only those occasions when we

Rare capture of 2 subadult tigers at 1 capture site.

determined that a site was suitable for capture. Of the 6 failures, we twice ran out of time (i.e., fuel or daylight), 3 times tigers entered dense conifer stands where capture was not possible, and we twice abandoned efforts because chase times were becoming excessive (>30 min). In the latter cases, windy conditions made it difficult to maneuver the helicopter to "herd" the tiger.

Mean time between first visual observation and the first dart hit was 18±22 minutes (n=9, data were not available from first 3 captures), and mean time between first and last darts fired from the helicopter was 42±26 minutes. However, these values are inflated by 2 unusual captures: 1 when the tiger hid and did not move for approximately 30 minutes prior to darting and 1 when an unusually long chase resulted from our lack of experience (later we avoided such attempts). Excluding these 2 captures, mean time between first visual observation and the first dart hit was 7±3 minutes (n=7) and mean time between first and last darts fired from

the helicopter was 23±9 minutes. These values are more useful because they provide a basis for deciding when capture attempts become too long and should be terminated.

Temperature (40±1°C, n=11) and respiration (27 ±17 breaths/min, n=10) of tigers captured from helicopters were greater than temperature (39.2± 0.9°C, n=14) and respiration (15±4 breaths/min, n =14) of those captured in snares (t_{23}=1.7, P=0.006 and t_{10}=2.1, P=0.03, for temperature and respiration, respectively), indicating greater physical stress associated with captures from helicopter.

Chemical anesthesia

Dosage rates of ketamine for helicopter (11.3± 4.3 mg/kg, n=12) and snare captures (10.5±2.8 mg/kg, n=21) did not differ (t_{32}=2.1, P=0.59), so we combined the data. Mean dosage rate of xylazine was 0.81±0.24 mg/kg (n=23). Ketamine dosage rate was less when we administered xylazine (10.1±2.7, n=24) than when we did not (12.6±4.4 mg/kg, n=9, t_{31}=−2.0, P=0.03); however, the dosage rate for ketamine when we did not administer xylazine was inflated by a single difficult capture from the helicopter when we administered

ketamine over a period of 92 minutes. Excluding data from this capture, there was no difference between dosage rate of ketamine when we also administered xylazine and when we did not (11.3± 2.6 mg/kg, t_{30}=-1.13, P=0.13), although small samples may have failed to detect a difference. Dosage rate for ketamine (10.8±3.4 mg/kg, n=33) was greater than the range recommended based on anesthesia of captive animals (recommended value =9 mg/kg, t_{31}=3.04, P=0.002).

Tigers seizured during 78% of 32 captures, and in response we administered diazepam in 21 cases (0.085±0.04 mg/kg, range 0.01 –0.19); this was effective at stopping seizures 81% of the time. Of 5 cases when diazepam was not effective, twice we administered it intramuscularly when intravenous is the preferred route, but we injected it intravenously in the 3 other cases (2 tigers).

We administered doxapram hydrochloride (Dopram-V, Aveco Co., Inc., Fort Dodge, Ia.) in 2 cases of respiratory arrest (<1 breath/min) and in 1 case when respiration dropped below 3/minute. In all cases, respiration increased immediately to 8–18/minute following a single intravenous dose (0.3 mg/kg). In all 3 cases, xylazine (a respiratory depressant) doses were less than recommended maximum for captive tigers (recommended dose ≤0.9mg/kg, doses administered were 0.47–0.78 mg/kg).

Discussion

Ground captures

Snares were effective for capturing tigers, although effort/capture was high. In general, a 2-month trapping season required 3 people on site full time and at least 1 other person part-time to supply the trapping crew. Our capture effort (558) was more than twice that reported by Logan et al. (1999) for pumas (202.5). A major advantage of snares was our ability to trap in remote, roadless areas, because snares are small and light enough to transport on foot. Thus, we could set them at kills and near radiocollared females to capture their cubs whenever the kill or tiger was within a half-day walk of a road, or we could transport snares into remote areas for longer trapping periods.

Snares set at kills were most successful, and we used this method to capture cubs of radiocollared animals and, in one case, to recapture a radiocollared tiger to change her collar. However, many tigers frequently did not return to kills following

Weighing an anesthetized Siberian tiger.

human disturbance; thus, we could not depend on this method for recapture. When we set snares at kills during winter, closing snares at night was ineffective because tigers usually did not return to kills during daylight after being disturbed by people. Trap-site transmitters were effective because we could anesthetize the tiger at night, but they were not a safe means to capture cubs due to increased danger of protective mothers or siblings at night.

Injury rates for snare captures were within acceptable limits for the purpose of our study, with 1 severe injury and 1 moderate injury. Although a broken canine may be considered a severe (potentially fatal) injury by some (e.g., Rabinowitz 1986), several of our tigers survived several years with 1 to 4 broken canines. It may be possible to further reduce our injury rate. Leg injuries likely resulted from tigers lunging against the snare cable, particularly when they charged us upon our approach, whereas loss of circulation to the foot probably played a lesser role. For example, the male fractured his metatarsals when he lunged against the snare cable as we approached to shoot the second dart. Also, 1 tiger exhibited a high degree of foot swelling even though the snare cable was loose; this tiger remained near the snare site for about 24 hours. However, in 2 cases tigers had been in snares for <3 hours; they moved off during the evening following capture. These responses suggest that the length of time an animal was in the snare was an important factor and may have been related to reduced circulation to the capture foot and the number of times a tiger lunged against the cable, both of which may cause swelling of the capture foot. Thus, injuries could be reduced by reducing the frequency and effect of a tiger lunging against the snare cable and reducing the amount of time a tiger is in a snare.

We used automobile hood springs to cushion lunges by tigers, but these were ineffective because the spring stretched out permanently in response to a tiger's weight. We are currently experimenting with heavy elastic cords attached to a slack loop in the cable (Logan et al. 1999), which seems more effective because the cords continue to stretch as the animal lunges. Frequency of lunging may be reduced by reducing amount of time people are close to the tiger. Although we always administered darts and backed off as quickly as possible, reloading the dart gun for multiple shots increased the time spent close to the tiger. However, 2 darts may be fired from a Telinject gun with reasonable accu-

racy at 10-15 m. On snare lines, reducing the amount of time an animal is in a snare will require checking snares twice/day. In autumn 1998, we checked some snares twice/day and caught 1 tiger and 1 Asiatic black bear between morning and evening snare checking.

Helicopter captures

The helicopter was effective to recapture tigers; in 6.5 years of work, we were always able to recapture resident tigers ($n=12$) before the batteries in their radiocollars failed. Success rate was reasonably high (63%), and in 12 captures there were no injuries. However, there was potential for injury, particularly from heat stress and drowning (Smith et al. 1983), because tigers sought water when air temperatures were high. To avoid this, we tried to capture animals during winter when temperatures were cool, snow was present, and water was frozen. Also, after early experiences with long (>45 min) chase times, we tried to limit chases to less than 30 minutes. We usually cooled overheated tigers with snow, but if snow cover was sparse or absent, we carried at least 8 liters of water for cooling. In addition to providing a medium for cooling, snow also made movement difficult for tigers and hence reduced chase times.

Chemical anesthesia

That dosage rates of ketamine were only slightly greater or the same when xylazine was not administered indicates that the dosage rate of xylazine (0.81 mg/kg) was at the lower end of the effective range. However, we were reluctant to increase xylazine doses because xylazine is a respiratory depressant (Seal et al. 1987) and for helicopter captures we were not always able to get to an animal immediately following anesthesia. Seal et al. (1987) reported that 2 captive tigers quickly recovered from severe respiratory depression following xylazine reversal with yohimbine, suggesting that xylazine was responsible for respiratory depression. We also observed 2 cases of respiratory arrest, although it was unclear whether xylazine was the cause. Kreeger (1996) recommends a mixture of 4 mg/kg ketamine and 2 mg/kg xylazine as an alternative drug to anesthetize tigers. We would be reluctant to use such a high dosage of xylazine in Amur tigers in the wild, given the respiratory depression observed and the difficulty associated with such problems in remote field situations. That our ketamine dosage rates were greater than those

used for captive tigers (Kreeger 1996, Seal et al. 1987) was probably due to added stress of wild capture situations and lower xylazine doses. For helicopter captures, ketamine was administered over an extended period of time, which also may result in greater dosage rates. However, there was no difference between dosage rates administered during helicopter captures and snare captures, when we administered drugs very quickly, which suggests that the time over which we administered darts during helicopter captures had a minimal effect on dosage rate. We continue to use xylazine because it reportedly reduces seizures and recovery time and provides smoother induction and recovery (Jones et al. 1977, Clark et al. 1992).

Diazepam was effective at stopping seizures in most (81%) cases when administered intravenously; it was ineffective during 2 captures of an adult tigress and 1 capture of her 14-month-old female offspring. When tigers seizured following darting from the helicopter, we usually gave diazepam at low doses (<0.1 mg/kg) because diazepam inhibits thermoregulation (Kreeger 1996).

We developed safe and effective capture techniques for Amur tigers despite their low density, large home ranges, and unpredictable movements. Also, the animals rarely take live or dead bait and require drugs at large volumes that cannot be administered in a single dart. These techniques allowed us to launch a successful radiotracking program on a species whose secretive nature and dense habitat make them otherwise difficult to study.

Literature cited

ABRAMOV, K. G. 1958. To protect the tiger. Okhota i Okhothichie Khozyaistvo 11:23. (in Russian).

CLARK, R. K., A. W. FRANSMANN, D. A. JESSUP, M. D. KOCK, N. D. KOCK, R. A. KOCK, AND P. VDB. MORKEL. 1992. Wildlife restraint series. International Wildlife Veterinary Sciences, Inc., Salinas, California, USA.

JONES, M. L., N. H. BOOTH, AND L. E. McDONALD. 1977. Veterinary pharmacology and therapeutics. Iowa University, Ames, USA.

JONKEL, J. J. 1993. A manual for handling bears for managers and researchers. Interagency Grizzly Bear Study Team, Montana State University, Bozeman, USA.

KREEGER, T. J. 1996. Handbook of wildlife chemical immobilization. International Wildlife Veterinary Sciences, Inc., Laramie, Wyoming, USA.

LOGAN, K. A., L. L. SWEANOR, J. F. SMITH, AND M. G. HORNOCKER. 1999. Capturing pumas with foot-hold snares. Wildlife Society Bulletin 27:201–208.

MATYUSHKIN, E. N. 1966. Tigers in the Sikhote-Alin. Okhota i Okhthichie Khozyaistvo 1:14–15. (in Russian).

MATYUSHKIN, E. N. 1977. A choice of the way and usage of territory by the Amur tiger. Pages 146–178 *in* (Focus) mammals. Nauka, Moscow, Russia. (in Russian).

MIQUELLE, D. H., E. N. SMIRNOV, H. B. QUIGLEY, M. G. HORNOCKER, I. G. NIKOLAEV, E. N. MATYUSHKIN. 1996. Food habits of Amur tigers in Sikhote-Alin Zapovednik and the Russian Far East, and implications for conservation. Journal of Wildlife Research 1:138–147.

MIQUELLE, D. G., W. T. MERRILL, Y. M. DUNISHENKO, E. N. SMIRNOV, H. B. QUIGLEY, D. G. PIKONOV, AND M. G. HORNOCKER. 1999. Hierarchical spatial analysis of Amur tiger relationships to habitat and prey. Pages 71–99 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: meeting the needs of people and wildlife in Asia. Cambridge University, Cambridge, New Jersey, USA.

QUIGLEY, K. 1992. Siberian tiger project immobilization and biological sampling protocols. Hornocker Wildlife Institute, Moscow, Idaho, USA.

RABINOWITZ, A. 1986. Jaguar. Arbor House, New York, New York, USA.

SEAL, U. S., D. L. ARMSTRONG, AND L. G. SIMMONS. 1987. Yohimbine hydrochloride reversal of ketamine hydrochloride and xylazine hydrochloride immobilization of Bengal tigers and effects on hematology and serum chemistries. Journal of Wildlife Diseases 23:296–300.

SMIRNOV, E. N. AND D. G. MIQUELLE. 1999. Population dynamics of the Amur tiger in Sikhote-Alin State Biosphere Reserve. Pages 61–70 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: meeting the needs of people and wildlife in Asia. Cambridge University, Cambridge, New Jersey, USA.

SMITH, J. L. D., M. E. SUNQUIST, M. TAMANG, B. RAI. 1983. A technique for capturing and immobilizing tigers. Journal of Wildlife Management 47:255–259.

SMITH, J. L. D., C. McDOUGAL, AND D. MIQUELLE. 1989. Chemical communication in free-ranging tigers, (*Panthera tigris*). Animal Behaviour 37:1–10.

STANDER, P. AND P. VDB. MORKEL. 1991. Field immobilization of lions using disassociative anaesthetics in combination with sedatives. African Journal of Ecology 29:137–148.

STANDER, P., X. GHAU, D. TSISABA, AND X. TXOMA. 1996. A new method of darting: stepping back in time. African Journal of Ecology 34:48–53.

TILSON, R., G., G. L. BRADY, K. TRAYLOR-HOLZER, AND D. ARMSTRONG, editors. 1994. Management and conservation of captive tigers. Minnesota Zoo, Apple Valley, USA.

ZAR, J. H. 1996. Biostatistical analysis. Third edition. Prentice Hall, Upper Saddle River, New Jersey, USA.
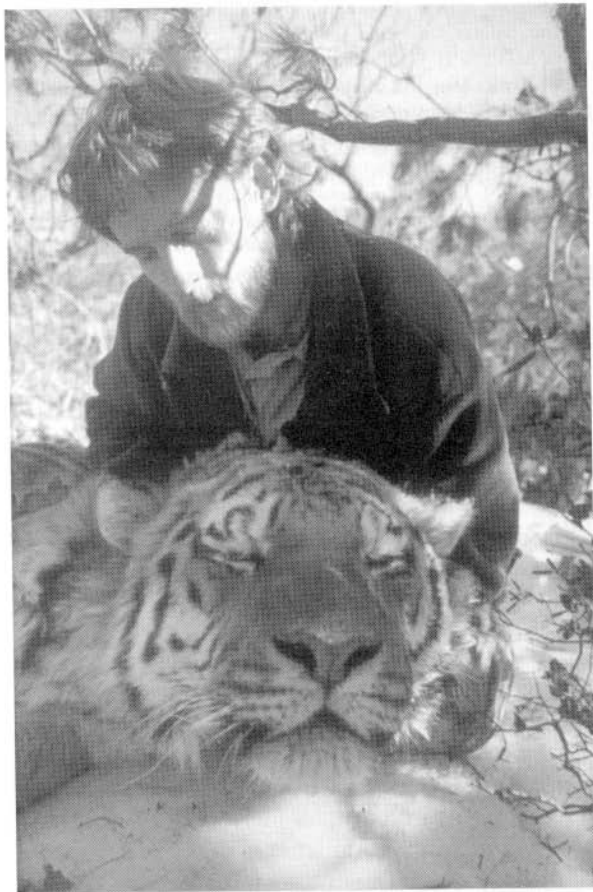
Since 1995, **John Goodrich** (photo) has lived and worked in Terney, Russia, as the field coordinator for the Wildlife Conservation Society (WCS)/Hornocker Wildlife Institute's Siberian Tiger Project. He has a B.S. from the State University of New York's College of Environmental Science and Forestry, an M.S. from the University of Nevada, Reno, and a Ph.D. from the University of Wyoming. **Linda L. Kerley** conducts research on tigers at Lazovsky Zapovednik in the Russian Far East and works part-time for the Hornocker Wildlife Institute. She received her B.S. from Oregon State University, her M.S. from the University of Nevada, Reno, and her Ph.D. from the University of Wyoming. She was co-field coordinator for the Siberian Tiger Project 1995–1999. **Bart O. Schleyer** has worked as a capture specialist for the Siberian Tiger Project since 1993. He has a B.S. and an M.S. from Montana State University and spent 22 years capturing and radiotracking grizzly bears in Montana. **Dale G. Miquelle** has been engaged in research and conservation of Amur tigers since 1992 in the Russian Far East, where he is currently program coordinator for the Wildlife Conservation Society. He has a B.S. from Yale University, an M.S. from University of Minnesota, and a Ph.D. from University of Idaho. **Kathy S. Quigley** is veterinary coordinator for the Hornocker Wildlife Institute and received her B.S. from the University of Alaska and her D.V.M. from Washington State University. **Yevgeny N. Smirnov** has degrees in biology from Moscow State University and the Institute of Biology and Pedology, Far Eastern Branch of Russian Academy of Sciences. In 1963 he began work as a research scientist at the Sikhote-Alin Biosphere Zapovednik, where he has conducted research on a variety of rodents, Asiatic black bears, brown bears, and Amur tigers. He has worked with the Siberian Tiger Project since 1991. **Igor G. Nikolaev** has a degree in zoology from the Far Eastern State University in Vladivostok, Russia. He has worked as a research scientist for the Institute of Biology and Pedology, Far Eastern Branch of Russian Academy of Sciences since 1964 and for the Siberian Tiger Project since 1991. He has conducted field research on tigers for over 35 years. **Howard B. Quigley** is Director of the Hornocker Wildlife Institute, a Division of the Wildlife Conservation Society, and received his B.S. from the University of California, Berkeley, M.S. from the University of Tennessee, Knoxville, and Ph.D. from the University of Idaho. **Maurice G. Hornocker** received his B.S. and M.S. from the University of Montana and his Ph.D. from the University of British Columbia. He was leader of the Idaho Cooperative Wildlife Research Unit from 1968 to 1985 and is currently senior scientist of the Hornocker Wildlife Institute, which he founded in 1985.

Associate editor: Ballard